CHAPTER 14

Groundwater

GOWRIE TO HELIDON ENVIRONMENTAL IMPACT STATEMENT

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

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14.1 Summary

The South East Queensland (SEQ) region has a hot and dry climate with warm-to-hot summers and mild-to-cool winters. Rainfall is seasonally distributed, with a distinct wet season, which occurs during the summer months of December through February, and an extended dry season from April through September.

The Great Dividing Range (GDR) is the highest point across the alignment, and creates a drainage divide between the east (coastal) and west (inland). West of the GDR, the main watercourse is Gowrie Creek, which flows west. East of the GDR, there are numerous watercourses and their semi-ephemeral gullies that flow in the valleys between the ridges, with the main watercourses incised in the underlying Marburg Subgroup rocks (mainly the Koukandowie Formation). The Project intercepts various semi-ephemeral watercourses (Six Mile, Oaky, and Rocky creeks) and Lockyer Creek, which is the main drainage system in the Lockyer Valley, east of the GDR.

The geology and hydrogeological regime(s) of the Project are influenced by the GDR, as it is a regional groundwater divide for shallow aquifers. West of the GDR is associated with the Main Range Volcanics (MRV) and areas east of the GDR transitions to the Marburg Subgroup—comprised of the Koukandowie Formation (upper member) and Gatton Sandstone (lower member). The Woogaroo Subgroup, outcrops northeast of the Project and underlies the Marburg Subgroup. The Toowoomba Range Tunnel primarily intersects the MRV, which is underlain by the competent Koukandowie Formation.

Local groundwater flow in the shallow alluvial aquifers is influenced by surface water–groundwater interaction, where there is a hydraulic connection to surface water. This is observed along Gowrie Creek, which flows west into the Condamine River Basin, and it is expected that groundwater in the shallow Gowrie Creek alluvium reflects surface water flow. East of the GDR, the Project crosses Rocky Creek, Oaky Creek, and Six Mile Creek, which flow east, into the Lockyer Creek; it is conceptualised that groundwater flow in the shallow alluvium mimics these surface water features and is limited in lateral and vertical extent by these alluvial deposits.

Groundwater quality data within the groundwater study area indicates groundwater is generally fresh-to-brackish and slightly alkaline. The acid sulfate soils (ASS) maps, underlying geology and geochemistry suggest the Project has low likelihood of encountering inland potential acid sulfate soils (PASS) material. This suggests there is low likelihood of causing acid rock drainage (ARD) during earthworks.

Existing registered groundwater bores identified in the groundwater study area indicate there are 202 registered bores; that includes 30 water supply bores, zero petroleum or gas exploration, and the remaining 172 bores with an undefined use. Available water entitlements indicate the MRV is extensively relied on for groundwater in the study area for urban-, irrigation- and stock-intensive purposes.

There are numerous moderate- and low-potential aquatic groundwater dependent ecosystems (GDEs) (from regional studies) in the groundwater study area, including Gowrie, Oaky, Six Mile and Lockyer creeks (and their tributaries). Available surface water and groundwater quality and level data indicate there is surface water and groundwater connectivity in the groundwater study area; particularly between the alluvial aquifers and surface water features.

There are numerous moderate potential terrestrial GDEs (from regional studies) in the groundwater study area. Ground-truthing of these environments was not undertaken due to land access constraints and it has been assumed for the purposes of the EIS, that the modelled extent of the aquatic GDEs are accepted as true presence and, thus, form a potentially sensitive receptor.

The construction and operation of the Project has the potential to impact on groundwater and groundwater users through:

- Loss of, or damage to, registered or unregistered bores
- Changes to groundwater level and flowpaths from embankment loading
- Reduced groundwater levels due to seepage into cuttings and the Toowoomba Range Tunnel
- Changes to groundwater quality from spills and uncontrolled releases, or from ARD.

The potential impacts of the Project on groundwater levels, flow and quality were identified and a significance assessment was undertaken, with the key conclusion being:

- A moderate residual significance risk was identified for the potential of reduced groundwater levels to impact groundwater users (bores and potential GDEs), due to the Toowoomba Range Tunnel and associated cuts and portals:
  - Ground-truthing of GDEs is required to confirm GDEs exist within predicted drawdown extents
  - Continued baseline groundwater level monitoring will confirm groundwater levels at the tunnel and inform additional investigations and modelling.
- A moderate residual significance risk during the construction phase was identified for potential contamination, or degradation of groundwater quality, including from spills and uncontrolled releases; water mixtures and emulsions from washdown areas; and wastewater from construction sites
- Low residual significance risks were identified as being low for all other potential impacts, including loss of registered bores due to destruction or loss of access, changes to groundwater levels due to loading from embankments (i.e. upstream mounding and damming, and downstream groundwater level reductions), ARD from cuts and vegetation removal.

A cumulative impact assessment (CIA) has been undertaken, which considered the adjoining ARTC rail alignments and surrounding developments. The CIA identified a low significance due to adoption and implementation of mitigation measures.

14.2 Scope of chapter

This groundwater chapter includes:

- A description of the existing hydrogeological regime (environment)
- A summary of potential impacts from the Project
- An assessment of the potential impacts of the Project on groundwater resources
- A description of proposed measures to mitigate these impacts.

Potential short- and long-term impacts have been assessed for the construction and operational phases of the Project. Cumulative groundwater impacts related to existing or planned activities in surrounding areas have also been assessed.

This chapter has been prepared in accordance with the groundwater-related ToR (refer Appendix A: Terms of Reference) and summarises groundwater investigations undertaken to inform this assessment. Full details of the groundwater impact assessment and the corresponding ToR requirements are provided in Appendix N: Groundwater Technical Report.

14.3 Terms of Reference

The ToR describe the matters the proponent must address in the EIS for the Project. The matters relating to water, and specifically water resources, are contained in the ToR sections 11.36–11.41, 11.44, 11.47, 11.48, 11.52, and 11.54–11.63.

Appendix B: Terms of Reference Compliance Table provides a cross-reference for each ToR against relevant sections in this EIS.

Table 14.1 presents the relevant groundwater ToR and the section in the chapter where discussed.

TABLE 14.1 GROUNDWATER TERMS OF REFERENCE

ToR ID	ToR Requirements	Relevant section in this chapter
Existing environment general		
11.36	Identify the water related environmental values and describe the existing surface water and groundwater regime within the study area and the adjoining watercourses in terms of water levels, discharges and freshwater flows.	Sections 14.6.2, 14.1.1, 14.6.3 14.6.6 and 14.6.10 Appendix N: Groundwater Technical Report, Sections 8, 7.1 and 7.4

ToR ID	ToR Requirements	Relevant section in this chapter
11.37	With reference to the Environmental Protection Policy (Water) 2009[a] and section 9 of the *Environmental Protection Act 1990* (EP Act), identify the environmental values of surface water 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 14.6.10 Appendix N: Groundwater Technical Report, Section 8
11.38	At an appropriate scale, detail the chemical, physical and biological characteristics of groundwater within the area that may be affected by the Project. Include a description of the natural water quality variability within the groundwater study area associated with climatic and seasonal factors, and flows.	Sections 14.6.3 and 14.6.4 Appendix N: Groundwater Technical Report, Section 7.3
11.39	Describe any existing and/or constructed waterbodies adjacent to the preferred alignment.	Section 14.6.2 Appendix N: Groundwater Technical Report, Section 4.3.2
11.40	Identify the location and source aquifer of licensed groundwater extraction in those areas potentially impacted by the Project (e.g. near tunnels).	Section 14.6.6 and Table 14.12 Appendix N: Groundwater Technical Report, Section 7.5, Table 7.10 and Table 7.11
Impact assessment water quality		
11.41	The assessment of impacts on water will be in accordance with the Department of Environment and Heritage Protection information guideline for an environmental impact statement – ToR Guideline – Water, where relevant, located on the Department of Environment and Heritage Protection website.	Sections 14.4 and 14.10 Appendix N: Groundwater Technical Report, Section 12
11.44	Where significant cuttings or tunnelling is proposed, identify the presence of any sulphide minerals in rocks with potential to create acidic, metalliferous and saline drainage. Should they be present, describe the practicality of avoiding their disturbance. If avoidance is not practicable, characterise the potential of the minerals to generate contaminated drainage and describe abatement measures that will be applied to avoid adverse impacts to surface and groundwater quality.	Sections 14.7.3.2, 14.6.4.3 and 14.7.4.2 Appendix N: Groundwater Technical Report, Sections 6.3, 10.2.2.3, 10.2.2.4, 10.3.2.1, and 10.3.2.2
Mitigation measures water quality		
11.47	Describe how the water quality objectives identified above would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Section 14.8.2 and Table 14.29 Appendix N: Groundwater Technical Report, Section 11.2
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 D - management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Section 14.8.2 and Table 14.29 Appendix N: Groundwater Technical Report, Section 11.2
Impact assessment water resources		
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.	Section 14.7.3.1 (Construction water supply) and Section 14.7.4.1 (Operation water supply) Appendix N: Groundwater Technical Report, Sections 10.1.6, 10.2.1.1, 10.2.1.8 and 10.3.1.6

ToR ID	ToR Requirements	Relevant section in this chapter
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.	Sections 14.7.1, 14.7.3, 14.7.4 and 14.7.4.1 (Loss or damage to existing landholder bores and GDEs and springs) Appendix N: Groundwater Technical Report, Section 9
11.55	Provide information on the proposed water usage by the Project, including: 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 re-use, rainwater re-use and any bore water volumes c) a plan outlining actions to be taken in the event of failure of the main water supply d) sufficient hydrogeological information to support the assessment of any temporary water permit applications.	Sections 14.7.3.1 (Construction water supply) and 14.7.4.1 (Operation water supply) Appendix N: Groundwater Technical Report, Sections 10.1.6, 10.2.1.7 and 10.3.1.6
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.	Sections 14.7.3.1 (Construction water supply) and 14.7.4.1 (Operation water supply) Appendix N: Groundwater Technical Report, Sections 10.1.6, 10.2.1.7 and 10.3.1.6
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 14.7.3.1 (Construction water supply) Appendix N: Groundwater Technical Report, Section 10.2.1.7
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 and Mines (DNRM), 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 14.4, 14.6.6, 14.7.4, Table 14.2 and Table 14.12 (Operations water supply) Appendix N: Groundwater Technical Report, Sections 2.3.2, 10.1.6 and 10.3.1.6
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 14.7.4.1 (Loss or damage to existing landholder bores), Table 14.24, Table 14.25, Table 14.26 and Table 14.27 Appendix N: Groundwater Technical Report, Sections 7.5, 10.2.1.2 and 10.3.1.2

ToR ID	ToR Requirements	Relevant section in this chapter
Mitigation measures water resources		
11.62	Describe measures to minimise impacts on surface water and ground water resources.	Section 14.8.2 and Table 14.29 Appendix N: Groundwater Technical Report, Section 11.0
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	Section 14.8.2 and Table 14.29 Appendix N: Groundwater Technical Report, Section 11.0

Table notes:

a The Environmental Protection Policy (Water and Wetland Biodiversity) 2019 replaced the Environmental Protection (Water) Policy 2009 on 1 September 2019. The 2019 guidelines are substantially similar to the 2009 legislation, with only minor amendments. There have been a number of amendments to the drafting style to ensure the legislation reflects current drafting practice. Some provisions have been renumbered as a result. Other amendments have been made to clarify the intent of provisions and align the policy to best available knowledge and contemporary practice.

14.4 Legislation, policies, standards, guidelines

This chapter has been prepared with consideration to key Commonwealth, State and local legislation, policies, standards and guidelines. Relevant legislation and policy are detailed in Table 14.2, with further discussion provided in Chapter 3: Project Approvals and Appendix N: Groundwater Technical Report.

The guidelines provided in Appendix 1: Policy and guidelines of the ToR (refer Appendix A: Terms of Reference) for the Project were also taken into consideration when undertaking the groundwater impact assessment.

TABLE 14.2 REGULATORY CONTEXT

Legislation, policy or guideline	Relevance to the Project
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The Project was referred to the Commonwealth Minister for the Environment in February 2017 and was subsequently determined to be a 'controlled action', due to potentially significant impacts on listed threatened species and communities (Sections 18 and 18A of the EPBC Act) in March 2017. The Project requires assessment and approval under the EPBC Act before it can proceed. The EIS includes an assessment of the Project's impacts on matters of national environmental significance (MNES) as per the EPBC Act. Appendix J: Matters of National Environmental Significance discusses the MNES related to the overall Project, including potential impacts on MNES as a result of changes to groundwater resources as a result of the Project.
Water Act 2007 (Cth)	The *Water Act 2007* (Cth) provides the legislative framework for ensuring that Australia's largest water resource—the Murray-Darling Basin (the Basin)—is managed in the national interest. In doing so, the Water Act 2007 (Cth) recognises that Australian states in the Basin continue to manage the Basin water resources within their jurisdictions. The *Water Act 2007* (Cth): ▸ Established the Murray-Darling Basin Authority (MDBA) with the functions and powers, including enforcement powers, needed to ensure that the Basin water resources are managed in an integrated and sustainable way ▸ Requires the Murray-Darling Basin Authority to prepare the Basin Plan—a strategic plan for the integrated and sustainable management of water resources in the Basin ▸ Establishes a Commonwealth Environmental Water Holder to manage the Commonwealth's environmental water, to protect and restore the environmental assets of the Basin and, outside the Basin, where the Commonwealth owns water. The Queensland Government has prepared the Water Plan (Condamine and Balonne) 2019, along with supporting documentation, such as a healthy water management plan under the *Water Act 2000* (Qld) (Water Act). The plan was accredited by the Australian Government minister as being consistent with the Basin Plan and commenced on 21 September 2019.to meet accreditation under the *Water Act 2007* (Cth). Compliance with the *Water Act 2007* (Cth)—Basin Plan 2012, will be achieved by complying with the Water Plan (Condamine and Balonne) 2019. The plan is the prevailing management plan for the surface water and groundwater resources (excluding water from the Great Artesian Basin) in the Condamine–Balonne water resource plan area, which includes Gowrie Creek catchment.

Legislation, policy or guideline	Relevance to the Project
Water Act 2007 (Cth) [continued]	The Project will also be required to adhere to EVs and corresponding WQOs (under the Queensland (EPP) (Water and Wetland Biodiversity), which is accredited under the Water Act (and the legislative instrument—Basin Plan), e.g. Healthy Waters Management Plan: Condamine River Basin (Department of Environment and Science (DES), 2019e), *Murray-Darling Basin environmental values and water quality objectives* (DES, 2018b).
State	

Environmental Protection Act 1994 (Qld) (EP Act)	The objective of the EP Act is 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 (i.e. ecologically sustainable development).
	The EP Act defines an environmental value (EV) as:
	▸ A quality or physical characteristic of the environment that is conducive to ecological health, or public amenity or safety
	▸ Another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.
	The EVs for the Project are provided in the following DES documents:
	▸ *Murray-Darling Basin environmental values and water quality objectives* (DES, 2018b)
	▸ *Healthy Waters Management Plan (HWMP): Condamine River Basin* (DES, 2019e)
	▸ *Lockyer Creek environmental values and water quality objectives* (DERM, 2010a).
	Further information regarding EVs is presented in Section 14.6.10.
	It is anticipated that the Project may involve the following Environmentally Relevant Activity (ERA) (in line with application requirements ESR/2015/1837) during the construction phase (sourced by the construction contractor), based on the predicted groundwater infiltration into the tunnel (refer Section 14.7.2):
	▸ Water treatment (ERA 64):
	  ▸ Consists of carrying out any of the following activities in a way that allows waste, whether treated or untreated, to be released into the environment—
	    a) Desalinating 0.5 megalitres (ML) or more of water in a day
	    b) Treating 10 ML or more of raw water in a day
	    c) Carrying out advanced treatment of 5 ML or more of water in a day.
	The technical guidelines for wastewater release to Queensland Waters (DES, 2016) and the *Receiving environment monitoring program guideline for use with environmentally relevant activities under the Environmental Protection Act 1994 (Qld)* (Department of Science, Information Technology, Innovation and the Arts, 2015a) would also need to be considered.
	The water treatment plant required for operation is unlikely to meet the above-mentioned thresholds, with the volume of water to be treated daily considerably less, while the water quality is generally suitable for discharge.

Water Act 2000 (Water Act)	The Water Act provides a framework for the: ▸ Sustainable management of Queensland's water resources and quarry material by establishing a system for the planning, allocation and use of water, including the preparation and implementation of water plans and water resource plans, and the allocation of quarry materials and riverine protection ▸ Sustainable and secure water supply and demand management for the south-east 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. Under the Water Act, the taking or interfering with the flow of water on, under or adjoining land (including surface water, artesian water, and in some instances overland flow where regulated through a water plan) may require a water licence under the Water Act and a development permit for operational works under the *Planning Act 2016* (Qld), where constructing or installing certain types of works. ARTC has consulted with Department of Regional Development, Manufacturing and Water (DRDMW) (formerly DNRME) regarding the water authorisation required under the various water plans because of the Project activities (e.g. construction water and inference with groundwater, short-term and long-term, due to the tunnel's construction and operation). DRDMW has noted the complexities of the groundwater resources in the area and the overarching legislation.

Legislation, policy or guideline	Relevance to the Project
Water Act 2000 (Water Act) [continued]	The Project is likely to involve taking or interfering with the flow of water during construction, while the tunnel operations may also be considered as taking or interfering with the flow of water. A water authorisation (i.e. a water allocation, water licence, water permit, seasonal water assignment notice or other authority to take water given under the Act or the repealed Act, other than a water permit for stock purposes or domestic purposes; or (b) a water licence, resource operations licence or distribution operations licence to interfere with water given under the Act or the repealed Act; or (c) an authority to take water given under another Act.) may also be required to take or interfere with water, including the extraction of surface water and groundwater to meet the construction water demand. Noting that this is one of the many options available to source water for the Project. Overland flow diversions are also proposed at the western tunnel portal of the Toowoomba Range Tunnel, the intermediate tunnel ventilation infrastructure drain diversion at Cranley and drainage infrastructure at Postmans Ridge. Further, the Project will also involve the taking or interfering with water as part of the Toowoomba Range tunnelling activities and the excavation or placing of fill in a watercourse. Further, the acquisition of land will result in the annulment of any existing water authorisation attached to the land parcel being acquired (in part or full). These authorisations will need to be re-established by the landholder and will form part of the acquisition process negotiations. There may also be an opportunity under the Water Act for the landholder to amend an existing authorisation prior to land acquisition, with this to be further explored with the landholder and the constructing authority. Further consultation with the DRDMW is planned to resolve some of the complexities associated with the Water Act and supporting water plans relevant to the Project. Noting that most of the issues relevant to the water authorisations for the construction (e.g. water permit) and operation (e.g. water licence) of the Project identified by DRDMW relate to groundwater allocations (i.e. water allocations for some units are exhausted), along with measures to rectify any impairments to existing bores due to the Project. It is also recognised that requirements for make-good agreements are well described under Part 3 of the Water Act for the mining and coal seam gas industry but are unclear for a Project of this nature; however, ARTC are proposing to adopt some of the make-good obligations under the Act to ensure that the bore holder is properly compensated for any impacts from the Project and that any impairment caused by the Project is 'made good'. Further and ongoing consultation with DRDMW will be undertaken regarding this matter noting that ARTC's preference will be for monetary compensation and for the works to be undertaken by the bore owners where applicable. It is also acknowledged that resolution of this matter will assist in securing the relevant water authorisations for the construction and operation of the Project.
Water Regulation 2016 (Water Regulation)	The Water Regulation is subordinate legislation made under the Water Act and prescribes administrative and operational matters for the Act. These 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 accepted development and assessable development for the Planning Act 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.
Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity)	The EPP Water and Wetland Biodiversity replaced the EPP (Water) 2009 as the as subordinate legislation under the EP Act, to achieve the objective of the EP Act in relation to Queensland waters. The objective of the EPP (Water and Wetland Biodiversity) is achieved by the: ▸ Identification of EVs and management goals for Queensland waters ▸ Stating water quality guidelines and water quality objectives (WQOs) to enhance or protect the identified EVs ▸ Provision of a framework for making consistent, equitable and informed decisions about Queensland waters ▸ Monitoring and reporting on the condition of Queensland waters. ▸ EVs relevant to the Project are presented in detail in Section 14.6.10.

Legislation, policy or guideline	Relevance to the Project

Water plans	Water plans have been developed under the Water Act to sustainably manage and allocate water resources in Queensland. *The Water Plan (Moreton) 2007, Water Plan (Condamine and Balonne) 2019,* and *Water Plan (Great Artesian Basin and Other Regional Aquifers)* 2017 are relevant to the Project.
	The purposes of the water plans are to:
	▶ Define the availability of water in the plan area
	▶ Provide a framework for sustainably managing water and the taking of water
	▶ Identify priorities and mechanisms for dealing with future water requirements
	▶ Provide a framework for reversing, where practicable, degradation that has occurred in the natural ecosystems
	▶ Provide a framework for:
	  ▶ Establishing water allocations to take surface water
	  ▶ Granting and amending water entitlements for groundwater
	  ▶ Granting water entitlements for overland flow water.
	ARTC has consulted with DRDMW regarding the water authorisation required under the various water plans because of the Project activities (e.g. construction water and inference with groundwater (short-term and long-term) because of the tunnel's construction and operation). DRDMW has noted the complexities of the groundwater resources in the area and the overarching legislation, and further consultation is required to confirm the approval process and to ensure that the Project complies with the legislative requirements under the Water Act and associated water plans, without adversely impacting existing water users and groundwater resources. The latter also includes measures to rectify any impairments to existing bores due to the Project. The outcomes of these discussions has informed the preparation of this chapter.

Water Plan (Great Artesian Basin and Other Regional Aquifers) (GABORA) 2017	This water plan is the prevailing management plan for water of the Great Artesian Basin. The water plan area underlies the entire groundwater study area, with the following groundwater units within, and adjacent to, the groundwater study area:
	▶ Hutton groundwater unit:
	  ▶ Koukandowie Formation
	  ▶ Gatton Sandstone
	▶ Springbok Walloon groundwater unit:
	  ▶ Walloon Coal Measures
	▶ Precipice groundwater unit:
	  ▶ Woogaroo Subgroup (not considered relevant to the Project due to depth below tunnel), including the Precipice Sandstone.
	These groundwater units are further broken down into sub-areas for water management purposes (water licence, permit, etc.). The relevant subareas of the Hutton groundwater unit include the Eastern Downs Marburg and Murphys Creek Marburg; Precipice groundwater unit subareas include the Eastern Downs Precipice and Murphys Creek Woogaroo; and the Springbok Walloon groundwater unit includes the Eastern Downs Springbok Walloon sub-area.
	Within these sub-areas, landholders are permitted to take water for stock and domestic purposes without the need for a water licence. The exception being the area within 5 km of the Lockyer Creek Spring where a licence is required for any new stock or domestic bore. All other uses require a water licence, water permit, or seasonal water assignment notice.
	The plan also identifies several groundwater-dependent ecosystems, where the decisions on a water licence are dependent on the distance between and/or cumulative drawdown on the groundwater-dependent ecosystems. There are two groundwater-dependent ecosystems under the plan within the general vicinity of the Project (refer Section14.6.9).
	It is noted that there is unallocated water under the water plans, which may be granted to a coordinated project under the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) (i.e., state or strategic reserve). Based on advice from DRDMW, there is State reserve water under the Water Plan (GABORA) 2017, with water potentially available in the Eastern Downs in the Springbok Walloons, Marburg and Precipice aquifers (approximately 990 ML).

Legislation, policy or guideline	Relevance to the Project
Water Plan (Moreton) 2007 (Water Plan (Moreton))	Surface water, overland flow (other than springs connected to underground water) and groundwater resources (excluding Great Artesian Basin) within the Lockyer Creek catchment are primarily managed by the *Water Plan (Moreton) 2007*. The Project between the GDR and Helidon (distance of 17.5 kilometres (km)) is located in the Lockyer Valley Groundwater Management Area (GMA), Implementation Area 2B, of the *Water Plan (Moreton) 2007*. The aquifers of relevance to this plan in the groundwater study area, and consideration for construction water supply options, are governed under this plan, specifically include: ▸ Rocky Creek alluvium ▸ Six Mile Creek alluvium ▸ Oaky Creek alluvium ▸ Lockyer Creek alluvium Implementation Area 2B consists of hard rock aquifers within this area, with the tunnel intersecting the MRV and, as a result, this unit. It is noted that there are other stratigraphic units not specified in the plan because they are not recognised groundwater units but are located within the plan area (e.g. colluvial sediments). Groundwater may not be taken in this GMA, unless it is for stock or domestic purposes, under a water entitlement or water permit, to allow monitoring or salinity control, or under an authorisation under section 72 of the plan (e.g. at the commencement of the plan, the owner of the land using an existing water bore on the land to take groundwater may continue to take groundwater using the bore). The *Water Plan (Moreton) 2007* includes performance indicators and objectives such as: ▸ Environmental flow objectives: assessing periods of low flow and medium-to-high flow ▸ Water allocation security objectives. DRDMW has advised that there is no unallocated water, including State reserves, within the above-mentioned units available to the Project.
Water Plan (Condamine and Balonne) 2019 (Water Plan (Condamine and Balonne))	The Water Plan (Condamine and Balonne) 2019, is the prevailing management plan for the surface water, overland flow (other than Great Artesian Basin (GAB) springs connected to underground water) and groundwater resources (excluding Great Artesian Basin) within Gowrie Creek catchment. This plan is endorsed under the *Water Act 2007* (Cth), as the Condamine and Balonne rivers are part of the Murray Darling Basin. This plan is applicable to groundwater in the western portion of the Project, west of the GDR and above the GAB sediments. This plan provides a framework for sustainably managing water (entitlements/allocations, ecosystems) under resource operations licence for the *Condamine–Balonne Water Resources Plan*, which states the process for granting or amending interim resource operation licences, and interim water allocations for the construction of infrastructure to which the interim resource operation licences related are governed. For groundwater resources, the Project is within the Condamine and Balonne Underground Water Management Area and the Upper Condamine Basalts Underground Water Management Unit, which is part of the Main Range Volcanics (MRV) aquifer system, composed of basaltic fractured rock aquifers. This plan applies to the following aquifers in the groundwater study area: ▸ MRV ▸ Gowrie Creek alluvium. The plan defines the Upper Condamine Basalts as a part of the MRV—the main aquifer of relevance to the Project under this plan. The Project is associated with the Toowoomba City Basalts groundwater sub-area; the tunnel is primarily located in this sub-area, except the eastern portion of the tunnel, located in the *Water Plan (Moreton) 2007* area. Under s29 of the *Water Act 2000*, the Toowoomba City Basalts groundwater sub-area comprises limitation areas of relevance to the Project, per below, where limitations on groundwater use can be applied: ▸ Toowoomba North Basalts—Gowrie Creek is the southern boundary of this limitation area and Project works to the north of the creek will intersect this limitation area ▸ Toowoomba South Basalts—the western extent of the Project is located within this limitation area, including the western tunnel portal and the start of the tunnel (i.e. underlying the Toowoomba Bypass).

Legislation, policy or guideline	Relevance to the Project
Water Plan (Condamine and Balonne) 2019 (Water Plan (Condamine and Balonne)) [continued]	The Toowoomba Water Services were contacted on February 2021 to understand the restrictions posed on the MRV in the Condamine and Balonne Water Plan. The following restrictions have been made to all licences in the MRV within the groundwater study area: - Pumping is undertaken on a Monday, Tuesday, Wednesday, and Friday from 7pm to 3am - Allocations have been restricted to 60% of the licensed allocation. DRDMW has advised that there is no unallocated water, including State reserves, in the above-mentioned units available to the Project.
EIS information guideline–Water 2016 (Department of the Environment and Heritage Protection (DEHP), 2016b)	DES have developed an informational guideline to assist in the development and assessment of water resources for EISs. This guideline was incorporated into the methodology, approach, and data sources for the groundwater impact assessment. The guideline is complementary to the Project-defined ToR prepared by the Coordinator-General.

14.5 Methodology

14.5.1 Groundwater study area

The EIS investigation corridor (herein referred to as the groundwater study area) includes an area within approximately 1 km of the Project alignment. The groundwater study area is illustrated on Figure 14.1.

Groundwater data outside of the defined groundwater study area for the Project has been used to understand groundwater resources and identify impacts within the groundwater study area.

The groundwater study area also includes the Project disturbance footprint permanent and temporary activities that have the potential to affect the groundwater environment directly or indirectly, and was used to identify groundwater users, including registered bores and potential groundwater dependent ecosystems (GDEs). The extent of groundwater drawdown was not limited by the groundwater study area (i.e. the drawdown extents outside of the groundwater study area are identified and discussed).

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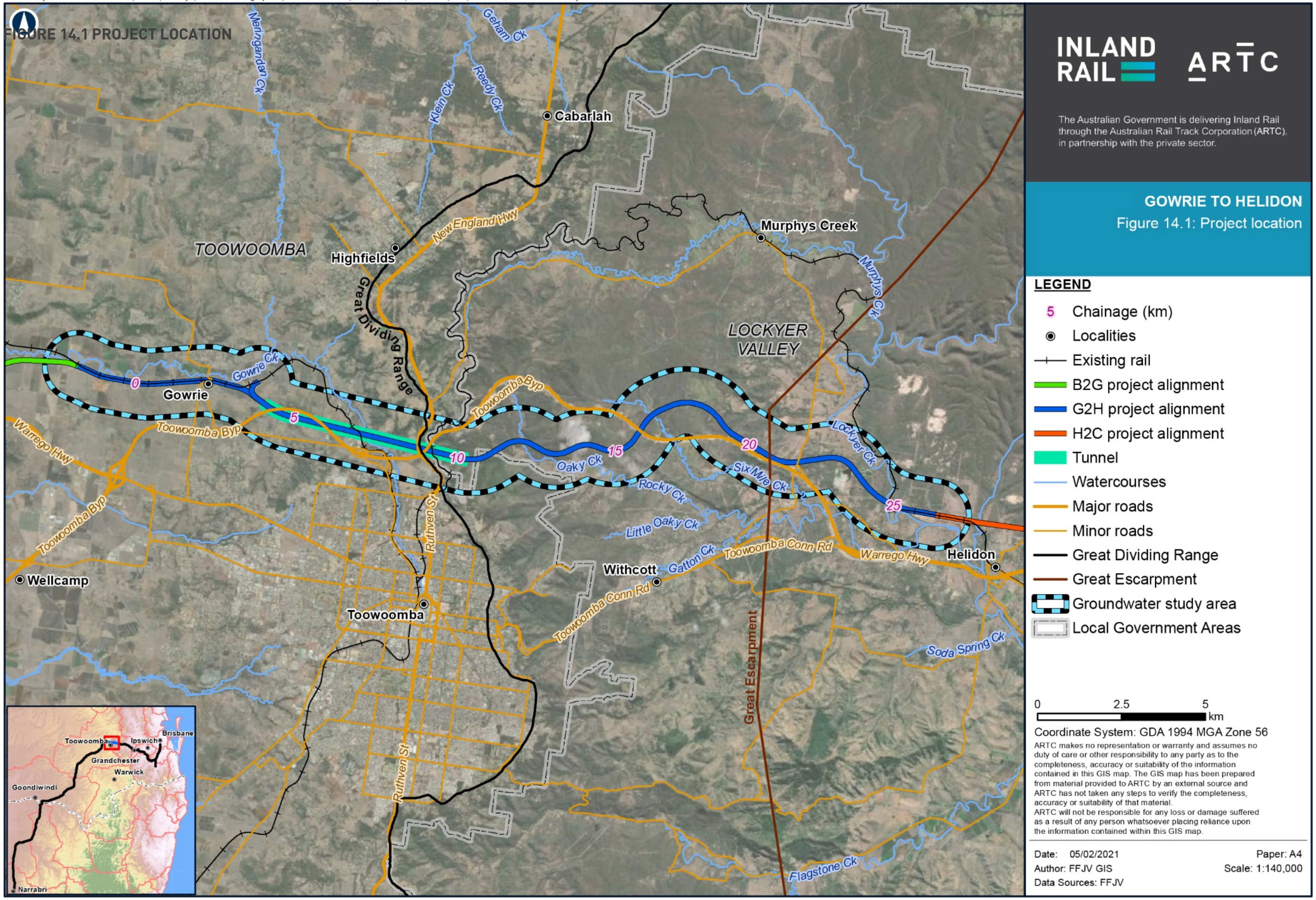

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14.5.2 Assessment methodology

To achieve the study scope and objectives outlined in the ToR, the groundwater impact assessment comprises two components:

- A description of the existing hydrogeological environment
- An assessment of the potential impacts of the Project on that environment.

A staged approach was adopted for development of the groundwater study to allow for compilation and assessment of sufficient data, to:

- Address the groundwater requirements of the EIS ToR
- Identify mitigation measures to be adopted in subsequent design, construction, and operation.

The stages undertaken to prepare the groundwater study are described below. Further details on the methodology adopted to describe the groundwater resources relevant to the Project, along with assessment approach to identify potential impacts and relevant mitigation measures is provided in Appendix N: Groundwater Technical Report.

14.5.2.1 Stage 1—Desktop study

Available geological and groundwater data were reviewed to inform a detailed description of the existing hydrogeological regime, identification of groundwater EVs and development of a conceptual groundwater model. A review of publicly available databases, inclusive of registered groundwater bores and use, was performed.

Data sources are discussed further in Section 14.5.3.

14.5.2.2 Stage 2—Geotechnical and hydrogeological investigations

Geotechnical and hydrogeological site investigations along the Project alignment were undertaken to inform the feasibility design for the EIS between July and December 2018. Findings of these investigations are provided in Appendix W: Geotechnical and the *Inland Rail Section 320—Gowrie to Helidon Hydrogeological Interpretative Report* (Golder, 2020a). The hydrogeological interpretative report is included in Appendix N: Groundwater Technical Report.

Twelve groundwater monitoring bores were installed and developed (refer to Figure 14.5) in accordance with the relevant standard at time of construction—the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee, 2020). A vibrating wire piezometer was installed at 320-01-BH2102.

Groundwater monitoring bores were equipped with 50 mm diameter class 18 polyvinyl chloride (PVC) threaded pipes, with 0.4 millimetre (mm) slotted screens and blank casing. A borehole diameter of 96 mm was drilled for the installation of the standpipe piezometers except for 320-01-BH2101, which was drilled at a diameter of 140 mm. A filter pack (1 to 3 mm washed and graded sand/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.

Dedicated pressure transducers with automated data logging capability were installed in all 12 groundwater monitoring bores for continuous groundwater level monitoring, from date of installation of the logger (between September and December 2018) to February 2019. Measurements were recorded at hourly intervals and calibrated by manual static water level measurements. The data logger for bore 320-01-BH2212 was installed above the groundwater level and, therefore, no data was available for consideration in the groundwater study. Available hydrographs are provided in Appendix N: Groundwater Technical Report.

In-situ hydraulic testing using the slug test method was conducted in eight of the monitoring bores. Bores 320-01-BH2207, 320-01-BH2209 and 320-01-BH2215 were dry at the time of monitoring. The recorded data allows for an estimation of hydraulic conductivity of the screened soil or rock material.

One round of groundwater sampling, 2018, was also conducted in accordance with AS/NZ 5667.1:1998 (Standards Australia, 1998a) and AS/NZ 5667.11:1998 (Standards Australia, 1998b) and *Monitoring and Sampling Manual* (DES, 2018a) after completion of all Project bores. Sampling (8 bores out of 12) was for the purpose of collecting baseline water quality, durability and salinity parameters. The following parameters were analysed for each groundwater sample:

- Major anions and cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), fluoride (F), sulphate (SO4), carbonate and bicarbonate (CO3/HCO3), as well as carbonate and bicarbonate alkalinity, and hardness
- pH
- Electrical conductivity
- Total dissolved solids (TDS)
- Selected total and dissolved metals (arsenic, boron, barium, beryllium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc and mercury)
- Nutrients (nitrate, nitrite, ammonia, reactive phosphorus, total nitrogen, total Kjeldahl nitrogen, total phosphorus)
- Sodium adsorption ratio.

The feasibility design stage investigations and subsequently produced predictive groundwater model (see Section 14.7.2), identified gaps in the understanding of the hydrogeological conditions the Project is expected to encounter. Since the feasibility design stage investigations in 2018, further geotechnical and hydrogeological investigations (Golder, 2020c/d) targeting the tunnel, portals and shaft, have been undertaken. Specifically, these investigations were undertaken from December 2018 through June 2020 and aimed to further characterise the key aquifers of relevance to the Project and their relationships with each other. The works included:

- Advancement of geotechnical boreholes and testing; geophysical surveys
- Conversion of a select set of geotechnical boreholes into groundwater monitoring bores (14), including one deep bore (230 mbgl) at Mt Kynoch; construction of seven (7) vibrating wire piezometers (VWPs) to automatically record groundwater pressures for conversion to water levels
- Groundwater quality sampling at eight (8) completed new bores, plus quality samples from aquifer characterisation testing at the western portal
- Deployment of automated pressure transducers in new bores
- Hydrogeological tests inclusive of variable head tests, pumping tests, and packer tests.

The results from these recently completed geotechnical and hydrogeological investigations (Golder, 2020c/d) were considered and are presented, at a high level, to complement the desktop geological and hydrogeological discussions (where applicable) in Section 14.6.2. Further, this data was used to refine the mitigation measures and commitments to address identified data gaps as a result of the EIS process in Section 14.8.2; be used to refine the predictive groundwater model prior to commencement of construction for the Project; and inform the indicative Groundwater Management and Monitoring (GMMP) (Section 14.8.2.1).

14.5.2.3 Stage 3—Groundwater impact identification

Potential short- and long-term impacts on groundwater (both local and regional) were assessed based on a review of proposed construction and rail operations activities, and considering the current geological and hydrogeological setting.

Results of the geotechnical modelling for the Toowoomba Range Tunnel were reviewed and interpreted to assess preliminary potential impacts on groundwater resources due to construction and operation of the tunnel; noting the predictive model will be refined with additional data prior to construction of the Project (see Section 14.7.2.2).

It is noted that ARTC have committed to refinement of the model and predictions from what is included in this report. The updated simulations will be completed and included in the Final EIS to better understand the impacts on groundwater and their significance.

14.5.2.4 Stage 4—Significance assessment

A qualitative significance assessment was undertaken of the identified potential short- and long-term groundwater impacts (as described in Chapter 4: Assessment Methodology). The sensitivity of the environmental value and the magnitude of the impacts are the key elements considered to determine significance. The sensitivity of the environmental value and the magnitude of the impacts were assessed via a significance matrix, which defines appropriate significance classifications.

The predictive modelling undertaken as a component of the geotechnical works has allowed for the assessment of potential impacts on groundwater resources based on sensitivity and magnitude criteria. Evaluation of significance classifications, with initial mitigation and proposed mitigation, was then performed; the results of which, provide input into a GMMP.

14.5.2.5 Stage 5—Reporting

This groundwater chapter was prepared with factual site-specific and publicly available data, predictive modelling and interpretation to assess the potential impacts of the Project on groundwater resources. This chapter is to be read in conjunction with the groundwater technical report (refer Appendix N: Groundwater Technical Report).

Potential cumulative impacts to groundwater as a result of the Project were assessed, together with existing or planned surrounding activities.

14.5.3 Data sources

Data used in this assessment includes investigation and review of publicly available information and a Project-specific geotechnical assessment. Regional (catchment) scale studies have also been reviewed to describe the existing groundwater resources, to allow for the assessment of the impact of the Project on current groundwater resources.

The description of the existing hydrogeological regime within the groundwater study area and the subsequent groundwater impact assessment is based on the following information sources in Table 14.3.

TABLE 14.3 DATA SOURCES

Data	Source
Hydrology/climate	Historical Climate Database—Bureau of Meteorology (BoM) (**www.bom.gov.au/climate/data/**) *Inland Rail Section 320–Gowrie to Helidon Hydrogeological Interpretive Report* (Golder, 2020a) in Appendix N: Groundwater Technical Report *Inland Rail: Phase 2–Gowrie to Helidon Geotechnical Factual Report* (Golder, 2020b) in Appendix W: Geotechnical *Geotechnical Factual Report G2K Geotechnical Data Collection project Gowrie to Helidon* (Golder, 2020c) Queensland Globe datasets (**qldglobe.information.qld.gov.au/**)
Soil types	*Inland Rail Section 320–Gowrie to Helidon Hydrogeological Interpretive Report* (Golder, 2020a) in Appendix N: Groundwater Technical Report *Geotechnical Factual Report G2K Geotechnical Data Collection project Gowrie to Helidon* (Golder, 2020c) Queensland Globe datasets (**qldglobe.information.qld.gov.au/**)
Geology/ Hydrostratigraphy	*Inland Rail Section 320–Gowrie to Helidon Hydrogeological Interpretive Report* (Golder, 2020a) in Appendix N: Groundwater Technical Report *Inland Rail: Phase 2–Gowrie to Helidon Geotechnical Factual Report* (Golder, 2020b) in Appendix W: Geotechnical *Geotechnical Factual Report G2K Geotechnical Data Collection project Gowrie to Helidon* (Golder, 2020c) *Summary Factual Report of Hydraulic Tests Toowoomba Tunnel Alignment* (Golder, 2020d) DRDMW groundwater database, accessed 1 May 2020 Queensland Globe datasets (**qldglobe.information.qld.gov.au/**)

Data	Source
Groundwater levels and quality	*Inland Rail Section 320–Gowrie to Helidon Hydrogeological Interpretive Report* (Golder, 2020a) in Appendix N: Groundwater Technical Report *Inland Rail: Phase 2–Gowrie to Helidon Geotechnical Factual Report* (Golder, 2020b) in Appendix W: Geotechnical *Geotechnical Factual Report G2K Geotechnical Data Collection project Gowrie to Helidon* (Golder, 2020c) *Summary Factual Report of Hydraulic Tests Toowoomba Tunnel Alignment* (Golder, 2020d) Queensland Globe datasets (**qldglobe.information.qld.gov.au/**) *Clarence-Moreton Bioregional Assessment* [Australian Government Department of Environment] (Rassam et al., 2014 & Raiber et al., 2016, 2017) (**bioregionalassessments.gov.au/assessments/clarence-moreton-bioregion**) Queensland Globe datasets (**qldglobe.information.qld.gov.au/**)
Groundwater Dependent Ecosystems (GDEs)	Bureau of Meteorology: GDE Groundwater Dependent Ecosystem Atlas: **bom.gov.au/water/groundwater/gde/map.shtml (BoM, 2019a)** *Clarence-Moreton Bioregional Assessment* (May 2014) (**bioregionalassessments.gov.au/assessments/clarence-moreton-bioregion**) Queensland Globe datasets (**qldglobe.information.qld.gov.au/**)
Groundwater use and management	Queensland Globe database DRDMW water entitlements database **data.qld.gov.au/dataset/water-entitlements** Bureau of Meteorology National Groundwater Information System **bom.gov.au/water/groundwater/ngis/** *Clarence-Moreton Bioregional Assessment (2014)* *Water Plan (Condamine and Balonne) 2019* *Water Plan (Great Artesian Basin and Other Regional Aquifers) (GABORA) 2017* *Water Plan (Moreton) 2007.*

14.5.4 Groundwater impact assessment

The construction and rail operation details were assessed to consider potential short- and long-term groundwater impacts (both local and regional), using analytical assessments and numerical predictive groundwater modelling to inform of initial impacts on groundwater resources and users as a result of the Project. Further details are presented in Appendix N: Groundwater Technical Report.

The modular finite difference flow model (MODFLOW) modelling software was selected as it allows for assessing variable saturation conditions, flow and mass transport simulations, and for integrated groundwater and surface water modelling. The model was constructed to include sufficient layers to simulate the geological (and corresponding groundwater resources) units that will potentially be impacted during construction, including alluvium, colluvium, MRV (olivine basalt and deeper rhyolite), and Marburg Subgroup sediments (including Koukandowie Formation and Gatton Sandstone). The model includes optimum grid spacing, with a factor of 3, to openings, which is recognised to have the least numerical discrepancies when calculating inflow into tunnels; therefore, the minimum grid spacing of 35 metres (m) was deemed appropriate as the grid spacing is roughly three times the tunnel diameter (11 m). Appropriate model boundaries were selected sufficiently far from the tunnel so as not to influence model predictions.

The model calibration target selected included groundwater-level data with constraints of reasonable ranges of hydraulic conductivity (provided form the geotechnical study and desktop review) and recharge and evapotranspiration data. Steady-state calibration, followed by transient calibration (water level data to be compiled from loggers installed during the geotechnical study), were performed. Model parametrisation was determined using both the simple (homogeneous) and complex (heterogeneous) approach. Model parameter values were determined using PEST (parameter estimation and uncertainty analysis software).

The calibrated model was used to assess potential impacts on current groundwater resources, short- and long-term groundwater drawdown (construction and operation). Uncertainty and sensitivity assessments were undertaken to allow for consideration of data gaps and model assumptions.

14.5.4.1 Significance assessment

The predictive groundwater modelling for the Project has allowed for the assessment of potential impacts as a result of to the Project, with consideration for sensitivity and magnitude criteria. This approach has allowed for the evaluation of significance classifications, with and without mitigation. These mitigations have been used as a basis for a GMMP for the Project, as presented in Appendix N: Groundwater Technical Report.

The significance assessment methodology is in Chapter 4: Assessment Methodology.

14.5.4.2 Cumulative impact assessment

A cumulative impact assessment (CIA) was undertaken to identify other existing, planned, or reasonably defined developments in proximity to the Project that may incrementally impact on the groundwater resources in the groundwater study area, in addition to the Project. The CIA process applied for groundwater was in accordance with the methodology outlined in Chapter 4: Assessment Methodology and Chapter 22: Cumulative Impacts.

The detailed groundwater CIA is presented in Appendix N: Groundwater Technical Report and is summarised in Section 14.9.3.

Where cumulative impacts could only be expressed qualitatively, professional judgement regarding the probability, duration and magnitude/intensity of the impact, as well as the sensitivity and value of the receiving environment, was used to assess the relevance and significance of potential cumulative impact(s).

14.6 Existing environment

14.6.1 Climate

The groundwater study area has a hot and dry climate with warm-to-hot summers and mild-to-cool winters. Rainfall is seasonally distributed, with a distinct wet season that occurs during the summer months of December through February, and an extended dry season from April through September. Mean maximum monthly temperatures typically range from 28°C in summer to 18°C in winter. Pan evaporation exceeds rainfall for each month of the year and an overall negative climate budget generally prevails in the region.

Climate data is only available at the Toowoomba Airport BoM station (041529); rainfall data from the Helidon Post Office BoM station (040096) was used for this study (refer to Appendix N: Groundwater Technical Report for further details).

A Cumulative Rainfall Departure (CRD) (Weber and Stewart, 2014) was prepared to evaluate short-term/monthly rainfall trends compared to long-term average monthly rainfall records, to identify periods of drought and above average rainfall, and can be associated with increased groundwater recharge to unconfined aquifers. The CRD is discussed in detail in Appendix N: Groundwater Technical Report. In summary, the CRD data indicates the region had a dry period between 1890 and 1920; however, there was significant and consistent rainfall events during the 1950s and again in 2011. It should be noted that in the past 24 months (through 2020) the region has received characteristically low rainfall and is currently drought declared since 2014 (The Long Paddock, 2021).

The topography of the groundwater study area is variable as the alignment traverses through the GDR and Great Escarpment and crosses several hills, valleys, creeks and alluvial floodplains. The alignment traverses the Gowrie Creek and Lockyer Creek catchments and various tributaries of these watercourses. The valleys in the Great Escarpment feed various creeks, including Oaky, Rocky and Six Mile creeks. These creeks are supported by local catchments within the escarpment and feed into Lockyer Creek via Rocky Creek west of Helidon.

The Project alignment traverses the GDR at Project Chainage (Ch) 10.2 km, which is the highest point on the western side of the Great Escarpment, with an elevation of approximately 644.5 m Australian Height Datum (AHD). The topography becomes significantly steeper and features extensive pockets of colluvium and steep slopes immediately east of the divide and, further east of the divide (across the Great Escarpment), the topography changes to comprise primarily rolling terrain with isolated hills.

The GDR is the highest point across the groundwater study area is a recharge area and divides the east (coastal) and west (inland) flowing watercourses. West of the GDR, the main watercourse is Gowrie Creek, which flows in the westerly direction. Gowrie Creek runs north of the alignment, from Ch -1.76 km (200 m proximity from the alignment) around the existing West Moreton System, and crosses the alignment at Ch 7.2 km (where the Project alignment is in tunnel, approximately 100 m below Gowrie Creek). A road bridge over Gowrie Creek is proposed at Gowrie.

East of the GDR there are numerous watercourses and their ephemeral gullies, which flow in the valleys between the ridges, with the main watercourses incised in the underlying Marburg Subgroup rocks (mainly the Koukandowie Formation). Notable watercourses east of the GDR are:

- Oaky Creek (intermittent)—runs perpendicular and to the north of the alignment and intersects at Ch 11.75 km and Ch 12.15 km, where it becomes Rocky Creek (perennial)
- Rocky Creek (perennial)—runs sub-parallel and to the south of the alignment, from approximately Ch 12.15 km to Ch 13.35 km (varying in proximity between 130 m and 700 m from the alignment)
- Six Mile Creek (perennial)—crosses the alignment at Ch 16.5 km and Ch 16.7 km and then runs south of the alignment from Ch 19.6 to Ch 20.0 km (varying in proximity between 600 m and 900 m from the alignment)
- Lockyer Creek (intermittent)—intersecting the alignment at Ch 24.7 km and then running south of the alignment, sub-parallel to the Helidon to Calvert connection near Ch 26.2 km.

These key features are depicted on Figure 14.2 and discussed further in Chapter 13: Surface Water and Hydrology.

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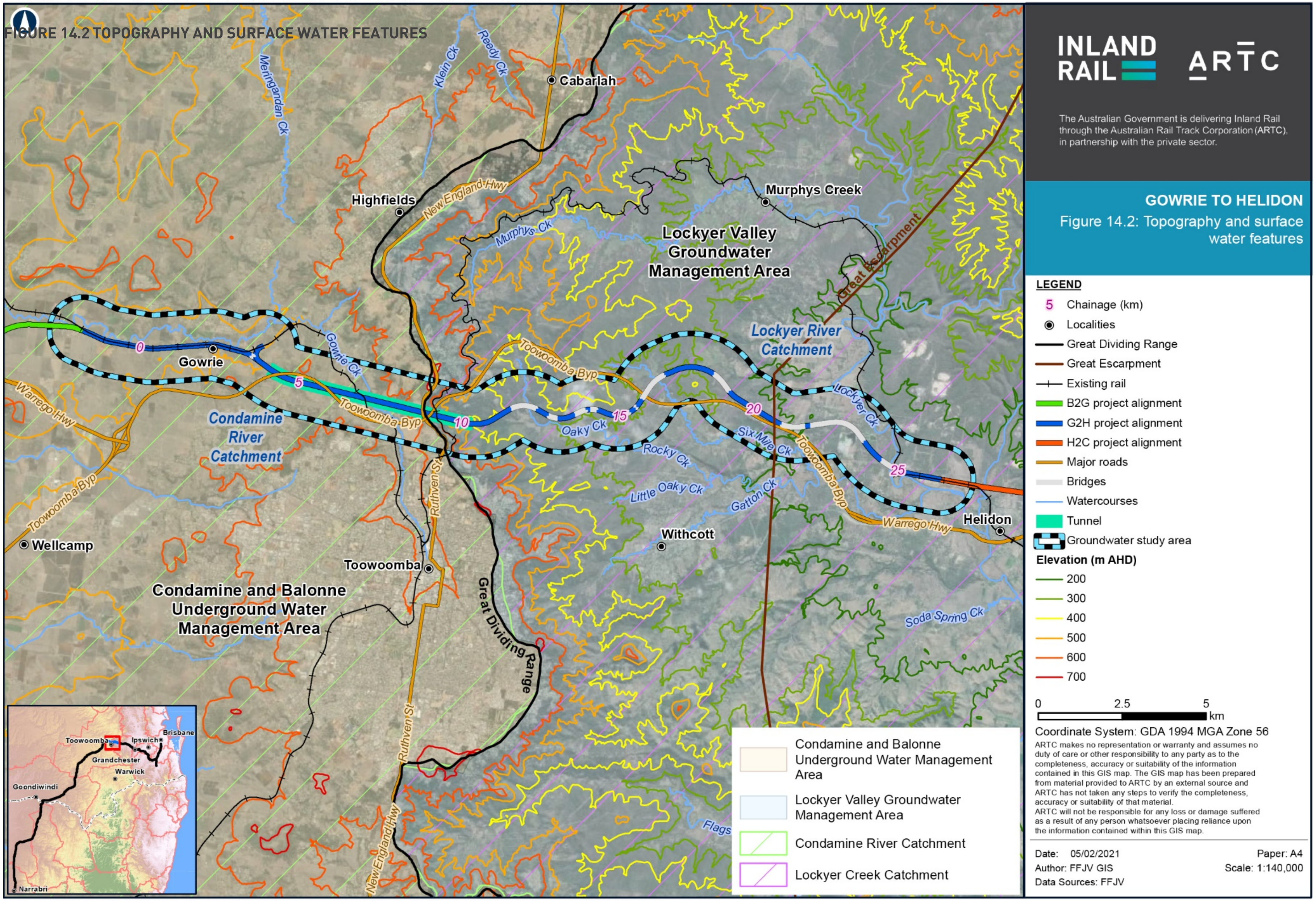

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14.6.3 Geology and hydrostratigraphy

The Project is within the northern section of the regional Clarence-Moreton Basin (CMB)—a sedimentary depositional basin. Understanding of the tectonic setting and structural elements in the CMB 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. Strike-slip movement occurred along several major faults, controlling the magnitude of extension during evolution of the CMB.

Figure 14.3 depicts the major structural elements of the CMB in relation to the groundwater study area. There is a northwest trending anomaly, which may be related to fissure feeders, dykes or other similar linear structures crossing the Toowoomba Range Tunnel alignment (Ch 4.2 km to Ch 10.2 km) at Ch 8.0 km and Ch 9.0 km. The trend line indicated on the radiometric image is sub-parallel with the alignment of the escarpment and with the New England Highway near its current crossing with the Toowoomba Bypass alignment.

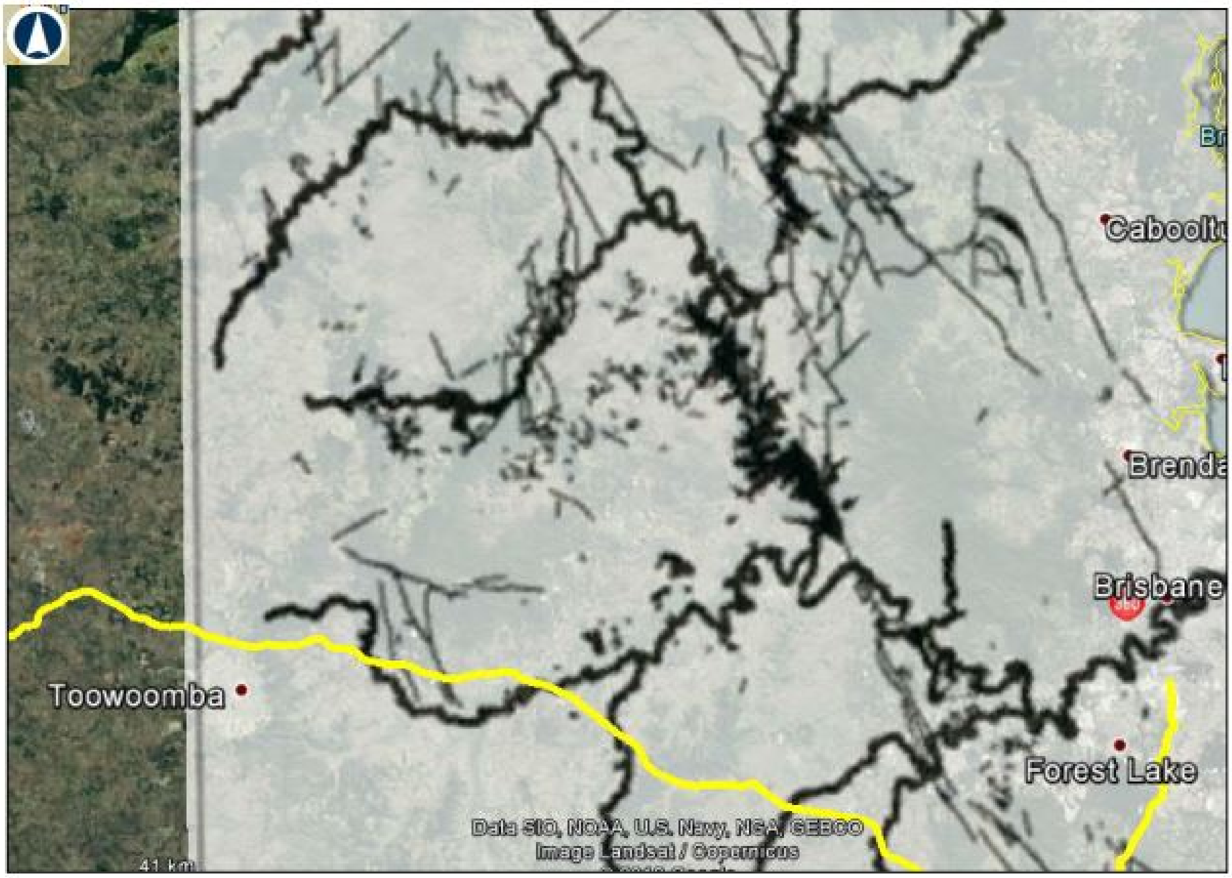

FIGURE 14.3 CLARENCE-MORETON BASIN IDENTIFIED FAULTS AND DRAINAGE PATTERN IN PROXIMITY TO THE GROUNDWATER STUDY AREA
Source: Hodgkinson et al. (2006)

The key geological units (youngest to oldest, noting overburden and soil cover are missing) present as outcrops/surface geology across the Project alignment are illustrated on Figure 14.4, and include:

- Deposits of Quaternary alluvial and colluvial sediments, including clays, silts, sands and gravels are associated with the primary surface water features. These deposits occur above the MRV in the groundwater study area, west of the GDR and above the Koukandowie Formation east of the GDR. There are instances of colluvium occurring east of the divide within the Great Escarpment, at the foothills near Rocky Creek and Six Mile Creek. The alluvial and colluvial sediments are considered limited in extent, both laterally and vertically, away from the watercourses.
- The Project alignment is underlain by the MRV from the western boundary (Ch -1.76 km) to the GDR (Ch 10.2 km) and it is expected that alluvium beneath Gowrie Creek is underlain by MRV. The Toowoomba Range Tunnel is mapped to intersect the MRV, specifically an informal subunit of the MRV, referred to as Toowoomba Volcanics (TV), which is reported to be up to 330 m thick along the escarpment at Toowoomba (Willey, 2012).

- Below the MRV, in the western portion of the groundwater study area, is the undifferentiated Tertiary sediments (UTS). While not a recognised stratigraphic unit, the UTS is the highly-to-extremely weathered older sedimentary rocks of the Walloon Coal Measures (WCM) or Koukandowie Formation, commonly represented by claystone where the plasticity of the resultant clays is significantly higher and includes the presence of tuff or tuffaceous layers. It is noted that the WCM and Koukandowie Formation are of Jurassic age; however, presence of this informal unit has been observed between Tertiary MRV flow deposits. The WCM are located, in isolated areas, under the MRV/UTS in the western portion of the groundwater study area.
- The alignment between the GDR (Ch 10.2 km) and the Great Escarpment (Ch 17.8 km) is underlain by the Koukandowie Formation (the upper member of the Marburg Subgroup). The eastern section of the alignment is underlain by the Gatton Sandstone (lower member of the Marburg Subgroup), from Ch 18 km to the end of the alignment (Ch 26.2 km).
- While it is noted that the Woogaroo Subgroup (including the Precipice Sandstone) underlies the Marburg Subgroup, due to the depth of occurrence (deepest unit in the CMB) and understood hydraulic connectivity of the Woogaroo Subgroup (outcrops northeast of the G2H Project) to the alignment, the unit is not considered to be of relevance for the Project. The Woogaroo Subgroup is included in the H2C project (inclusive of registered bores and groundwater users).

The primary groundwater bearing units relevant to the Project are summarised in Table 14.4. The ability of these units to transmit groundwater is determined in large part by its permeability (or the hydraulic conductivity). The higher the permeability the more readily it can transmit groundwater. An aquifer is a unit that transmits water relatively easily due to its higher permeability (for example sands and gravels, or fractured rock), compared to an aquitard that stores groundwater but cannot readily transmit water due to its low permeability (e.g. clays, silts and unfractured bedrock).

There are three primary aquifers identified in the groundwater study area:

- Quaternary aquifer/s: shallow unconfined and/or perched aquifer(s) in colluvium or alluvium units
- MRV aquifer: a fractured basalt aquifer in the MRV that may be unconfined, semi-confined (leaky), or confined, dependent on aquifer and flow characteristics and degree of alteration (weathering)
- Sedimentary aquifer/s: a confined/semi-unconfined aquifer in the sedimentary rock of the Gatton Sandstone, the Koukandowie Formation and the WCM.

These aquifers are included in Table 14.4 and described in the sections below.

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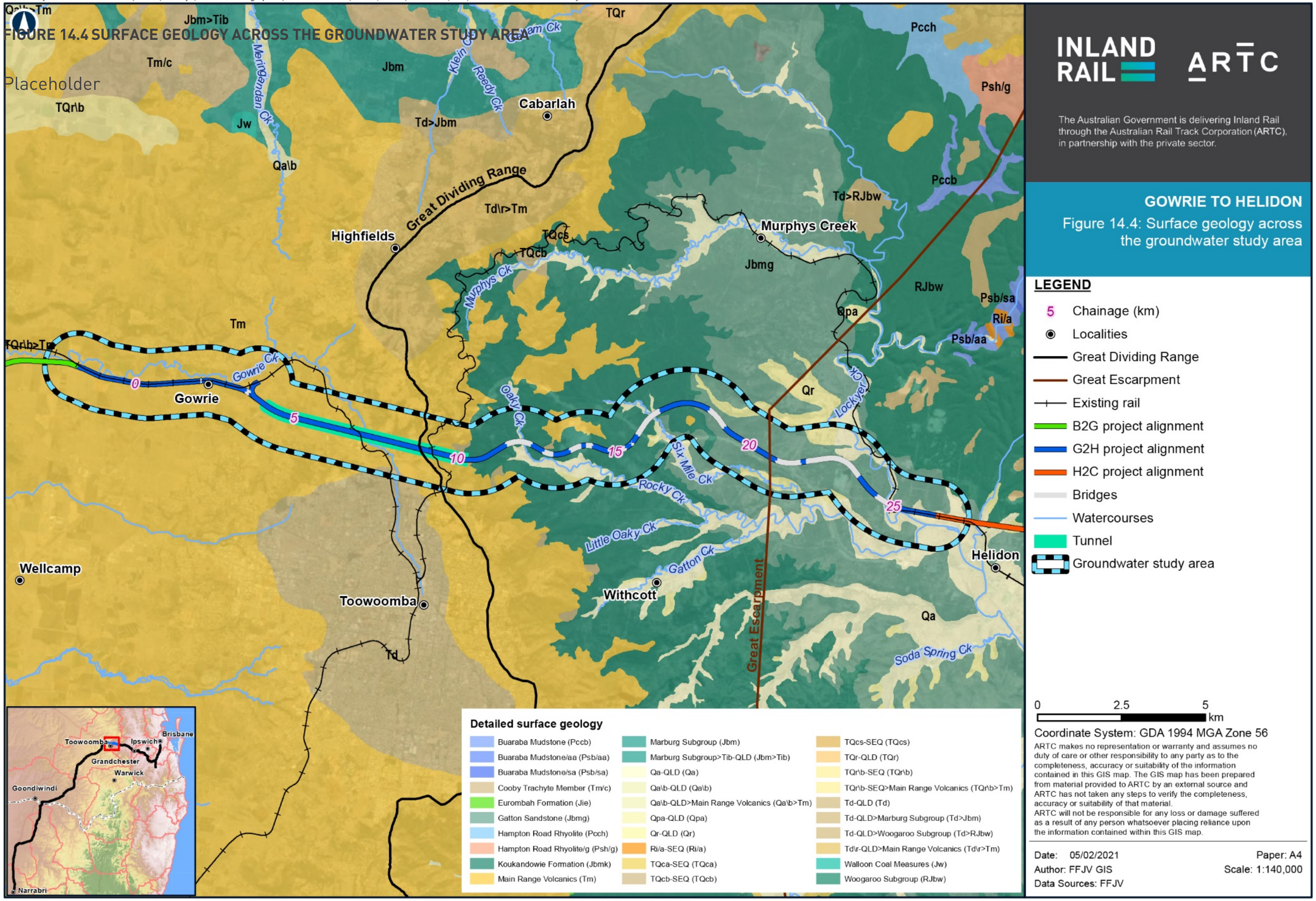

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TABLE 14.4 GROUNDWATER OCCURRENCE IN THE STUDY AREA

Hydrostratigraphic unit	Main occurrences	Approximate proportion of alignment	Thickness[1,2]	Lithology	Comments
Quaternary alluvium/colluvium	Below primary watercourses including Gowrie, Oaky, Rocky, Lockyer, and Six Mile creeks	10%	Up to approximately 20 m[1]	Clay, silt, sand and gravel; in a generally fining upward sequence	Aquifer (unconfined)
Tertiary volcanics and intrusives (MRV)	The GDR	40%	2 to 93 m[1] 330 m[2]	Basalts, rhyolite, dolerite and gabbro with interbedded agglomerate/tuff/mudstone	Aquifer (unconfined to confined)[3]
UTS	As isolated lenses beneath or within MRV volcanics/ intrusives	<1%	Up to approximately 12 m[2]	Clay, tuff, mudstone and fine-grained sandstone	Low permeability aquifer/ aquitard
WCM	The GDR	<1%	67 to 154 m[1]	Lithic and silty sandstone with interbedded mudstone, siltstone, coal (no coal reported in bore cards for study area)	Aquifer/ aquitard
Koukandowie Formation	Underlies MRV in western portion of study area and GDR; subcrops and outcrops along eastern portion of the GDR	25%	10 to 17 m[1] 12 to 152 m[2]	Interbedded sandstone, siltstone, claystone and minor coal	Low permeability aquifer/ aquitard
Gatton Sandstone	Between the GDR to Helidon township and is below alluvium at creeks in the Great Escarpment	25%	2 to 93 m[1] 330 m[2]	Medium- to coarse-grained sandstone	Low permeability aquifer/ aquitard
Woogaroo Subgroup	Underlies Gatton Sandstone	0% (located adjacent to the groundwater study area)	1 to 146 m[1]	Fine- to medium-grained sandstone	Aquifer. The source aquifer for springs located north-east of the Project.

Table notes:
m = metres
1 Local data sourced from the Queensland Globe database within 1 km of the Project. Data for the Woogaroo Subgroup has been sourced from >1 km of the Project, to the north-east of G2H.
2 Regional data sourced from Raiber, et al. (2016)
3 Variable aquifer conditions (unconfined to confined) may be present in this unit due to the complex heterogeneity of the non-massive basalts in the unit.

14.6.4 Groundwater quality

14.6.4.1 Salinity

The quality of groundwater is often considered in terms of its salinity (the concentration of salt in water) and considered to indicate the suitability of the water for various uses, e.g. drinking water, stock, irrigation, etc. Electrical conductivity (EC) and/or TDS are typically used to indicate salinity/groundwater quality. EC is a measure of how well an aqueous solution can carry an electrical current and reported as micro siemens per centimetre (µS/cm). This can be converted to an estimated TDS value by using a conversion factor. TDS (sometimes referred to as 'salinity') is an estimate of the mass of dissolved solids (salts) in the water and typically expressed as milligram per litre (mg/L). The higher the EC or TDS, the higher the salinity of the water. By way of comparison, a TDS of less than 1,000 mg/L is considered 'fresh', 1,000 to 2,000 mg/L is described as 'brackish' and 2,000 to 10,000 mg/L is saline.

Regional groundwater chemistry in the CMB varies considerably between aquifer systems due to spatial and temporal separation. Groundwater in Quaternary aquifers (alluvial/colluvial units) is generally fresher than groundwater in sedimentary rock aquifers (including the WCM, Koukandowie Formation and Gatton Sandstone). The main control of spatial variability between aquifer systems is the nature of the connectivity between surface water systems and shallow aquifers with deep aquifer systems, e.g. groundwater in the MRV near the headwaters of Lockyer Creek is commonly fresh due to increased recharge from Quaternary aquifers and rainfall. A gradual decrease in groundwater quality has been observed downstream of the headwater where connectivity with Quaternary aquifers is conceptualised to decrease (Rassam, et al., 2014).

Water quality of the confined aquifers ranges from fresh to saline and exhibits greater variability than overlying Quaternary aquifers. Water quality in the MRV aquifer is generally fresh due to thin soil coverage and rapid recharge from fractures, whereas groundwater in the sedimentary rock aquifer of the WCM varies between 750 and 49,475 mg/L (Metgasco, 2007).

An assessment of salinity and EC in the CMB was undertaken by Rassam, et al. (2014) based on multiple references and data sets. A summary is provided in Table 14.5; data from bores in the groundwater study area is included in Table 14.6 (where available) and were collected from Project bores in October 2018. Laboratory results for EC and salinity are detailed in Appendix N: Groundwater Technical Report. This monitoring event provides a baseline water quality data set along sections of the alignment that could help to inform future groundwater monitoring and management plans.

Salinity and EC ranges are generally consistent with the findings of Rassam, et al. (2014) for the wider CMB, with salinity values in groundwater from sedimentary bedrock formations in the groundwater study area typically brackish (i.e. between 1,001 and 10,000 mg/L).

TABLE 14.5 SUMMARY OF GROUNDWATER SALINITY—REGIONAL

Aquifer unit	No. samples	Salinity[1] (mg/L) Min	Mean	Max	EC (µS/cm) Min	Mean	Max	Groundwater study area Sample size	Median EC and salinity
Lockyer Valley alluvium[2]	307[a]	~91	1,904	18,000	-	-	-	8	380 µS/cm 233 mg/L
	NR[a]	-	-	-	-	3,327	-		
	100[c]	-	-	-	350	-	25,000		
Koukandowie Formation[4]	9[a]	359	4,248	14,496	-	6,607	-	39	2,150 µS/cm 1,333 mg/L
	21[a]	-	-	-	765	4,750	20,000		
MRV	NR[a]	500	-	1,500	-	-	-	100	1,290 µS/cm 673 mg/L
WCM[3]	92[a]	-	-	-	86	4,095	26,500	3	1,000 µS/cm 520 mg/L
Gatton Sandstone	42[a]	333	6,452	24,294	-	9,971	-	7	2,850 µS/cm 1,806 mg/L
	11[c]	-	-	-	-	7,643	-		
	7[d]	-	866	-	-	-	-		

Table notes:

Source as referenced by Raiber, et al. (2016): a—Pearce et al. (2007a); b—DNRM (2013); c—Pearce et al. (2007b); d—McKibbin (1995); N—Not reported

1 Salinity term used by Raiber, et al. (2016), rather than TDS

2 No regional data available for Oaky Creek, Rocky Creek and Gowrie Creek

3 Data only available for the Upper Condamine Catchment (west of Toowoomba)

4 Data not available for Koukandowie Formation in the Queensland Globe database; therefore, data for Marburg Subgroup is shown in table

TABLE 14.6 SUMMARY OF GROUNDWATER SALINITY ACROSS PROJECT BORES

Bore ID	Formation sampled	EC (uS/cm)	Salinity (mg/L)
320-01-BH2103	Koukandowie Formation	1,460	921
320-01-BH2201	Koukandowie Formation	2,640	1,570
320-01-BH2216	Gatton Sandstone	2,800	1,770
320-01-BH2217	Gatton Sandstone	2,080	1,300
320-01-BH2218	Gatton Sandstone	1,210	1,160
320-01-BH2301	Koukandowie Formation	5,690	3,420

Table notes:

Of the 12 monitoring bores installed for the feasibility design investigations, three project bores had insufficient water to procure a quality sample (320-01-BH2207, 320-01-BH2209 and 320-01-BH2215) and three bores had no data reported (320-01-BH2101, 320-01-BH2203 and 320-01-BH2212) and are, therefore, not included in the table. See Appendix N: Groundwater Technical Report for further discussion.

The post-feasibility design stage geotechnical and hydrogeological investigations (Golder, 2020c/d) indicate groundwater quality from new bores installed since 2018 is consistent with the data in Table 14.5 and Table 14.6 for key aquifers of the groundwater study area.

14.6.4.2 Groundwater characterisation

The Piper diagram is one of the most commonly used techniques to interpret water chemistry data. This method plots 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 and anions of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), fluoride (Fl), sulfate (SO4), carbonate (CO3) and bicarbonate (HCO3) alkalinity and hardness.

Groundwater characterisation for the key aquifers in the groundwater study area is summarised in Table 14.7; groundwater chemistry data has been obtained from the Queensland Globe datasets and the feasibility design stage geotechnical and hydrogeological investigations (Golder, 2020b) for this characterisation.

TABLE 14.7 SUMMARY OF GROUNDWATER CHARACTERISATION

<table>
<tr><th>Aquifer</th><th>Hydrochemical type</th><th>Explanation</th></tr>
<tr><td>Alluvium units west of the GDR
(Gowrie Creek alluvium)</td><td>Mg-Cl</td><td rowspan="2">The geochemistry of alluvium aquifers is impacted by connectivity with the MRV, which occurs west of the divide. The freshwater characteristics observed in the alluvium (mean salinity of 720 mg/L) is present in the MRV (mean salinity of 920 mg/L), this indicates there is recharge from alluvium units occurring.
Groundwater characteristics of the alluvial aquifers (east and west) are consistent with areas of mixing. The alluvium aquifer is likely influenced by local factors such as agricultural activities as well as proximity to roads and topographic highs (particularly the GDR).</td></tr>
<tr><td>Alluvium units east of the GDR
(Oaky Creek, Rocky Creek, Six Mile Creek, Lockyer Creek)</td><td>Mg-Cl-HCO3</td></tr>
<tr><td>MRV</td><td>Unclear</td><td>Groundwater in the MRV is highly variable in the groundwater study area. The two main groups observed are Mg and Na dominant, where the Mg dominant group is possibly reflecting cation exchange between Na and Mg. The scattered nature of the samples indicates that there are multiple processes occurring in the aquifer and these range from recent recharge to mixing environments, and cation exchange of magnesium and calcium for sodium.</td></tr>
<tr><td>Marburg Subgroup (interpreted as Koukandowie Formation)</td><td>Unclear</td><td>Groundwater varies between Na-Cl and Na-HCO3 water types. Variation of water types may be attributed to water bores screened across formations, geological structures separating formations or general variability over time. The Project bore screened in the Koukandowie Formation (320-01-BH2201) is classified as Na-HCO3 water type with high Cl content, which confirms the geochemistry observed within the Marburg Subgroup in the groundwater study area.</td></tr>
</table>

Aquifer	Hydrochemical type	Explanation
Gatton Sandstone	Na-HCO3	Gatton Sandstone unit does not have a clear characterisation but it is Na-HCO3 dominant. The Project bore sampled in the Gatton Sandstone (320-01-BH2217) is Na-HCO3, which is consistent with regional observations. The Project bore screened in Koukandowie Formation (320-01-BH2201) had the same characterisation but it had higher relative content in Cl.

14.6.4.3 Groundwater quality summary

The publicly available groundwater quality data (DRDMW groundwater database, 5 km search radius from centreline) along with results from the feasibility design stage investigations, as presented in Table 14.8, were compared with guideline values including the Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) for stock water and the National Health and Medical Research Council and Natural Resource Management Ministerial Council (NHMRC) *Australian Drinking Water Guidelines* (2018). This comparison allows for a cursory assessment of the ambient water quality conditions, prior to construction, to identify areas where degradation currently exists and to inform of the EVs to be maintained.

TABLE 14.8 COMPARISON OF GROUNDWATER QUALITY DATA TO GUIDELINE VALUES, WITHIN THE RELEVANT ALLUVIUM AQUIFERS, IN THE GROUNDWATER STUDY AREA

	Guidelines		Rocky Creek Alluvium (n = 2)			Gowrie Creek Alluvium (n = 1)			Oaky Creek Alluvium (n = 1)			Lockyer Creek alluvium (n = 8)		
Parameter	ANZG stock water (2018)	NHMRC Drinking Water (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Physiochemical														
Electrical conductivity (μS/cm)	-	-	991	1,680	1,336	-	-	5,800	-	-	1,640	150	2,350	380
pH value (pH units)	-	6.5–8.5	7.9	8.0	7.95	-	-	7.8	-	-	7.6	5.9	8.3	6.9
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-	-		
Hardness as CaCO3 (mg/L)	4,000	6,000	374	576	475	-	-	2,699	-	-	671	15	525	71
Alkalinity (mg/L)	-	-	205	274	240	-	-	152	-	-	429	31	634	86
Sodium adsorption ratio	-	-	1.5	2.2	1.9	-	-	1	-	-	1.2	1.6	9.1	2.7
Total Dissolved Solids (mg/L)	2,000[b]	600	524	867	696	-	-	-	-	-	-	119	1,433	233
Dissolved anions														
Bicarbonate (mg/L)	-	-	248	334	291	-	-	185	-	-	520	38	750	105
Carbonate (mg/L)	-	-	-	-	1.1[a]	-	-	-	-	-	1.3	0.2	11.5	2.95
Chloride (mg/L)	-	250	156	430	293	-	-	1,920	-	-	277	29.6	610	61
Fluoride (mg/L)	2	1.5	-	-	0.1[a]	-	-	0.5	-	-	0.2	0.1	0.8	0.3
Sulfate as SO4 (mg/L)	1,000	250	6	13	10	-	-	245	-	-	16	5.0	20.5	5.7
Dissolved cations														
Sodium (mg/L)	-	180	66	119	92	-	-	120	-	-	72	21.1	355	46
Potassium (mg/L)	-	-	-	-	1.5[a]	-	-	-	-	-	1	0.6	7.7	1.5
Iron (mg/L)	-	0.3	-	-	-	-	-	-	-	-	-	0.01	1.4	0.02
Calcium (mg/L)	1,000	-	60	79	70	-	-	112	-	-	102	0.5	62	11
Magnesium (mg/L)	-	-	54.3	92	73.2	-	-	588	-	-	101	3.4	90	9.3
Nutrients														
Phosphate (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Nitrogen (mg/L)	-	-	4.2	10.9	7.6	-	-	-	-	-	-	-	-	-

Parameter	Guidelines		Rocky Creek Alluvium (n = 2)			Gowrie Creek Alluvium (n = 1)			Oaky Creek Alluvium (n = 1)			Lockyer Creek alluvium (n = 8)		
	ANZG stock water (2018)	NHMRC Drinking Water (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Dissolved metals														
Zinc (mg/L)	20	3	-	-	-	-	-	-	-	-	-	-	-	-
Aluminium (mg/L)	5	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Boron (mg/L)	5	4	-	-	-	-	-	-	-	-	-	-	-	-
Copper (mg/L)	0.5	2	-	-	-	-	-	-	-	-	-	-	-	-

Table notes:

Data source: Section 9.3 Livestock drinking water guidelines (ANZG, 2018); Table 10.6 Guideline values for physical and chemical characteristics (NHMRC, 2018)

a Only single data value available

b Most conservative guideline value out of the range provided in Table 9.3.3

c Highlighted cells show where exceedances of the relevant guidelines occurred

TABLE 14.9 COMPARISON OF GROUNDWATER QUALITY DATA TO GUIDELINE VALUES, WITHIN THE RELEVANT AQUIFERS, IN THE GROUNDWATER STUDY AREA

Parameter	Guidelines		MRV (n = 100)			WCM (n = 3)			Koukandowie Formation (Marburg Subgroup) (n = 39)			Gatton Sandstone (n = 7)		
	ANZG stock water (2018)	NHMRC Drinking Water (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Physiochemical														
Electrical conductivity (μS/cm)	-	-	440	7,520	1,190	940	2,560	1,000	791	9,000	2,150	980	3,690	2,850
pH value (pH units)	-	6.5–8.5	6.8	8.9	7.8	6.8	8.3	8.0	7.1	8.9	8.0	7.4	8.7	7.7
Turbidity (NTU)	-	-	-	-	1,450[a]	-	-	-	-	-	-	-	-	-
Hardness as CaCO3 (mg/L)	4,000	6,000	5	2,494	256	105	506	308	20	733	162	72	1,157	217
Alkalinity (mg/L)	-	-	15	717	223	84	374	220	100	1,647	654	280	1,257	1,024
Sodium adsorption ratio	-	-	0.7	21.4	3.2	1.7	7.3	7.0	1.4	41	14.9	3.9	29	23.7
Total Dissolved Solids (mg/L)	2,000[b]	600	254	4,338	673	489	550	520	448	4,954	1,333	567	2,311	1,806
Dissolved anions														
Bicarbonate (mg/L)	-	-	18.3	870	268	102	450	260	120	2,000	791	336	1,530	1,210
Carbonate (mg/L)	-	-	0.1	10	1.3	3.2	3.6	3.4	0.6	63	6.65	1.0	43	2.5
Chloride (mg/L)	-	250	40	2,520	223	79	812	185	85.7	2,690	215	160	1,092	2.04
Fluoride (mg/L)	2	1.5	0.01	103	0.2	0.1	0.2	0.15	0.1	1.6	0.5	0.2	2.04	0.89
Sulfate as SO4 (mg/L)	1,000	250	1.1	273	17	4.5	100	8.5	1.2	96	10	3	140	14
Dissolved cations														
Sodium (mg/L)	-	180	2	1,340	124.5	67	378	165	62	1,670	505	133	820	572
Potassium (mg/L)	-	-	0.3	15	2.15	6.0	8.6	7.3	1.8	64	15	5	36	15
Iron (mg/L)	-	0.3	0.01	0.85	0.02	0.05	6.0	3.025	0.01	0.11	0.02	-	-	-
Calcium (mg/L)	1,000	-	2	292	50	32	171	41	4.1	122	35	7.8	188	36
Magnesium (mg/L)	-	-	0.1	487	35	6	50	19	0.9	122	18	5.7	167	29
Nutrients														
Phosphate (mg/L)	-	-	-	-	1.0[a]	-	-	-	-	-	-	-	-	-
Nitrogen (mg/L)	-	-	0.1	250	8.7	-	-	0.5[a]	0.2	21	1.2	1.0	3.5	1.0

Parameter	Guidelines		MRV (n = 100)			WCM (n = 3)			Koukandowie Formation (Marburg Subgroup) (n = 39)			Gatton Sandstone (n = 7)		
	ANZG stock water (2018)	NHMRC Drinking Water (2018)	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
Dissolved metals														
Zinc (mg/L)	20	3	0.01	0.14	0.01	-	-	-	-	-	-	-	-	1.9[a]
Aluminium (mg/L)	5	0.2	0.01	0.05	0.035	-	-	-	-	-	-	-	-	0.05[a]
Boron (mg/L)	5	4	0.01	0.06	0.03	-	-	-	-	-	-	-	-	0.39[a]
Copper (mg/L)	0.5	2	0.02	0.03	0.03	-	-	-	-	-	-	-	-	0.03[a]

Table notes:

Data source: Section 9.3 Livestock drinking water guidelines (ANZG, 2018); Table 10.6 Guideline values for physical and chemical characteristics (NHMRC, 2018)

a Only single data value available

b Most conservative guideline value out of the range provided in Table 9.3.3

c Highlighted cells show where exceedances of the relevant guidelines occurred

As a general overview of water quality in each aquifer zone, the following have been identified as exceeding guideline values:

- TDS is outside the NHMRC Drinking Water Guidelines in the Rocky Creek alluvium
- TDS exceeds both the NHMRC Drinking Water and ANZG Stock Water Guidelines in the MRV, Marburg Subgroup and Gatton Sandstone
- Chloride exceeds the NHMRC Drinking Water Guidelines in all aquifers
- Fluoride, sodium and iron exceed the NHMRC Drinking Water Guidelines in the MRV, Marburg Subgroup and Gatton Sandstone.

Groundwater in Project bores were screened in the Koukandowie Formation and Gatton Sandstone. The pH in Project bores ranged between 7.1 and 8.8, which is considered neutral to slightly alkaline. Sulfate is generally low and total alkalinity (as CaCO3) is high. Registered bores in the groundwater study area have similar characteristics to Project bores. As a result, groundwater characteristics in the groundwater study area reflect alkaline conditions, which have low potential of causing acid drainage. Furthermore, the probability of encountering potentially acid sulfate soils (PASS) is considered extremely low/very low for 80 per cent of the Project and considered low/very low for the remaining alignment (based on the Atlas of Australian Acid Sulfate Soils). This suggests there is low likelihood of causing acid rock drainage (ARD) during earthworks.

14.6.5 Groundwater yields

Regional yield test records are considered strongly biased towards the high end of the hydraulic conductivity range, due to most bores being drilled for irrigation uses, and, therefore, target the high-yielding alluvial/colluvial aquifers. The Quaternary sedimentary aquifers are likely transversely isotropic due to interbedding of sandy layers with beds of silt and clay. Yield values were sourced from the Queensland Globe database for registered bores within 5 km of the Project. Yield values for bores screened in alluvium units varies between 2.5 to 6.2 litres per second (L/s) across the groundwater study area, with a mean value of 4.35 L/s. This high range of yield variability is attributed to the variable extent and nature of alluvial sediments that vary from coarse gravels to silty clays.

The MRV are comprised of primary permeability in the form of vesicular zones with secondary porosity in the form of cooling joints and fractures (Office of Groundwater Impact Assessment (OGIA), 2019). As a result, groundwater occurrence and hydraulic properties of the MRV are inherently variable due to the nature, location and frequency of fractures and joints. Yield values were sourced from the Queensland Globe database for registered bores within 5 km of the Project—116 yield values, which ranged between 0.1 and 6.9 L/s with a mean yield of 1.3 L/s. Site-specific hydraulic conductivity values were estimated from slug tests conducted in October and November 2018. The MRV aquifer was tested at 320-01-BH2101, with four falling head tests undertaken. Hydraulic conductivity values ranged between 2.6×10^{-8} and 6.2×10^{-7} metres per second (m/s), which reflects the lower end of the regional values observed in the MRV. This high range of yield variability is attributed to the fractured nature of the MRV aquifer. Recently completed geotechnical and hydrogeological investigations (Golder, 2020c/d) in the MRV in proximity to the Toowoomba Range Tunnel support the highly variable nature of this unit, with yield rates that range from inferred confined conditions with yield of 0.016 L/s and estimated hydraulic conductivity of 1.3×10^{-8} (Mt Kynoch, tunnel invert area) to yields that range from 0.8 L/s to 7 L/s in the MRV near the western portal.

Regional studies have shown the pre-Cenozoic aquifers in the CMB sequence are generally low yielding. Average yields range from 0.5 to 2.5 L/s in the sandstones, siltstones, and conglomerates of the Bundamba Group, which includes the Marburg Subgroup, the Gatton Sandstone, and the Koukandowie Formation (Rassam, et al., 2014). Local yield values were sourced from the Queensland Globe database for registered bores within 5 km of the Project. There was a single yield value of 0.2 L/s in the Koukandowie Formation for this section of alignment. There were 10 yield values associated with the Marburg Subgroup in this segment of alignment, with values ranging between 0.1 and 6.3 L/s and mean value of 1.0 L/s. This indicates the hydraulic conductivity of the Koukandowie Formation is highly variable, which reflects the fractured nature of the aquifer and the variability in hydraulic conductivity of the siliciclastic rocks with depth across the weathering profile.

Local yield values for the Gatton Sandstone were sourced from the Queensland Globe database. Values from 15 registered bores reported yields ranging between 0.3 and 6.0 L/s and a median value of 2.5 L/s. There were 22 registered bores screened in the Marburg Subgroup in this section of the alignment and yields ranged between 0.1 and 6.1 L/s with a mean yield of 2.1 L/s.

Regional studies have reported yields from the WCM to average 0.5 L/s with a maximum recorded of 5 L/s (Rassam, et al., 2014). Yield values were sourced from the Queensland Globe database for registered bores within 5 km of the Project. There was a single yield value of 0.8 L/s in the WCM aquifer.

In general, yields from bedrock sediments in the groundwater study area are likely to be relatively low but are dependent on the lithology intersected (sandstone, siltstone, mudstone etc.) and frequency, size, and interconnectivity of fractures. Individual bore yield estimates may be affected by the available drawdown, bore construction, and capacity of the pump used during testing.

14.6.6 Groundwater levels and flow patterns

The groundwater table is typically a subdued version of topography, with the depth to groundwater increasing beneath topographic highs (e.g. the GDR and Great Escarpment) and encountered at shallower depths in lower lying reaches close to surface water drainage lines (e.g. in the MRV and Gatton Sandstone). The presence of shallow aquitards, surface water features and groundwater extraction can locally affect depths to groundwater and flow patterns.

The water table occurs in the alluvial/colluvial sediments or outcropping MRV across much of the groundwater study area west of, and within, the GDR. The Koukandowie Formation, east of the GDR, and the Gatton Sandstone, in the eastern portion of the groundwater study area, form the upper (water table) aquifer in these areas.

A summary of groundwater level data from registered bores in the groundwater study area, along with 8 of 12 monitoring bores installed along the Project alignment, is provided in Table 14.10.

Groundwater level data indicates there is limited data available along the Toowoomba Range Tunnel alignment. It is noted that the post-feasibility design-stage geotechnical and hydrogeological investigations (Golder 2020c/d) installed VWPs and deployed automated pressure transducers in select new monitoring bores. This data will be used to refine the predictive model and will be incorporated into the Final EIS.

TABLE 14.10 LONG-TERM GROUNDWATER LEVEL DATA WITHIN 5 KM OF THE ALIGNMENT

Bore ID	Aquifer	Groundwater elevation* (m AHD)	Depth to groundwater (mbgl)	Screen interval (mbgl)	Location
14320196	Lockyer Creek Alluvium	122.69	5.08	11–11.9	Ch 2.2 km (H2C)
14320850	Lockyer Creek Alluvium	120.96	11.94	-	Ch 4.1 km (H2C)
14320851	Lockyer Creek Alluvium	118.18	14.00	-	Ch 4.1 km (H2C)
14320852	Lockyer Creek Alluvium	116.07	17.37	-	Ch 4.0 km (H2C)
14320853	Lockyer Creek Alluvium	112.13	20.72	-	Ch 4.0 km (H2C)
14320854	Lockyer Creek Alluvium	117.59	16.10	-	Ch 4.0 km (H2C)
14320948	Gatton Sandstone	155.33	9.41	11.1–12.4	Ch 25.0 km
14320949	Gatton Sandstone	148.78	12.92	3.0–15.0	Ch 24.6 km
14320950	Gatton Sandstone	125.85	16.10	22.7–23.9	Ch 2.9 km (H2C)
42230955	MRV	495.04	10.91	10.0–16.0 15.0–17.3 27.0–33.0	Ch 2.1 km
42231225	MRV	587.78	64.61	71.0–77.0	Ch 7.3 km
42231250	MRV	592.85	22.73	40.6–45.2 79.6–81.9	Ch 6.0 km
42231269	MRV	660.25	14.50	13.7–15.2	Ch 3.4 km
42231653	MRV	604.63	41.88	80.0–102.0	Ch 12.4 km
42231654	TV	619.29	27.11	55.0–70.0	Ch 12.4 km
42231656	MRV	547.51	92.60	162.0–172.0	Ch 6.5 km
42231657	MRV	610.93	29.33	40.0–64.0	Ch 6.5 km
42231659	MRV	571.61	2.65	18.0–24.0	Ch 6.9 km
42231660	MRV	550.64	14.9	25–30	Ch 8.2 km
42231662	MRV	471.11	93.7	153–166	Ch 8.2 km

Bore ID	Aquifer	Groundwater elevation* (m AHD)	Depth to groundwater (mbgl)	Screen interval (mbgl)	Location
320-01-BH2101	Koukandowie Formation	474.66	101.24	104–117	Ch 5.6 km Toowoomba Range Tunnel
320-01-BH2103	Koukandowie Formation	377.60	12.40	9–11	Ch 10.4 km Eastern tunnel portal, offices, fuel storage
320-01-BH2201	Koukandowie Formation	320.52	6.36	9–10	Ch 11.8 km Oaky Creek Viaduct Pier Access
320-01-BH2212	Gatton Sandstone	188.74	10.93	8–10	Ch 21.2 km Murphys Creek Road Viaduct
320-01-BH2216	Gatton Sandstone	160.55	13.45	10–12	Ch 22.6 km
320-01-BH2217	Gatton Sandstone	149.35	10.34	7.5–9.5	Ch 24.6 km Bridge laydown for Lockyer Creek bridge
320-01-BH2218	Gatton Sandstone	140.32	14.90	9–10	Ch 24.8 km Bridge laydown for Lockyer Creek bridge
320-01-BH2301	Koukandowie Formation	309.31	10.59	10–11	Ch 15.6 km Bridge laydown for McNamaras Road Bride Roadworks site

Table notes:

* Indicative elevation

mbgl = metres below ground level

Groundwater levels and flow direction in the Toowoomba region are influenced by the GDR, which forms a groundwater divide in the region. Groundwater in the west GDR occurs in the alluvial/colluvial sediments or outcropping MRV. To the east of the GDR, the Koukandowie Formation and the Gatton Sandstone form the upper (water table) aquifer in these areas.

Six registered bores with long-term groundwater data were reported to be constructed in alluvial units with groundwater levels between 112.13 and 122.69 m AHD. The groundwater levels in alluvial/colluvial sediments are expected to typically occur in low-lying areas near watercourses where bridges/viaducts are predominantly proposed. Local groundwater levels are influenced by surface water—groundwater hydraulic connectivity and, as such, influenced by rainfall seasonality and events. Due to the nature and topography of the alluvial/colluvial deposits, there is potential for localised perched groundwater tables in the groundwater study area.

There is limited long-term groundwater level data in the groundwater study area west of the GDR, specifically along the Toowoomba Range Tunnel alignment. While a total of 11 groundwater bores with long-term groundwater data were reported to be constructed in the MVR, levels were variable (471.11 to 660.25 m AHD) and difficult to correlate due to the various confining attributes of the contributing units in the MRV, nature of isolated fractured rock aquifers and/or local influence from abstraction.

There are no registered bores screened in the Koukandowie Formation with long-term groundwater level observations within 5 km of the Project alignment; however, four geotechnical bores (located along the alignment) were converted to monitoring bores during a geotechnical investigation in 2018. The site-specific data indicates the water level in this formation, along the alignment, decreases gradually from the GDR to the west and decreases more rapidly east of the GDR.

A total of three bores were identified with long-term groundwater level data available in the Gatton Sandstone aquifer, in addition to four geotechnical bores (located along the alignment) converted to monitoring bores during a geotechnical investigation in 2018. Groundwater elevations (125.85 to 155.33 m AHD) decrease from Ch 21.2 km towards the eastern end of the alignment following the topography.

Registered bores reported for the WCM were not encountered.

As a result of the EIS process, the paucity of localised continuous groundwater level data (publicly available and from the feasibility design stage investigations) has promoted the construction of new monitoring bores and VWPs as part of the post-feasibility design stage geotechnical investigations, to inform this recognised data gap. The new monitoring bores were equipped with automated pressure transducers. The data recorded on the new VWPs and automated pressure transducers along with those installed in the feasibility design stage investigation bores (continuous datasets from 2018) will be assessed and incorporated into the predictive model refinement, to enhance the existing predictions of Project impacts on water levels for the Final EIS.

In summary, from the highest point of the GDR and the apex of the groundwater divide, groundwater flow gently flows west of the GDR following topography. East of the GDR, shallow groundwater follows the escarpment, with steep relief, towards Helidon. The flow direction of the alluvium aquifer is typically represented by the surface water catchment boundaries, which reflects the groundwater divide.

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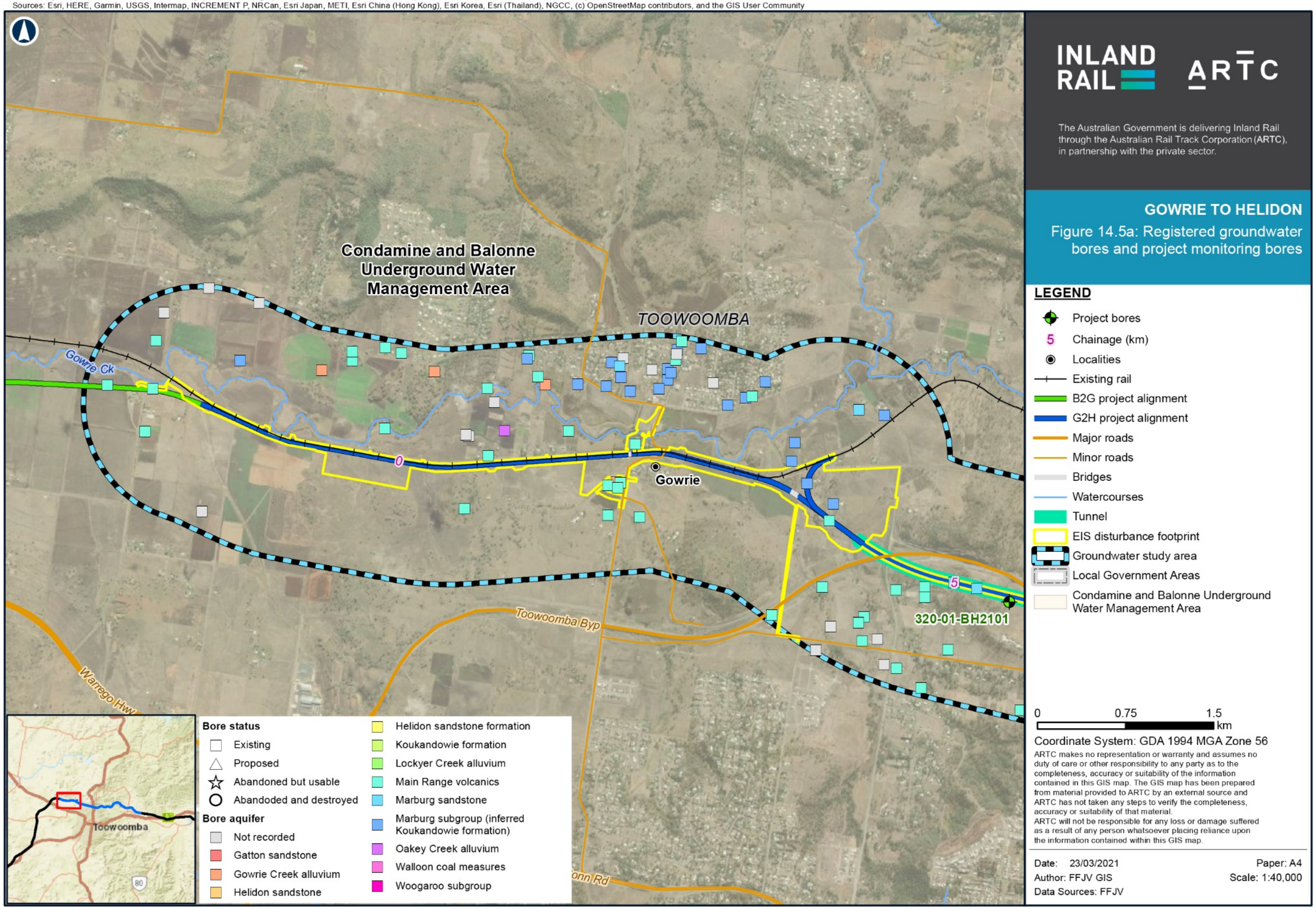

Map by: GN/DTH Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201909051619_G2H_Groundwater_Figures\320-EAP-201909051619_ARTC_Fig14.5_BoresGDE_v6.mxd Date: 24/03/2021 15:15

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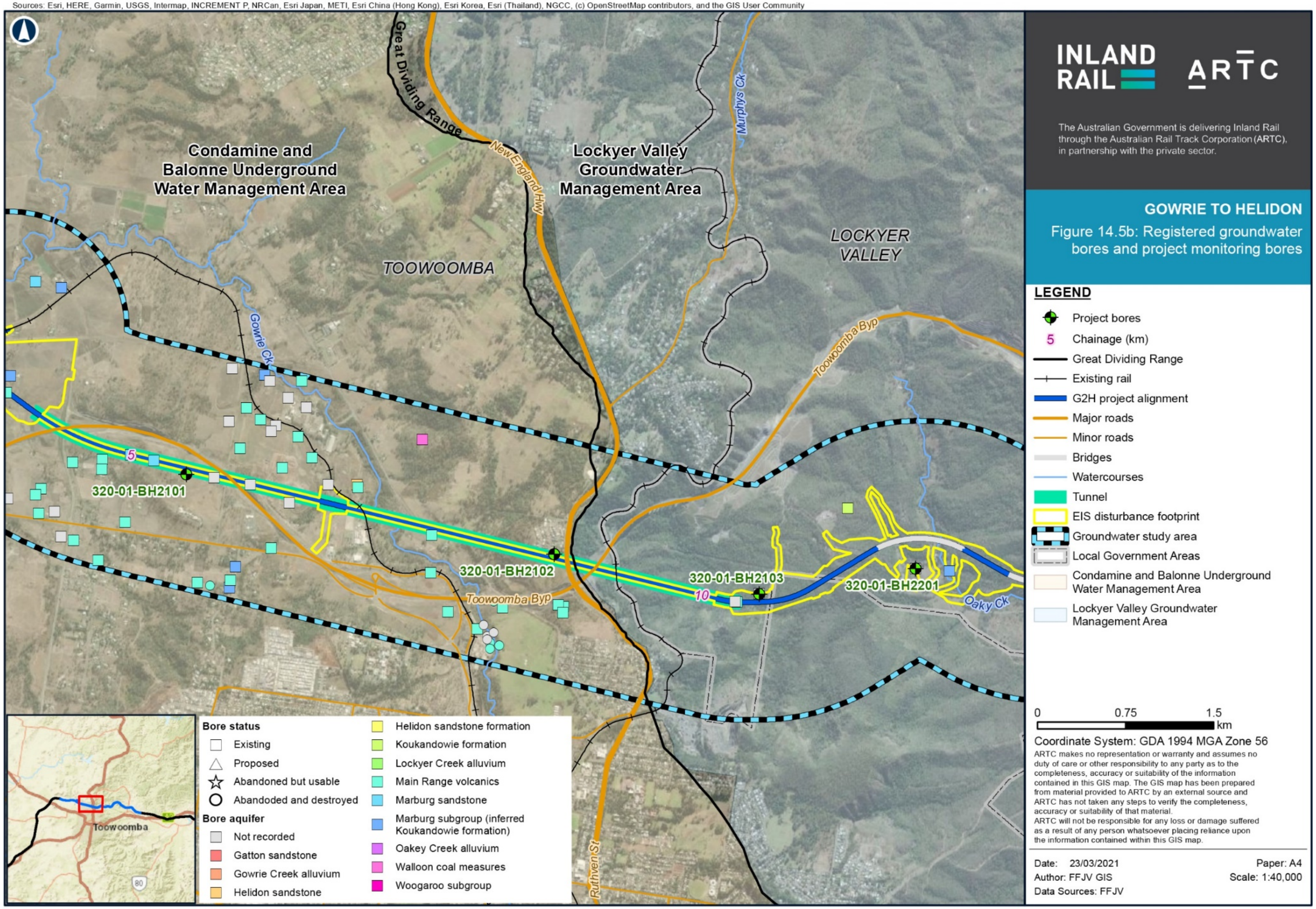

GOWRIE TO HELIDON
Figure 14.5b: Registered groundwater bores and project monitoring bores

Map by: GN/DTH Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201909051619_G2H_Groundwater_Figures\320-EAP-201909051619_ARTC_Fig14.5_BoresGDE_v6.mxd Date: 24/03/2021 15:15

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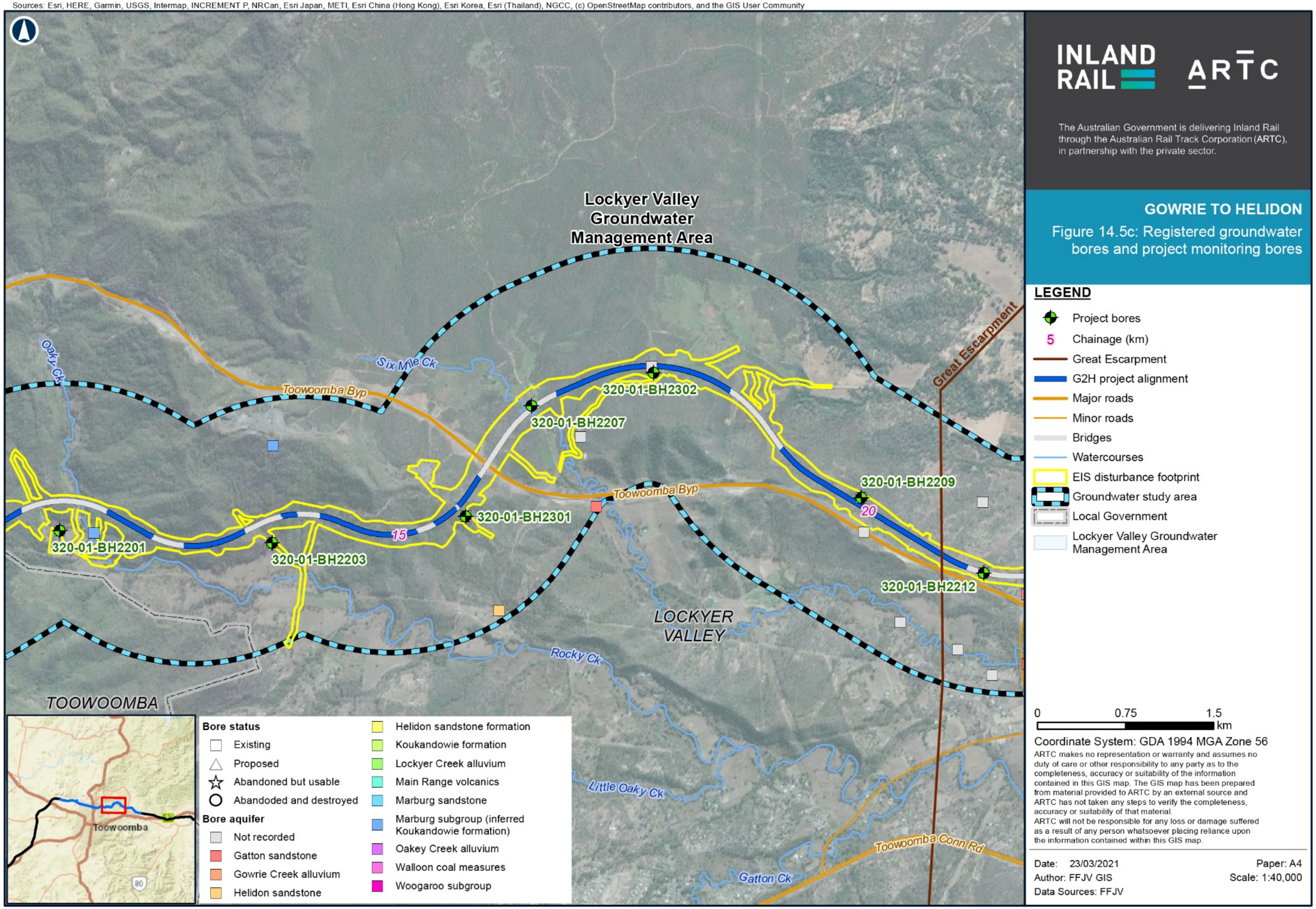

Map by: GN/DTH Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201909051619_G2H_Groundwater_Figures\320-EAP-201909051619_ARTC_Fig14.5_BoresGDE_v6.mxd Date: 24/03/2021 15:15

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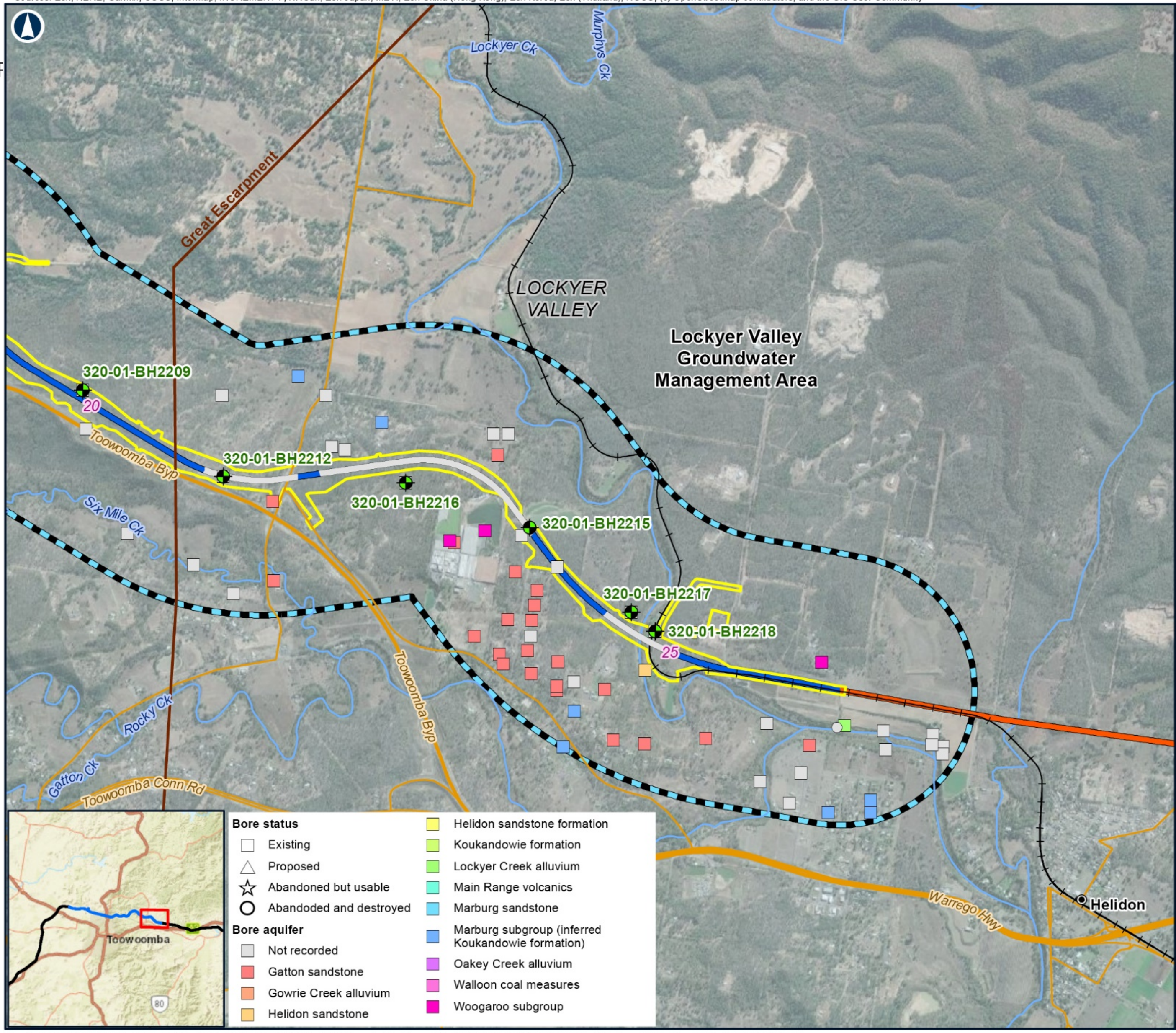

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GOWRIE TO HELIDON

Figure 14.5d: Registered groundwater bores and project monitoring bores

LEGEND

- Project bores
- Chainage (km)
- Localities
- Great Escarpment
- Existing rail
- G2H project alignment
- H2C project alignment
- Major roads
- Minor roads
- Bridges
- Watercourses
- EIS disturbance footprint
- Groundwater study area
- Local Government Areas
- Lockyer Valley Groundwater Management Area

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Local groundwater flow in the alluvial aquifers (Gowrie Creek, Oaky Creek, Rocky Creek, Six Mile Creek and Lockyer Creek alluvium) is generally influenced by surface water-groundwater interaction, where there is a hydraulic connection. This is observed along Gowrie Creek, which flows west into the Condamine River sub-catchment, and it is expected that groundwater in the shallow Gowrie Creek alluvium has a similar trend. Section 14.6.7 further discusses the hydraulic connectivity inferred between Gowrie Creek, associated alluvial sediments and the underlying MRV.

East of the divide, the Project crosses Rocky Creek, Oaky Creek and Six Mile Creek, which flow east, and feed Lockyer Creek; it is expected that groundwater flow in the shallow alluvial aquifers' mimic topography and surface water features. The potentiometric surface in the CMB indicates that lower groundwater elevations (deeper depth to groundwater) correspond to alluvial sediments along the eastern portion of the groundwater study area, suggesting that these alluvium sediments act as regional discharge areas for the underlying and flanking CMB sedimentary sequence (e.g. Gatton Sandstone in the eastern portion of the groundwater study area).

The degree of interconnection varies laterally due to local variations in alluvial sediment lithology, underlying bedrock geology and drainage channel morphology, as well as seasonally, due to changes in groundwater elevations. At times, watercourses may change from gaining systems (receiving baseflow from shallow groundwater) to losing systems (with surface water locally recharging the alluvial sediments).

The height of groundwater above the tunnel and the hydraulic gradient either side of the GDR affects the rate of flow to the tunnel and portals. Since hydraulic heads increase during high-rainfall episodes/seasons and decrease during extended periods of no/low rainfall, seasonality is also a factor controlling groundwater flow.

Climate change can cause groundwater reduction due to prolonged periods of drought. The Project has been in a fully drought-declared area since 2014 (The Long Paddock, 2021). Drought reduces surface water levels, which acts as a recharge source (along with rainfall) to the alluvial aquifers. Alluvial groundwater levels will reduce in these areas, under drought conditions, which rely on surface water to recharge. Groundwater levels will also reduce in areas where groundwater discharges to surface water. Recharge to aquifers that subcrop/outcrop (other than alluvium) are also considered to be impacted by prolonged drought conditions. Groundwater will also be impacted by prolonged drought where there are dams that act as artificial recharge (e.g. controlled releases).

14.6.7 Surface water—groundwater interaction

The groundwater study area is located in the Clarence-Moreton bioregion assessment area where strong evidence of interaction between groundwater and surface water has been reported (Raiber, et al., 2016). This supposition is based on several lines of evidence inclusive of assessment of groundwater and surface water quality, streamflow time-series data, groundwater hydrographs and streambed elevation.

It is anticipated that there will be interaction between watercourses and shallow groundwater in the associated alluvial and colluvial sediments at some locations, particularly where watercourses and/or drainage lines are more deeply incised and groundwater levels are shallow. The degree of interconnection will vary laterally due to local variations in alluvial/colluvial sediment lithology, underlying bedrock geology and channel morphology, as well as seasonally, due to changes in groundwater elevations.

At times, watercourses may change from gaining systems (receiving baseflow from shallow groundwater) to losing systems (with surface water locally recharging the alluvial sediments).

Local surface water and groundwater interaction was assessed by identifying trends between water level and salinity in surface water and groundwater over time. There are two surface water monitoring gauges located in the groundwater study area with available data, including:

- Gowrie Creek (422326A): located 287 m upstream of the Project (proximal to main tunnel ventilation shaft)
- Lockyer Creek (143203C): located 913 m downstream of the Project, at Lockyer Creek. Long-term groundwater level data downstream of the Lockyer Creek gauge has been reviewed from RN14320190, located approximately 300 m to the northeast, which has provided continuous data since 2002.

Surface water and groundwater are both responsive to rainfall over time and share similar trends, which indicates surface-water–groundwater connectivity. This is likely evident in the unconsolidated material in the alluvium aquifer within the groundwater study area. Groundwater elevation in the Lockyer Creek alluvium is responsive to rainfall recharge over long periods, although the response and recovery are more gradual when compared to the rapid and short duration observed in the Lockyer Creek stream gauge.

The hydraulic relationship between Gowrie Creek and adjacent units, including the associated alluvial sediments and underlying MRV, are of interest to the Project. It is important to understand the local relationship between these units, particularly temporal influences on recharge and discharge mechanisms between groundwater units so that an informed impact assessment can be undertaken for the Project.

Generally, it is recognised that these units (Gowrie Creek alluvium and MRV) are hydraulically connected at various locations where Gowrie Creek has incised into the MRV (direct relationship) and where alluvial sediments overlie the (weathered) MRV (indirect relationship) and influence each other, hydraulic gradient dependent. The degree of connectivity, particularly in the groundwater study area, is not well defined; therefore, the hydraulic relationship between Gowrie Creek and the MRV can only be inferred in the groundwater study area due to a paucity of aquifer characterisation data for the MRV at Gowrie Creek.

The Upper Condamine Basalts (comprise the Toowoomba City Basalts sub-area of the Water Plan (Condamine and Balonne) 2019 area—a recognised groundwater unit of importance in the MRV in the groundwater study area), are considered to generally consist of an upper unconfined weathered and fractured zone with a lower, more limited in extent, semi-confined fracted zone (DNRME, 2018). The presence of numerous small, overlapping lava flows and columnar joints creates vertical and horizontal hydraulic discontinuities. The upper weathered basalt layers are important for groundwater recharge during heavy precipitation events, with a delay period of about a month between rainfall and recharge (DNRME, 2018). In some areas, the upper weathered basalt (the major recharge zone) feeds creek beds even during dry periods (Willey, 2003). It is noted that the *Gowrie Creek Management Strategy* (WBM and Hassell, 1998) indicated seepage/recharge from the MRV into surface units/features that had primary occurrence in West and East creeks, tributaries to Gowrie Creek.

The Wetalla Wastewater Treatment Plant is recognised to provide artificial recharge to Gowrie Creek that supports the perennial nature of this creek north and upgradient of the Project. In the perennial areas of the creek, where alluvial sediments are consistently saturated, the vertical hydraulic gradients may act as recharge to the underlying MRV after significant rain events; however, in areas of the creek that are not perennial/saturated, it is considered that the underlying MRV act as recharge to the alluvial aquifers associated with Gowrie Creek in and nearby the groundwater study area.

14.6.8 Groundwater use

The groundwater study area is located in the Water Plan (Moreton) 2007, Water Plan (Condamine and Balonne), and Water Plan (Great Artesian Basin and Other Regional Aquifers (GABORA)), 2017 (refer Table 14.2). The Water Plan (GABORA) 2017 underlies the entire groundwater study area and is the prevailing management plan for water of the Great Artesian Basin. The other two plans apply to groundwater resources other than water from the Great Artesian Basin.

Under the Water Plan (GABORA) 2017, the groundwater study area is located in the Hutton Sandstone and Springbok Walloon groundwater units. These groundwater units include the Eastern Downs Marburg, Murphy's Creek Marburg and Eastern Downs Walloon Sub-Areas of the Water Plan (GABORA 2017). Within these Sub-Areas, landholders are permitted to take water for stock and domestic purposes without the need for a water licence; the exception being the area within 5 km of the Lockyer Creek Spring where a licence is required for any new stock or domestic bore. All other uses require a water licence, water permit, or seasonal water assignment notice.

Under the Water Plan (Moreton) 2007, the groundwater study area is located in the Lockyer Valley GMA and the Tenthill Creek and Ma Ma Creek (implementation area 2B), with the latter consisting of alluvial and hard rock aquifers (groundwater units 1 and 2, respectively). Within this GMA, the Project is in tunnel for approximately 1.5 km, along with 6.7 km of viaducts and a large number of cuts and embankments. Groundwater users who were taking groundwater for purposes, other than stock and domestic at the time the plan commenced, were authorised to continue to use the groundwater. Those authorisations remain today, as a licensing process has not yet been carried out in these areas.

For Water Plan (Condamine and Balonne) 2019, the groundwater study area is in the Condamine and Balonne Underground Water Management Area and the Upper Condamine Basalts Underground Water Management Unit. Within this unit the Project is associated with the following groundwater units:

- Toowoomba City Basalts sub-area—the tunnel is primarily located in this unit (i.e. area west of Boundary Street to the Toowoomba LGA boundary in the east)
- Toowoomba South Basalts limitation area—the western extent of the Project, west of Boundary Street area south of Gowrie Creek is located in this area. This includes the eastern tunnel portal and the start of the tunnel.
- Toowoomba North Basalts limitation area (i.e. local road network changes north of Gowrie Creek).

Groundwater authorisations are currently required for all uses, except stock and domestic, and allocations in the Toowoomba City Basalts sub-area are restricted to 60 per cent of the licensed volume. For the two limitation areas, limitations on use can be applied under s29 of the Water Act.

The registered use of bores in the groundwater study area, as well as those with groundwater entitlements (licences) to extract groundwater, are detailed in the following subsections.

14.6.8.1 Registered bores

Registered bores provide details of the location, water levels, construction details, stratigraphic logs, and water quality information for private registered bores, and Queensland Government groundwater investigation and monitoring bores. A review of reported groundwater use from registered bores in the groundwater study area has been completed to assist with the evaluation of EVs, discussed in Section 14.6.10.

A search of existing registered bores in the groundwater study area indicate there are 202 registered bores, which includes 30 water supply bores and 172 bores with unknown purpose (refer Table 14.11). Water entitlements indicate the MRV unit is most extensively used in the groundwater study area (60 per cent of all entitlement are in MRV) and the main purpose is irrigation (90 per cent of allocations are for irrigation). The Water Plans in the groundwater study area indicate groundwater allocations are at capacity.

Registered groundwater bore usage types have been sourced from the Queensland Globe database (accessed on 1 December 2020). Where licensed groundwater extraction exists for registered bores these are identified, noting that no entitlement is required for domestic and stock watering use.

It should be noted that bores constructed prior to 2002 were not required to register with DNRME (now DRDMW) and, as a result, the Queensland Globe database is not a complete record of bores in the groundwater study area; however, it is the most accurate and recent information available publicly. A groundwater bore survey will be undertaken during the detailed design phase to accurately capture all groundwater bores (registered and unregistered) in the groundwater study area (refer Section 14.8). Since 2002, all groundwater bores, regardless of type, are required to be registered/included (drillers must submit the bore's drill/lithologic and construction log to DRDMW) in the database.

TABLE 14.11 SUMMARY OF REGISTERED BORE WITHIN THE GROUNDWATER STUDY AREA

Aquifer	Water supply bores	Petroleum or Gas Exploration	Not defined	Total number of bores
Gowrie Creek alluvium	-	-	1	1
Oaky Creek alluvium	-	-	1	1
MRV	-	-	10	10
WCM	-	-	1	1
Helidon Sandstone	10	-	-	10
Marburg Subgroup	3	-	-	3
Woogaroo Subgroup	1	-	-	1
Aquifer not listed	16	-	159	175
Total	30	0	172	202

Source: Queensland Globe database accessed on 1 December 2020 (data.qld.gov.au/dataset/groundwater-database-queensland)

14.6.8.2 Groundwater entitlements

Water entitlements (licences) allow landholders to take water for use on that land, including from a spring, watercourse, lake aquifer of flowing water across the land. A review of reported groundwater uses from relevant aquifers for the Project has been completed, to assist with the evaluation of EVs. This review is based on the Queensland Water Entitlements Database (DNRME, 2019d) that details the licence type and source aquifer in Queensland. Groundwater entitlements in the groundwater study area are summarised in Table 14.12.

A total of 25 groundwater entitlements are licensed to extract groundwater from the study area. The largest groundwater entitlement (83456R) that overlaps with the groundwater study area is for the authorised purpose of Urban (various uses). The entitlement, which includes 54 registered bores located across 15 land parcels (i.e. entitlements are linked to land parcels) within the Toowoomba City Basalts sub-area, allows for the extraction of a total of 3,800 megalitres per year (ML/yr) from the MRV. Out of the 15 land parcels, only one is located in the groundwater study area, at Ch 9 km (Lot 924 on SP154259). A single registered bore is located in this land parcel (RN172182). The entitlement is part of the Water Plan (Condamine and Balonne) 2019.

The remaining groundwater licences to extract groundwater from the Gowrie Creek Alluvium (35 megalitres per year [ML/yr]), MRV (121 ML/yr; excludes 3,800 ML previously discussed), Eastern Downs Marburg (inferred Koukandowie Formation) (65 ML/yr), and the Helidon Sandstone of Clarence Moreton 3 Management unit (36.5 ML/yr). The licensed purposes include Urban, Irrigation, Stock Intensive, Domestic Supply, and Education Facility. The entitlements are part of the Water Plan (GABORA) 2017 and Water Plan (Condamine and Balonne) 2019. While there are water licences in the Murphys Creek Marburg (reported as Helidon/Precipice Sandstone in the database) and Murphys Creek Woogaroo, these are for stock and domestic purposes and do not impact/reduce the available overall volume from these units.

The water plans relevant to the Project indicate groundwater allocations are at capacity for the groundwater units intersected by the Project.

Further details of groundwater supply are included in Appendix N: Groundwater Technical Report.

TABLE 14.12 SUMMARY OF WATER LICENCES FROM AQUIFERS WITHIN THE GROUNDWATER STUDY AREA

QLD Water Plan	Water source	Licensed purpose	No. of entitlements[1]	Water made available (ML/yr)[2]	% of assigned water volume
Water Plan (Condamine and Balonne) 2019	Gowrie Creek Alluvium	Irrigation	2	35	100
	Toowoomba City Basalts (MRV)	Urban	1	3,800	97
		Irrigation	2	12.7	3
	Toowoomba North Basalts (MRV)	Irrigation	4	13	
	Toowoomba South Basalts (MRV)	Irrigation	5	95	
		Stock intensive	1	1	0.02
Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017	Eastern Downs Marburg (Marburg Subgroup – inferred Koukandowie Formation)	Irrigation	6	63	97
		Educational Facility	1	2	3
	Murphys Creek Marburg (Helidon [Precipice] Sandstone)	Domestic Supply	1	No data	0
	Murphys Creek Woogaroo (Precipice Sandstone)	Domestic Supply / Stock	1	No data	0
	Helidon [Precipice] Sandstone (Clarence Moreton 3 Management Unit)	Construction	1	36.5	100

Table notes:

1 DRDMW water entitlements database accessed online on 1 October 2020 (data.qld.gov.au/dataset/water-entitlements)

2 The Toowoomba City Basalts sub-area is currently subject to a limitation notice under the *Water Act 2000* (Qld).

14.6.9 Groundwater dependent ecosystems

The Groundwater Dependent Ecosystems Atlas (GDE Atlas) was developed by the BoM as a national dataset of Australian GDEs and potential GDEs; inclusive of:

- **Aquatic** ecosystems: reliant on the surface expression of groundwater and includes surface water systems (freshwater only) that may have a groundwater component (i.e. rivers, springs and wetlands)
- **Terrestrial** ecosystems: reliant on the subsurface presence of groundwater and includes all vegetation ecosystems
- **Subterranean** ecosystems: such as caves and aquifer ecosystems.

It is important to note that the Atlas GDE 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 including field work, analysis of satellite imagery and application of rules/conceptual models. The Queensland State GDE Database has been developed by the DES (last updated in May 2018) and is available in the DRDMW *QSpatial Catalogue*.

In 2012, the Australian Government funded the development of the national BoM GDE Atlas and co-funded, with the Queensland Government, the Queensland GDE Mapping Project (responsible for the regional/state GDE dataset) (Department of Science, Information Technology and Innovation (DSITI), 2015). Regional studies included in the Queensland Globe platform among other state datasets managed by the DES were included to complement the BoM GDE Atlas with Queensland data. The primary datasets that comprise the regional studies include primarily regional ecosystem maps, wetlands maps, and a springs database (DSITI, 2015).

The identification of potential GDEs in the Atlas does not confirm that the ecosystem is groundwater dependent, this is confirmed by undertaking an ecological investigation to identify the location, extent and source of the GDE. Ground truthing of GDEs was limited due to the climatic conditions limiting the likelihood of confirming the presence of a GDE (e.g. the recharge area for any springs east of the divide is limited and seepage will be dependent on local rainfall) with no springs or seepages identified during ground-truthing activities (e.g. geotechnical investigations or ecological surveys). Land access conditions also impacted the extent of survey works in some areas; therefore, the modelled extent of the aquatic GDEs are accepted as true presence and, thus, forms a potentially sensitive receptor.

As a conservative approach, for the purposes of the EIS, it has been assumed that the modelled extent of the aquatic and terrestrial GDEs are accepted as true presence and, thus, form a potentially sensitive receptor.

Further, it is noted that there are no GDEs listed under the water plans relevant to the Project; Lockyer Creek Spring (along with the section of Murphys Creek between Fifteen Mile Creek and Alice Creek); and the section of Lockyer Creek downstream of the Murphys Creek and Alice Creek confluence to Lockyer Siding Road are recognised as GDEs under the GABORA water plan. The latter is recognised under the GABORA as Murphy's Creek is approximately 5 km upstream of the proposed Lockyer Creek crossing.

14.6.9.1 Potential aquatic groundwater dependent ecosystems

There are numerous moderate- and low-potential aquatic GDEs (from regional studies and the GDE Atlas) in the groundwater study area, including Gowrie, Oaky, Six Mile and Lockyer creeks and their tributaries. Available surface water and groundwater quality and level data indicate there is potential for surface water and groundwater connectivity in the groundwater study area.

Near Gowrie Creek, the ecosystems are intermittently connected to aquifers with brackish salinity in unconsolidated Quaternary alluvium, associated with catchment constrictions. Towards the GDR and in the upper reaches of Oaky Creek, the ecosystems are intermittently connected to aquifers with fresh salinity in permeable rock (basalt) and in low rainfall areas. In Lockyer Creek and Six Mile Creek, the GDEs are associated with alluvial aquifers along these ephemeral creeks.

The locations of potential aquatic GDEs are shown on Figure 14.6.

All of the aquatic habitats/watercourses assessed as a component of the aquatic and terrestrial ecology field works for the EIS were found to be of poor-to-fair condition. This included three locations associated with Gowrie Creek, four locations associated with Rocky Creek, three locations associated with Lockyer Creek, and one location associated with Six Mile Creek (refer Appendix I: Terrestrial and Aquatic Ecology).

There are no registered groundwater springs within the groundwater study area based on a review of the Queensland Globe website. There are eight registered wetlands within 10 km of the Project, which are typically located near existing watercourses (shown in Figure 14.6). The closest spring is Lockyer Creek Spring located approximately 3.2 km upstream of the Project, in Lockyer Creek. The reported source aquifer for the Lockyer Creek Spring is the Precipice Sandstone (Woogaroo Subgroup); this aquifer is not expected to be encountered by the Project.

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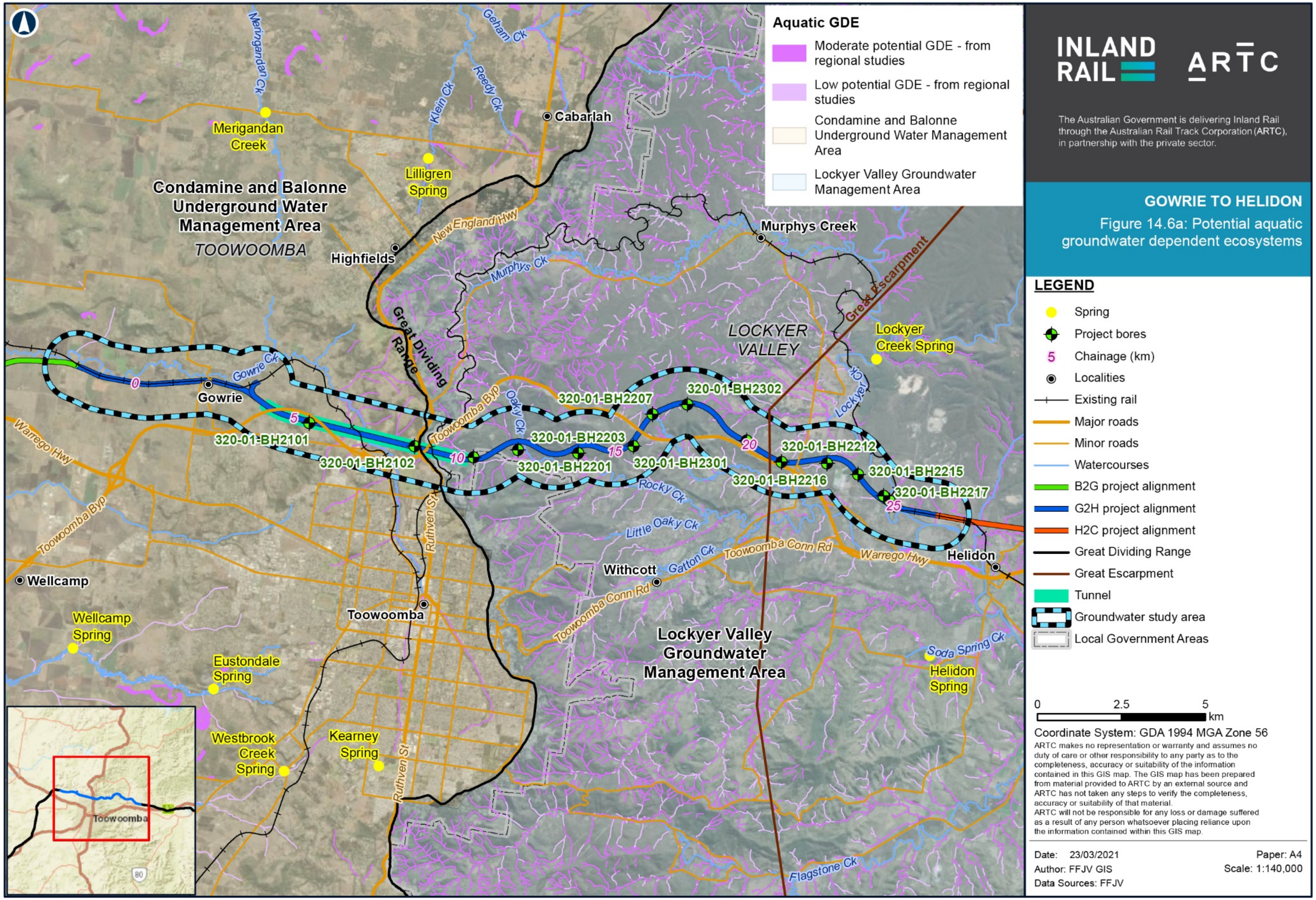

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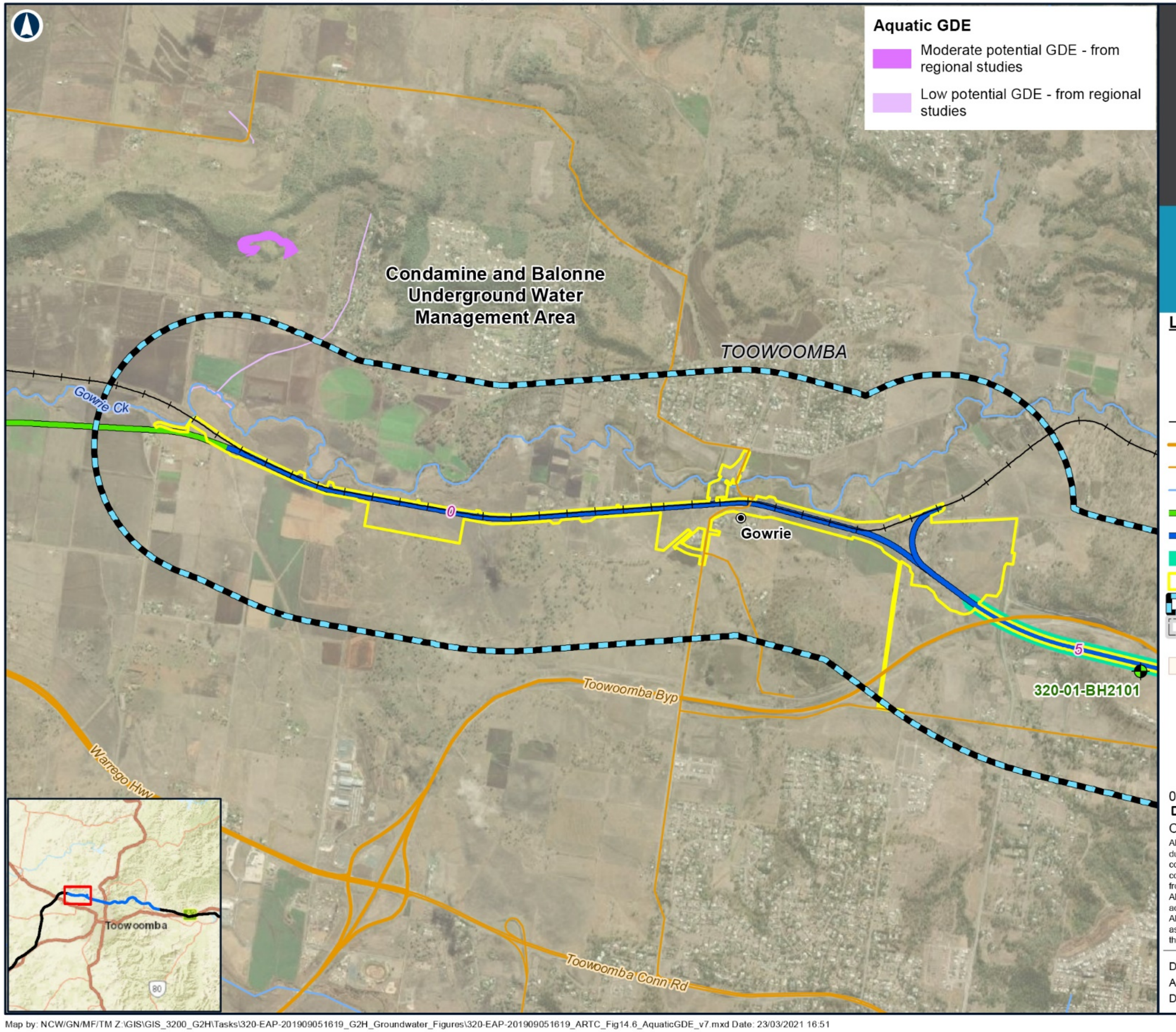

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GOWRIE TO HELIDON

Figure 14.6b: Potential aquatic groundwater dependent ecosystems

LEGEND

- Project bores
- Chainage (km)
- Localities
- Existing rail
- Major roads
- Minor roads
- Watercourses
- B2G project alignment
- G2H project alignment
- Tunnel
- EIS disturbance footprint
- Groundwater study area
- Local Government Areas
- Condamine and Balonne Underground Water Management Area

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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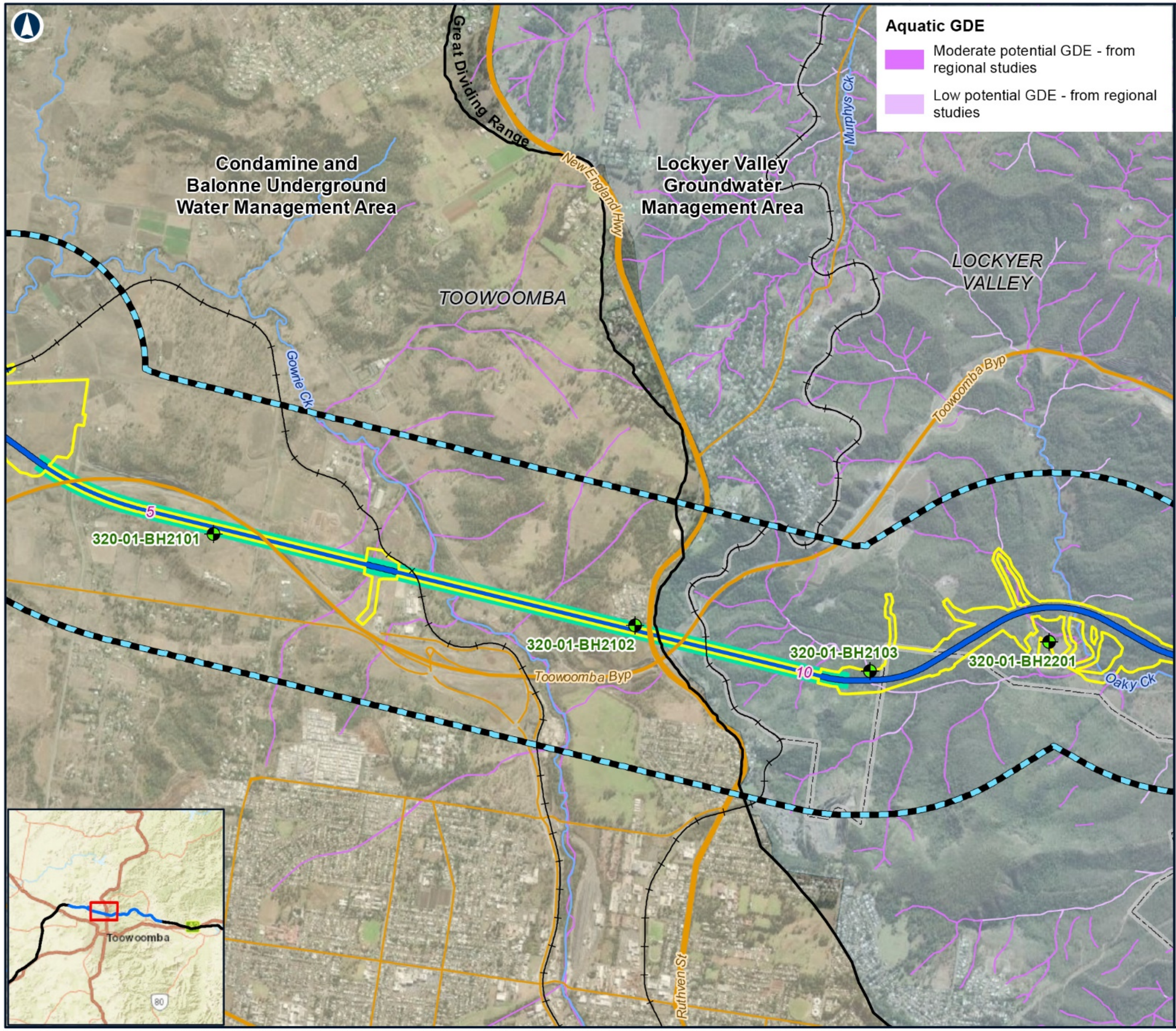

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GOWRIE TO HELIDON

Figure 14.6c: Potential aquatic groundwater dependent ecosystems

LEGEND

- Project bores
- 5 Chainage (km)
- Localities
- Existing rail
- Major roads
- Minor roads
- Watercourses
- G2H project alignment
- Great Dividing Range
- Tunnel
- EIS disturbance footprint
- Groundwater study area
- Local Government Areas
- Condamine and Balonne Underground Water Management Area
- Lockyer Valley Groundwater Management Area

0 0.75 1.5 km

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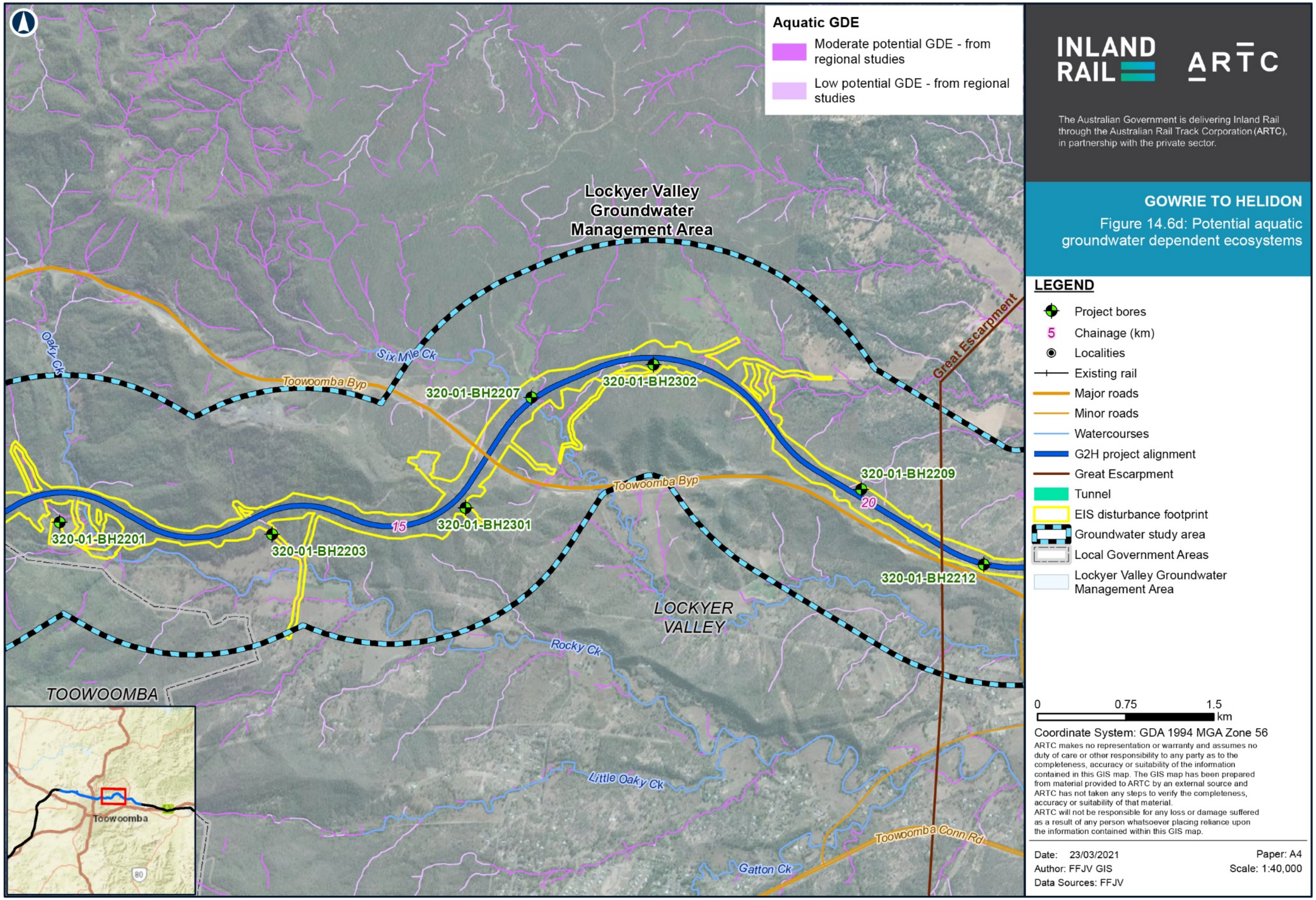

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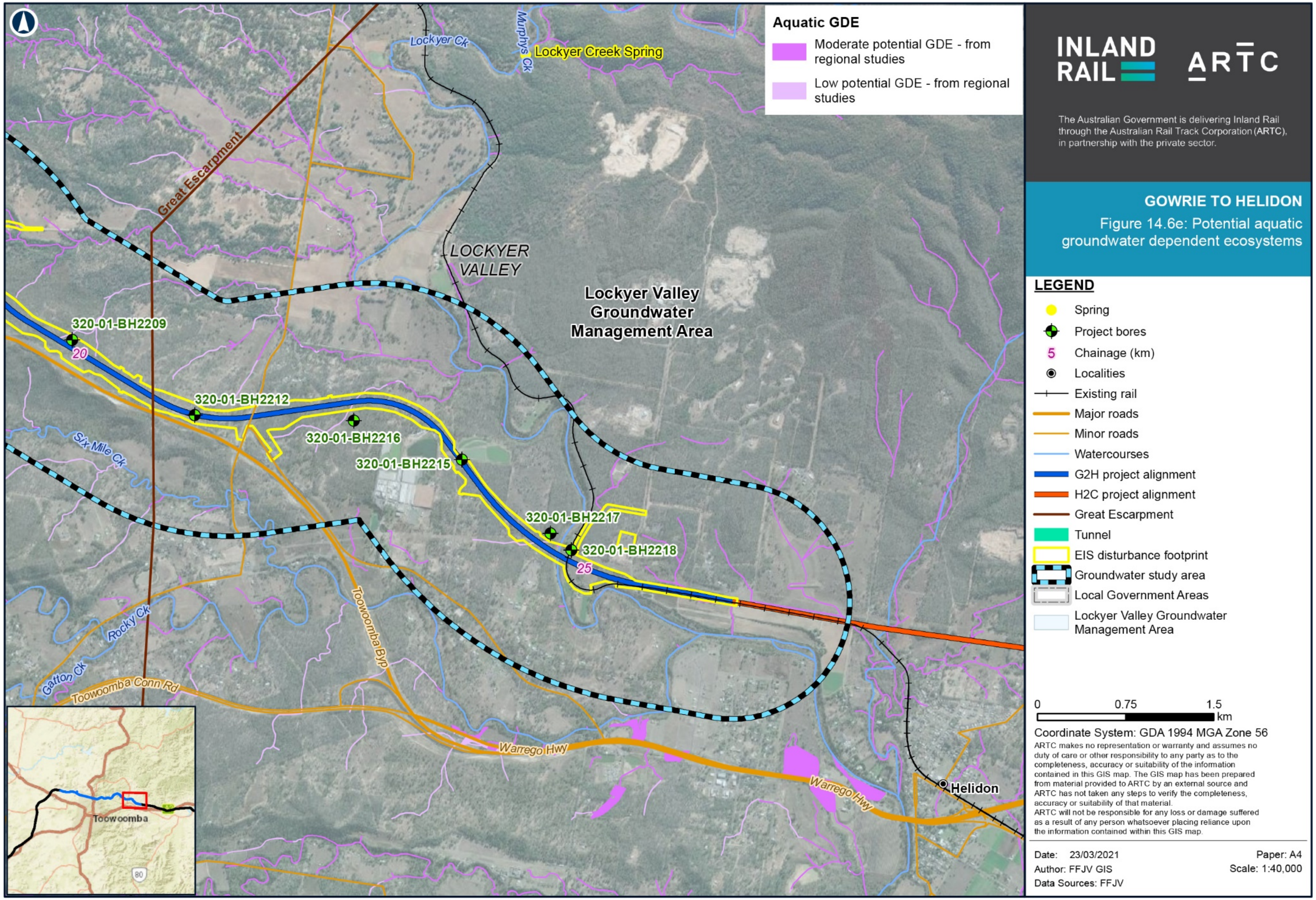

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Details of the wetland springs are summarised in Table 14.13.

TABLE 14.13 WETLAND SPRINGS

Wetland spring name	Spring type	Latitude	Longitude	Surface elevation (m AHD)	Distance from alignment (km)	Source aquifer (primary)1
Lockyer Creek Spring	Permanently Saturated	-27.49412	152.09059	176*	3.2	Precipice Sandstone (Woogaroo Subgroup)
Helidon Spring	Permanently Saturated	-27.57383	152.10626	149*	3.8	Unknown
Merigancan Creek	Permanently Saturated	-27.42661	151.90710	491**	7.9	Basalt[2]
Wellcamp Spring	Intermittently Saturated	-27.57014	151.84716	483*	8.2	Basalt[2]
Eustondale Spring	Intermittently Saturated	-27.58157	151.89009	531*	8.4	Basalt[2]
Lilligreen Spring	Intermittently Saturated	-27.43901	151.95607	598**	8.5	Basalt[2]
Kearneys Spring	Permanently Saturated	-27.60254	151.93932	667**	9.5	Basalt[2]
Westbrook Creek	Intermittently Saturated	-27.60388	151.91082	597**	10.3	Basalt[2]

Table notes:
*   Elevation sourced from FFJV Section 320 LiDAR
**   Elevation sourced from Google Earth because outside of FFJV Section 320 LiDAR
Data from the Queensland Springs Database (data.qld.gov.au/dataset/springs/resource/4cdc89ef-b583-446e-a5c7-0836a91a3767)
It is assumed that basalt is referring to the MRV observed in the detailed surface geology maps

Anecdotal information suggests there are additional (unmapped) wetland springs in the groundwater study area that are not included in the published maps. These wetlands are likely located in the eastern portion of the study area and near the eastern portal of the Toowoomba Range Tunnel. Further field investigation will be undertaken post-EIS, during optimal conditions, to confirm locations of such springs in relation to the Project.

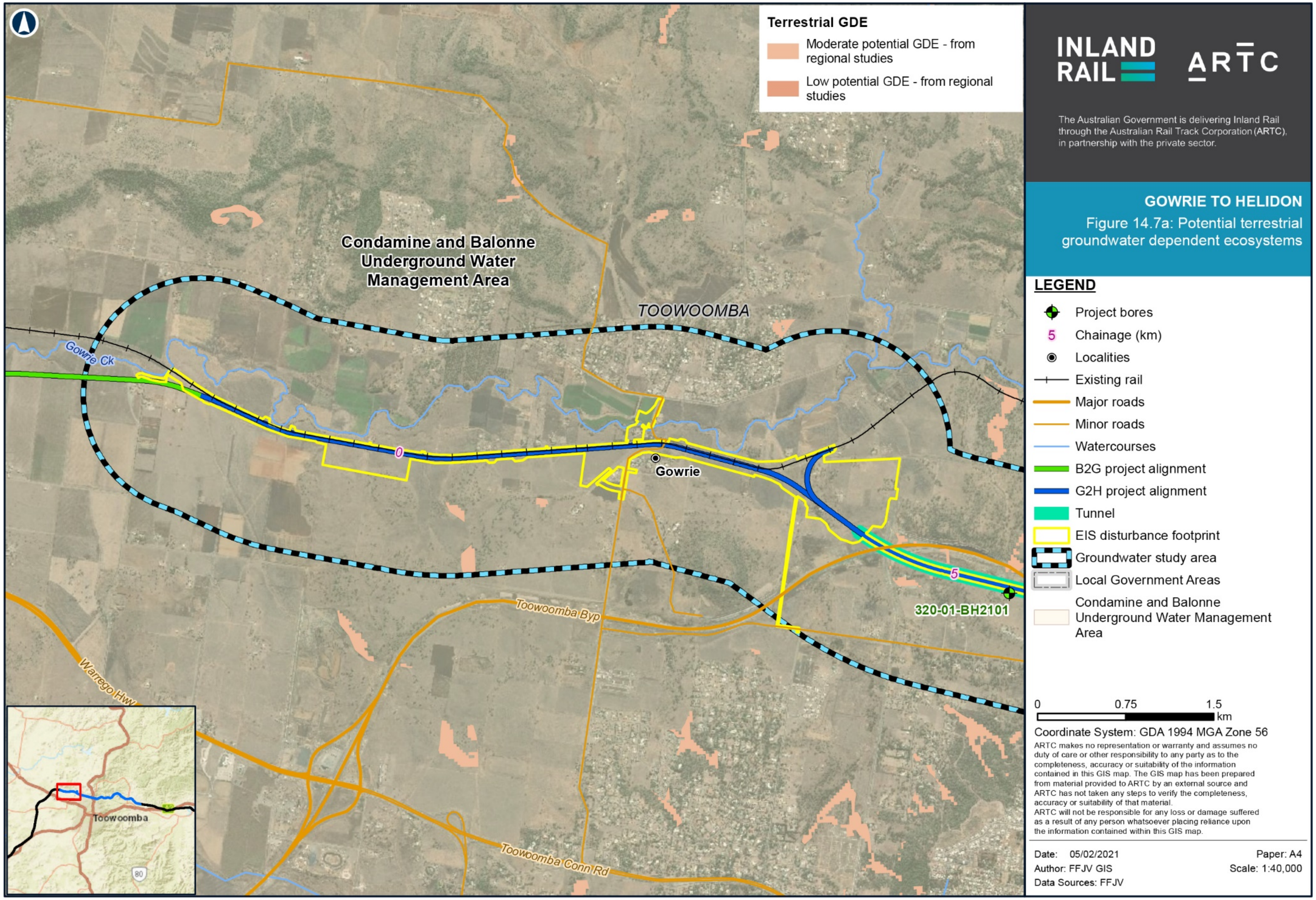
It is noted that several wetlands were identified as a component of the aquatic and terrestrial ecology field works; however, no wetland springs/spring-fed wetlands were identified. Generally, wetlands identified were dams, reservoirs, farm dams and wetlands associated with floodplains. Refer Appendix I: Terrestrial and Aquatic Ecology for further details.

14.6.9.2 Potential terrestrial groundwater dependent ecosystems

There are numerous low and moderate potential terrestrial GDEs (from regional studies) in the groundwater study area. Near Gowrie Creek, the ecosystems are intermittently connected to aquifers with brackish salinity in unconsolidated Quaternary alluvium associated with catchment constrictions. Towards the GDR and in the upper tributaries of Oaky Creek, the GDEs are in low-rainfall and low-capacity permeable rock, associated with basalt (MRV). Near Lockyer Creek and Six Mile Creek, the terrestrial GDEs are associated with alluvial aquifers along these ephemeral watercourses.

The locations of potential terrestrial GDEs are shown on Figure 14.7. Mapped terrestrial GDEs are primarily located in the groundwater study area, from Ch 8.5 km to Ch 19 km, and with Lockyer Creek on the eastern end of the study area (Ch 24 km to Ch 26 km).

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



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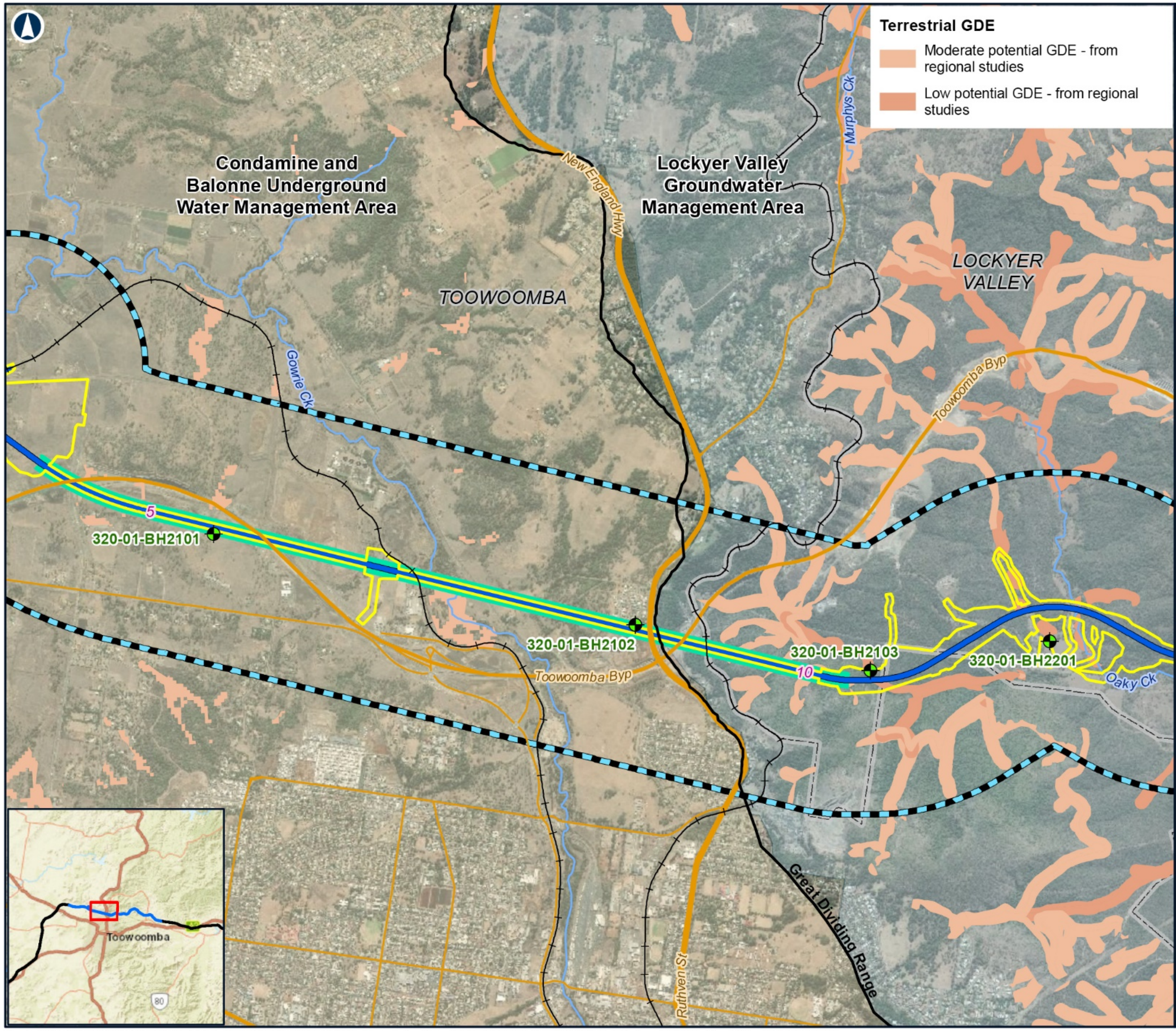

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GOWRIE TO HELIDON

Figure 14.7b: Potential terrestrial groundwater dependent ecosystems

LEGEND

- Project bores
- Chainage (km)
- Localities
- Existing rail
- Major roads
- Minor roads
- Watercourses
- G2H project alignment
- Great Dividing Range
- Tunnel
- EIS disturbance footprint
- Groundwater study area
- Local Government Areas
- Condamine and Balonne Underground Water Management Area
- Lockyer Valley Groundwater Management Area

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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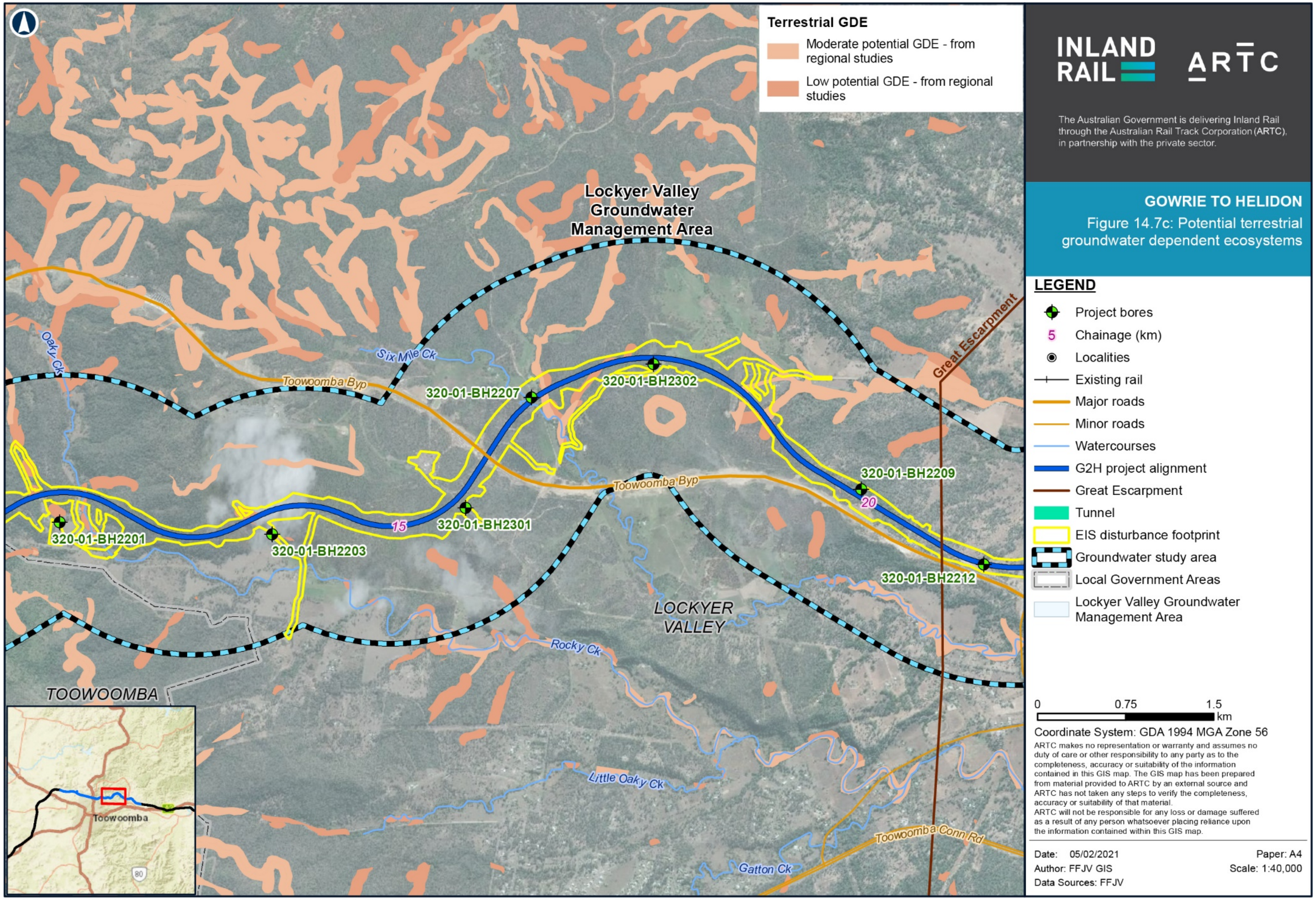

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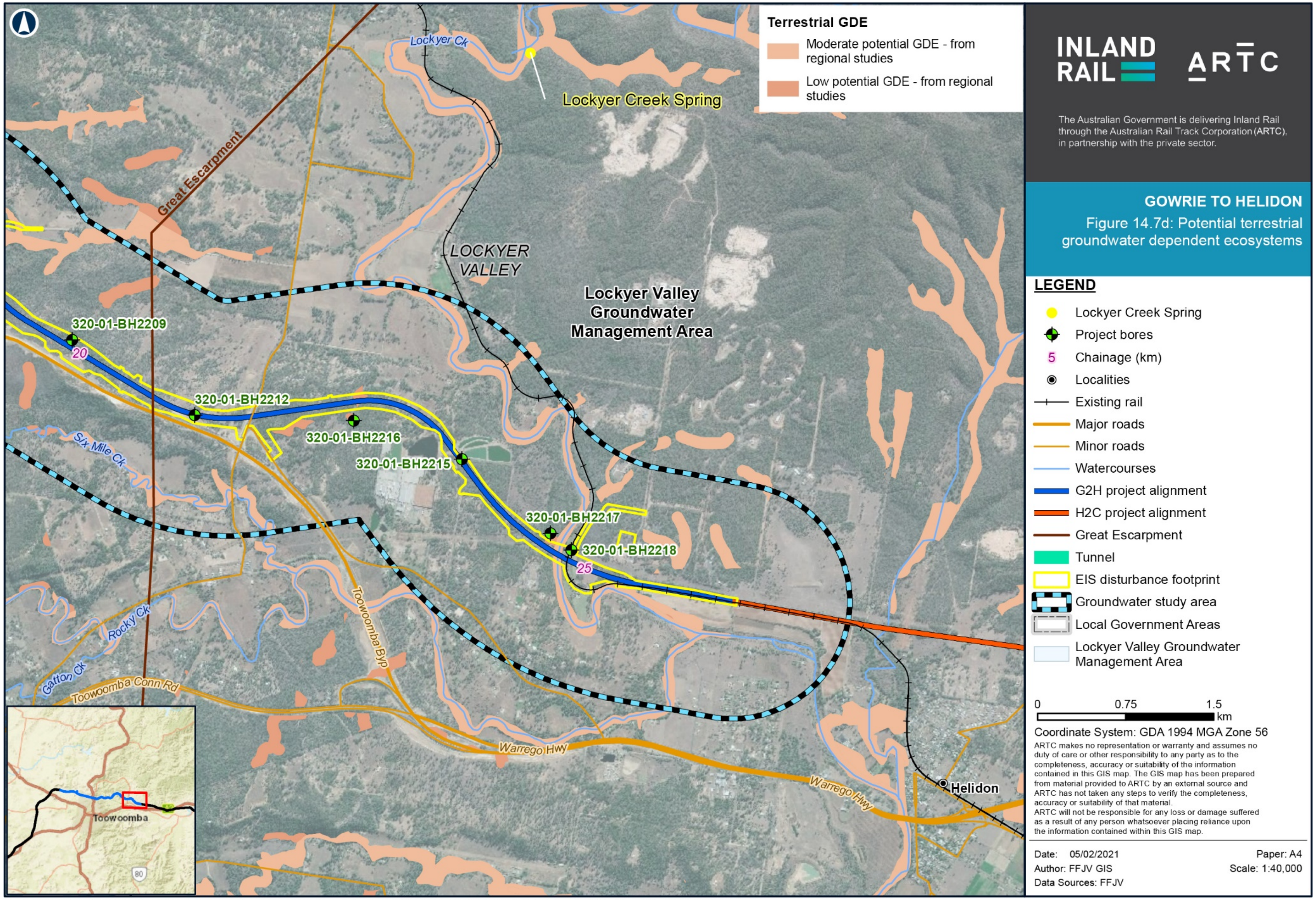

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14.6.9.3 Potential subterranean groundwater dependent ecosystems

No potential subterranean GDEs were identified in the groundwater study area from review of the Atlas (**bom.gov.au/water/groundwater/gde/**) and regional studies.

14.6.10 Groundwater environmental values

The quality of Queensland waters (including water in rivers, streams, wetlands, lakes and groundwater) is protected under the EPP (Water and Wetland Biodiversity) 2019, refer to Table 14.2. It provides a framework for identifying the EVs and establishing water quality guidelines and objectives to enhance or protect Queensland waters.

This section identifies and describes groundwater-related EVs in the groundwater study area. For the purposes of this assessment the 'values', as defined in the EPP (Water), are those attributes of the groundwater systems in the groundwater study area that are sufficiently important to be protected or enhanced.

The Project is situated across both the Condamine River Basin (Gowrie Creek catchment) and Brisbane Basin (Lockyer Creek catchment) , which are separated by the GDR. Relevant sub areas under the EPP (Water) were identified in accordance with Schedule 1:

- The western extent of the Project (approximately Ch -1.76 km to Ch 8.8 km): located, including the majority of the Toowoomba Range Tunnel, within the Gowrie Creek catchment, part of the Upper Oakey sub-catchment, of the Condamine River Basin. Relevant EVs and WQOs are described in the *Draft Murray-Darling Basin environmental values and water quality objectives* (DES, 2018b), and *Healthy Waters Management Plan (HWMP): Condamine River Basin* (DES, 2019e)
- The eastern extent of the Project (approximately Ch 10.2 km to Ch 26.2 km): located east of the GDR in in the Lockyer Creek sub-basin (inclusive of Lockyer Creek, Rocky Creek, Oaky Creek, Six Mile Creek), part of the Brisbane Basin. Relevant EVs and WQOs are described in the Department of Environment and Resource Management document: *Lockyer Creek environmental values and water quality objectives* (DERM, 2010a).

Groundwater EVs associated with the Condamine River Basin are defined by aquifer type and are shown in Figure 17 and 18 in the HWMP: *Condamine River Basin* (DES 2019e) and Figure 22 and 23 in the *Draft Murray-Darling Basin environmental values and water quality objectives* (DES, 2018b). Both guidelines provide EVs for alluvium and Toowoomba region basalts in the Condamine River Basin. There is no direct reference to the MRV in either guideline; therefore, EVs and WQOs for the Toowoomba region basalts have been adopted.

The guidelines for the Lockyer Creek catchment (DERM, 2010a) provide EVs and WQOs for the Lockyer Creek alluvium and Gatton Creek alluvium, which includes Oaky Creek, Rocky Creek and Six Mile Creek.

The EVs for groundwater to be protected or enhanced in the groundwater study area are listed in Table 14.14 and discussed further in Table 14.15. EVs for surface water features in proximity to the Project disturbance footprint are presented in Chapter 13: Surface Water and Hydrology.

TABLE 14.14 ENVIRONMENTAL VALUES OF GROUNDWATER

Environmental value	Definition
Aquatic ecosystems	'A community of organisms living within or adjacent to water, including riparian or foreshore area' (EPP (Water), schedule 2). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas, e.g. biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation, e.g. irrigation of crops, pastures, parks, gardens and recreational areas
Farm water supply/ use	Suitability of domestic farm water supply other than drinking water, e.g. water used for laundry and produce preparation
Stock watering	Suitability of water supply for production of healthy livestock
Aquaculture	Health of aquaculture species and humans consuming aquatic foods (such as fish, molluscs and crustaceans) from commercial ventures
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, e.g., coarse screening and/or disinfection.
Industrial use	Suitability of water supply for industrial use. e.g. food, beverage, paper, petroleum and power industries. Industries usually treat water supplies to meet their needs
Cultural, spiritual, and ceremonial values	Cultural, spiritual and ceremonial values of water mean its aesthetic, historical, scientific, social or other significance, to the past, present or future generations

TABLE 14.15 SUMMARY OF ENVIRONMENTAL VALUES, WATER QUALITY OBJECTIVES AND RELEVANCE TO THE PROJECT

Environmental value	WQOs/Guidelines to assess WQOs	Evaluation of relevance to the Project
Groundwater—Aquatic and Terrestrial Ecosystems	**Lockyer Creek catchment:** WQOs[a] defined in Table 2b for the Lockyer Creek and Gatton Creek alluvium in the *Lockyer Creek environmental values and water quality objectives* (DERM, 2010a). **Condamine River catchment:** WQOs[a] defined in Table 13 for the Oakey Creek alluvium in the *Condamine River Basin: aquatic ecosystem water quality objectives* (DES, 2018b). WQOs[a] defined in Table 31 for the Oakey Creek alluvium and Table 32 for the Toowoomba region basalts in the *HWMP: Condamine River Basin* (DES, 2019e).	**Potential aquatic GDEs:** Regional aquatic GDE data was evaluated in Section 14.6.9.1, which indicated there are numerous moderate- and low-potential aquatic GDEs in the groundwater study area. These include Gowrie Creek, Oaky Creek, Six Mile Creek and Lockyer Creek (and their tributaries). There are no high potential aquatic GDEs traversed by, or in close proximity to, the Project (refer Figure 14.6). The closest spring is Lockyer Creek Spring located in Lockyer Creek, approximately 3.2 km upstream from the alignment (Ch 23.0 km). There are no Wetlands of International Importance (Ramsar wetlands) within the groundwater study area. There are no high ecological significance wetlands located in the groundwater study area. There is the potential for low-to-moderate 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 14.8. **Potential terrestrial GDEs:** Regional terrestrial GDE data was evaluated in Section 14.6.9.2, which indicated moderate potential GDEs are traversed at Ch 4.4 km, Ch 6.2 km and Ch 24.2 km (shown in Figure 14.7). Low potential GDEs are traversed at Ch 10.6 km, Ch 16.6 km and Ch 19.4 km; 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 14.8. There are no high potential terrestrial GDEs traversed by the alignment. This EV is considered relevant to the Project.
Groundwater—Irrigation	ANZG 2018 Guidelines—Section 4.2.3.3 and Table 4.2.2 i.e. The threshold salinity tolerances for plants grown in loamy to clayey soils (considered the primary soil conditions traversed by the Project) are 600 µS/cm to 7,200 µS/cm as stated in Section 4.2.4 of the ANZG guidelines (2018).	Groundwater used for irrigation is the main EV for the region, particularly from shallow aquifers such as the alluvium units and MRV (refer Section 14.6.8). Section 4.2.4 of the ANZG guidelines (2018) states that the threshold salinity tolerances for plants grown in loamy to clayey soils are 600 µS/cm to 7,200 µS/cm. Loamy to clayey soils is considered to be the primary soil condition in the groundwater study area. Based on regional mean groundwater salinity data, in Table 14.5, the main aquifers in the Project (alluvium units, Marburg Subgroup and MRV) are suitable for irrigation. The maximum EC value recorded across the Project bores (from the 6 bores sampled out of 12 installed along the Project alignment) was 5,690 µS/cm (based on one round of sampling in October 2018), indicating that groundwater quality at these locations is generally suitable for irrigation. This EV is considered relevant to the Project.

Environmental value	WQOs/Guidelines to assess WQOs	Evaluation of relevance to the Project
Groundwater—Farm Supply/use	ANZG guidelines (2018)	The salinity in the groundwater study area (refer to Table 14.5) is variable, with salinity ranging from 1,000 to 6,000 mg/L across the main aquifers (alluvial units, Marburg Subgroup and the MRV) (refer Section 14.6.4.1). This generally precludes groundwater from being suitable for farm supply uses such as laundry or produce preparation. Regionally, the shallow alluvium and hydraulically connected creeks are considered of significance to this environmental value (i.e. Lockyer Creek and its tributaries). This EV is considered relevant to the Project.
Groundwater–Stock Water	ANZG guidelines (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 licence allocations and water use discussed in Section 14.6.8 indicates stock water is another important EV for the region, particularly in the MRV. Section 4.3.3.5 of the ANZG guidelines (2018) states that a loss of production and a decline in animal health occurs if stock are exposed to high salinity water for prolonged periods. Salinity less than 4,000 mg/L is considered acceptable for livestock except for dairy cattle and poultry. Dairy cattle require salinity less than 2,500 mg/L and poultry require less than 2,000 mg/L (**agric.wa.gov.au/livestock-biosecurity/water-quality-livestock).** The regional and site-specific salinity values (refer Table 14.5) indicate that groundwater is generally suitable for stock watering from the alluvium units (mean 740 mg/L), Gatton Sandstone (mean 1,570 mg/L), Marburg Subgroup (mean 1,380 mg/L), MRV (mean 860 mg/L) and WCM (mean 520 mg/L). Salinity across all main aquifers within 5 km of the alignment ranged between 250 and 5,000 mg/L. Salinity across Project bores ranged between 920 and 3,420 mg/L (refer Table 14.6). This EV is considered relevant to the Project.
Aquaculture	ANZG guidelines (2018)	This environmental value is not considered applicable to in-situ groundwater and more directly applicable to surface water. The nearest registered springs are located within 4 km of the alignment and they are Lockyer Creek Spring and Helidon Spring (refer Section 14.6.9.1). Groundwater seepage from the alluvium or incised Clarence-Morton sedimentary units into watercourses can deliver short duration baseflow into rivers and creeks immediately following heavy rains or flooding; however, after larger flood events, suitability of these waters for recreation may be limited by other factors. This value is more common for surface water features that are accessible for recreational use and visual interaction but can be affected by groundwater quality if they are a receiving waterbody (i.e. groundwater baseflow). There is currently no evidence to suggest that groundwater is directly used for recreational or aesthetic purposes in the groundwater study area; as a result, this EV is not considered relevant to the Project.

Environmental value	WQOs/Guidelines to assess WQOs	Evaluation of relevance to the Project
Groundwater—Drinking Water	ANZG guidelines (2018) HWMP (Condamine River)–Table 61	The suitability of water for human consumption is defined in the *Australian Drinking Water Guidelines* (National Health and Medical Research Council, 2018). Salinity less than 600 mg/L is considered good quality and up to 900 mg/L is fair quality. Salinity greater than 900 mg/L is considered poor quality and greater than 1,200 mg/L is unacceptable for consumption. The regional (see Table 14.5) and site-specific salinity values (Table 14.6) indicate groundwater is generally suitable for human consumption across the main aquifers, including the alluvium units (mean salinity of 740 mg/L), Gatton Sandstone (mean salinity of 1,570 mg/L), Marburg Subgroup (mean salinity of 1,380 mg/L), MRV (mean salinity of 860 mg/L) and WCM (mean salinity of 520 mg/L). Salinity across all main aquifers within 5 km of the alignment ranged between 250 and 5,000 mg/L. Salinity across Project bores ranged between 920 and 3,420 mg/L. Based on the salinity data presented in Section 14.6.4.1, the aquifers relevant to the study would be suitable for drinking water without treatment. As a result, 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.	Industrial use covers less than 4% of the MRV, 11% of the Marburg Subgroup and 5% of the WCM aquifers and all groundwater across alluvium units is used for irrigation (refer Section 14.6.8). As a result, this EV is not considered relevant to the Project.
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 Condamine-Balonne River and Lockyer Creek catchments have cultural and spiritual recognised EVs for all relevant aquifers traversed by the Project. This EV is considered relevant to the Project.

Table note:

a The complete list of WQOs applicable to the groundwater study area is provided in Table 8.3 in Appendix N: Groundwater Technical Report.

14.6.11 Conceptual hydrogeologic model

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

Key aspects of the hydrogeological regime in the groundwater study are presented as a conceptual understanding on Figure 14.8. A hydrogeological conceptualisation of the Toowoomba Range Tunnel, which commences in the MRV and crosses into the underlying Koukandowie Formation, is depicted on Figure 14.9.

Groundwater is associated with the MRV and the underlying Koukandowie Formation and generally follows topography. East of Six Mile Creek the underlying geology changes to the Gatton Sandstone, with groundwater level generally following the topography.

The conceptual models were developed based on the feasibility design stage works, and ARTC commit to updating these models to incorporate the results of the recent geotechnical and hydrogeological investigations (Golder, 2020c/d). The updated conceptual models will then be used to refine the existing predictive groundwater model for the Final EIS (see Section 14.7.2.2); this approach will allow for the predicted impacts in Section 14.7.3 and Section 14.7.4 to be re-assessed with more robust and comprehensive groundwater data before construction commences.

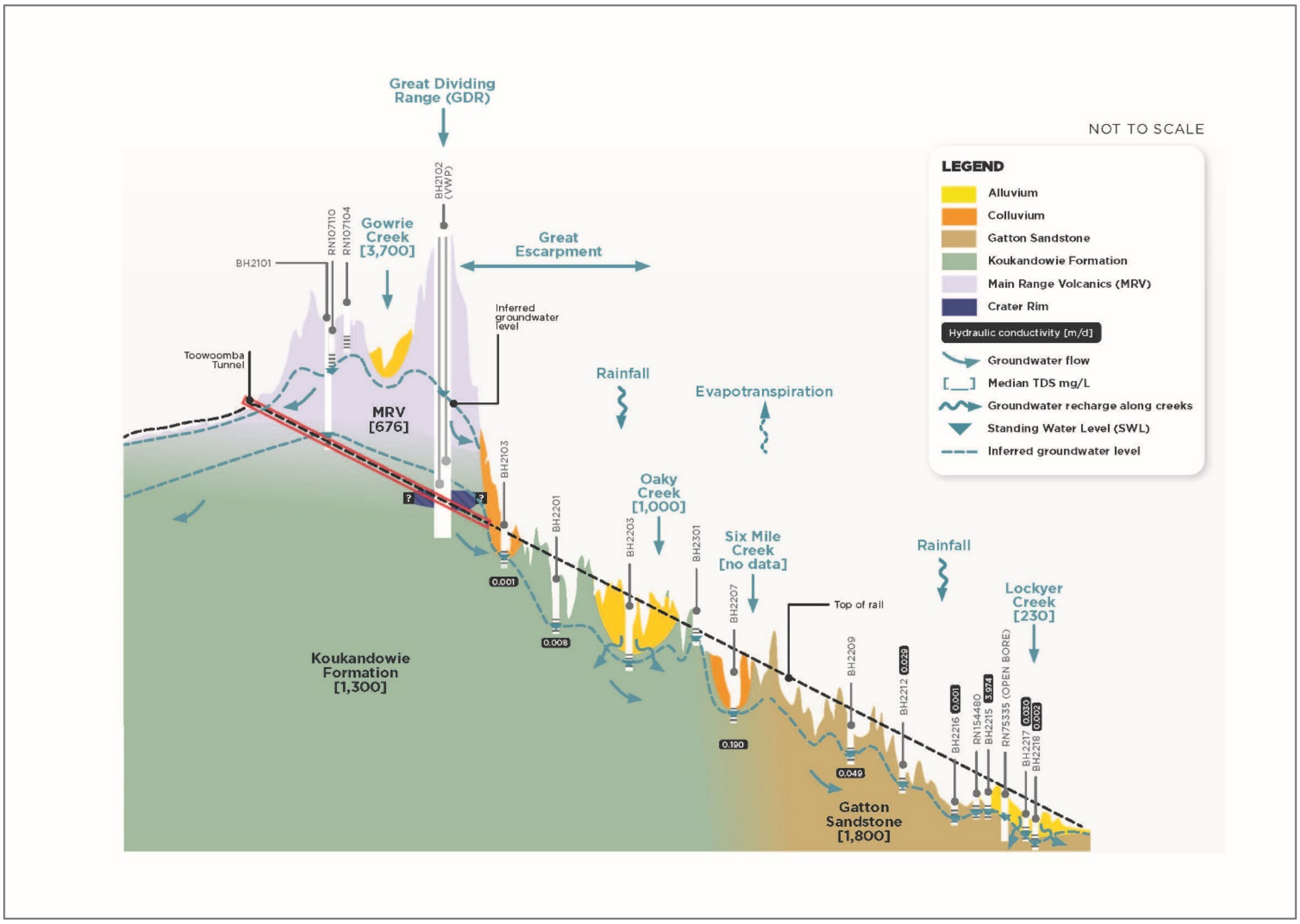

FIGURE 14.8 CONCEPTUAL MODEL OF THE GROUNDWATER STUDY AREA

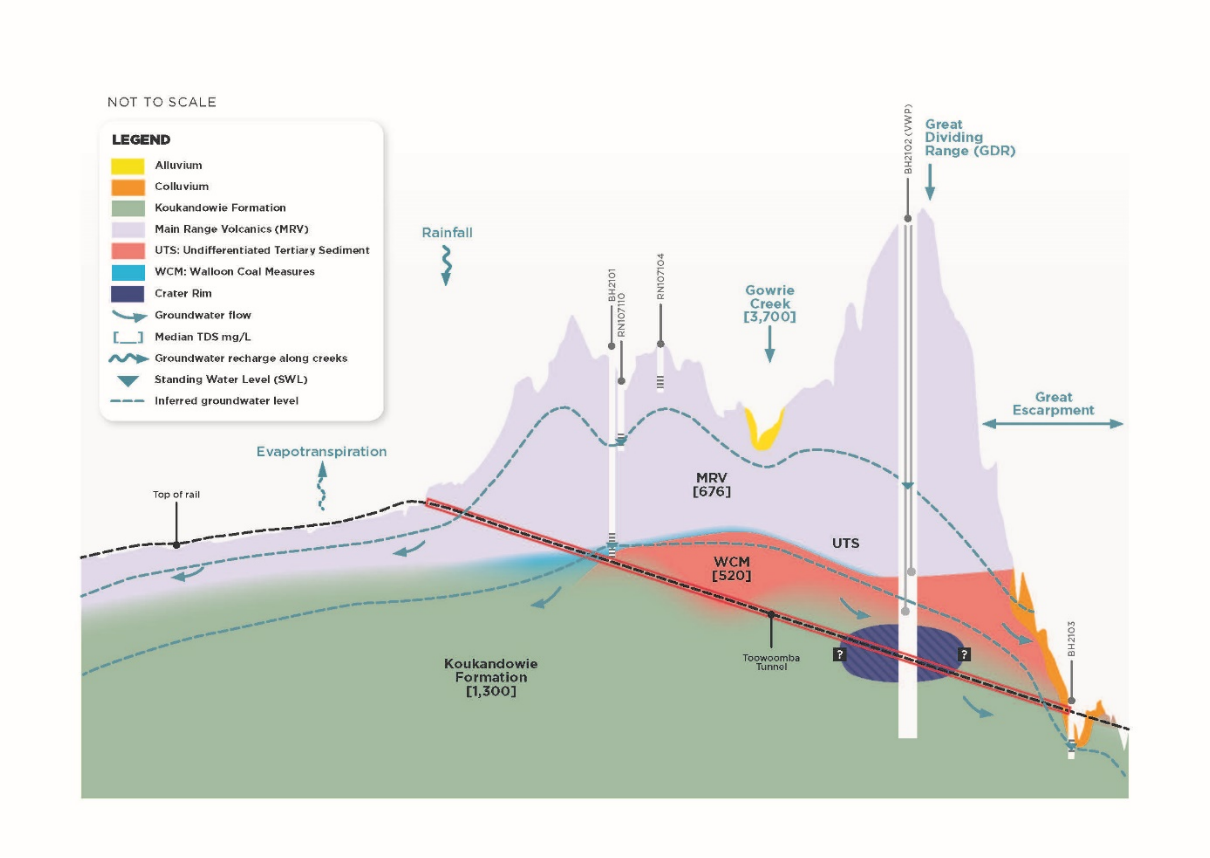

FIGURE 14.9 CONCEPTUALISATION OF THE TOOWOOMBA RANGE TUNNEL

14.7 Potential impacts

14.7.1 Construction methodology

Construction of the Project will involve a combination of earthworks for cuts, bridges, viaducts and embankments to ensure required grade for the Project and construction of the Toowoomba Range Tunnel. The proposed construction activities for the Project with potential to interface with groundwater are summarised in Table 14.16.

TABLE 14.16 SUMMARY OF CONSTRUCTION ACTIVITIES FOR THE PROJECT

Activity	Description
Embankments	Volumes of material emplaced and compacted to raise the profile of the railway alignment to meet design specifications. A total of 15 embankments are proposed, with a total length of 15.41 km. Embankment lengths range between 160 m and 1,550 m.
Cuts/portals	Removal of soil and rock to maintain the grade of the alignment design. Cuts are proposed in all main geological units. The Project comprises 14 deep cut locations (>10 m below ground level) with at least 8 cuts anticipated to encounter groundwater. Cut lengths range between 90 m and 870 m (total cut length is 6.65 km).
Toowoomba Range Tunnel	Approximately 6.240-km long through the GDR (diameter of 13 m). Construction will include tunnel boring machine (TBM) and road-header methods. The portals will be drained, while the eastern section of the tunnel will be constructed using a mined-tunnel and cut and cover tunnel. The mined tunnel and cut and cover tunnel (approximately 700 m in total) will drained until lining is installed by the TBM.
Bridge, viaducts, and pilings	Thirteen (13) bridges, including two road-over-rail bridges total approximately 6.7 km in length, are proposed to cross watercourses and roads. Cast-in-Place (CIP) or driven pilings are to be emplaced for each bridge/viaduct. The bridges and viaducts are in areas where there are watercourses that range between 24 m and 1,840 m in width.

A profile of the Project that presents the surface geology, locations of cuts, bridges, fill, and bore locations is depicted in Appendix N: Groundwater Technical Report. Detailed discussion of the construction methodology is presented in Chapter 6: Project Description.

14.7.2 Groundwater predictive modelling

A groundwater model is a simplification of a complex system and its behaviour is 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.

A summary of the numerical predictive modelling undertaken to provide an initial assessment of potential groundwater ingress and drawdowns associated with the Toowoomba Range Tunnel and intermediate ventilation shaft, tunnel portals, and cuts of the Project is provided in the subsections below; further details are provided in Appendix N: Groundwater Technical Report.

Results of the predictive modelling have been used to evaluate potential impacts on groundwater in the groundwater study area, identify gaps, and develop mitigation and management measures. The main potential impact is from groundwater drawdown during the construction and operational phases, and these are discussed in detail in Sections 14.7.3 and 14.7.4.

14.7.2.1 Toowoomba Range Tunnel

The predictive model developed to support the Project's feasibility stage hydrogeological design and impact assessment used USGS MODFLOW code and GMS 10.4 as the graphical user interface. The model was used to estimate the inflows to the tunnel, portal cuts and the intermediate ventilation shaft. The model was also used to estimate preliminary drawdown and inflows for the MRV, Koukandowie Formation (Marburg Subgroup) and colluvium, to inform an assessment of the potential to construct the Toowoomba Range Tunnel (undrained), and adjacent portal cuts (drained) and cut and cover (drained), and the intermediate ventilation shaft (undrained) on these groundwater resources. Table 14.17 summarises the design aspects modelled.

Numerical models are a simplified representation of a real system and there are inherent uncertainties. Uncertainty analyses were also undertaken for predicted long-term drawdown. The sensitivity analysis considered the potential effects of increasing the hydraulic conductivity in the MRV and Koukandowie Formation and included the presence of three higher permeability structural features.

The Marburg Subgroup comprises the Koukandowie Formation and Gatton Sandstone members. The Marburg Subgroup nomenclature was adopted for the predictive groundwater model (Golder, 2020a); for the impact assessment, Koukandowie Formation was adopted because the impacts are generally within this member of the subgroup.

Figure 14.10 depicts the predictive model domain and relevant water plan areas.

TABLE 14.17 SUMMARY OF REFERENCE DESIGN ASPECTS MODELLED

Design aspect	Chainage (km)		Length (m)	Adopted construction/ excavation dates*		Permanent lining*		Permanent drained condition
	Start	Finish		Start	Finish	Start	Finish	
Western portal	3.70	4.10	400	June 2022	February 2023	NA		Drained
TBM tunnel	4.10	9.76	5660	May 2023	November 2024	Progressively lined		Undrained, limit of 0.3 L/s
Mined tunnel	9.76	10.235	475	October 2023	July 2024	July 2024	August 2024	
Cut and cover	10.235	10.34	105	May 2023	October 2023	January 2025	July 2025	Drained
Eastern portal	10.34	10.40	60	June 2022	February 2023	NA		Drained
Intermediate Ventilation Shaft	6.83	6.929	99	March 2023	August 2023	August 2023	May 2024	Undrained, limit of 0.0062 L/s

Table notes:
TBM—tunnel boring machine
NA—not applicable
*Dates are indicative for inclusion in the model

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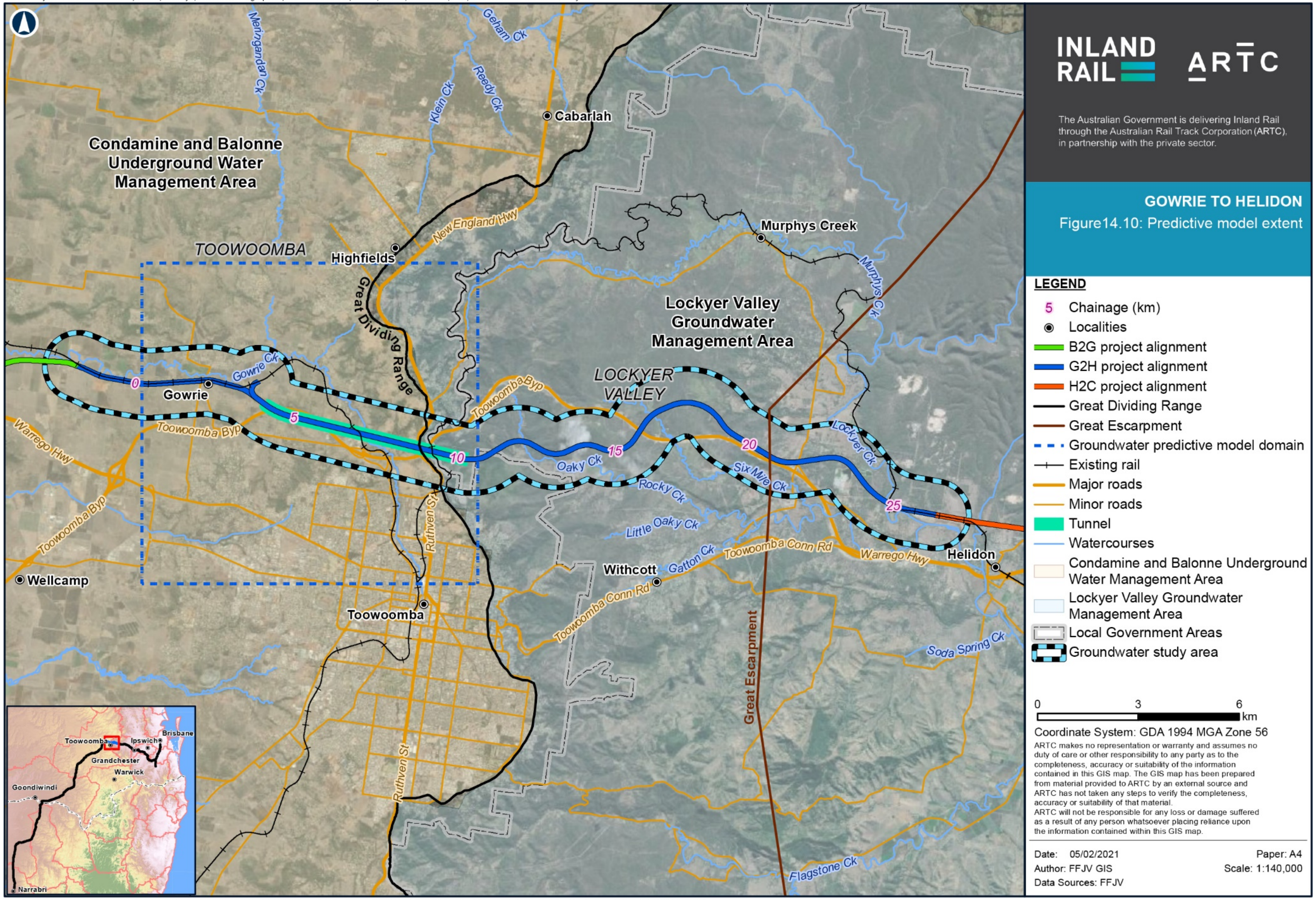

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Groundwater inflow—construction

The groundwater inflow resulting from the design was estimated for short term (construction phase) and long term (operational phase, modelled over 20 years). Predicted long-term inflow to the tunnel is an average and will vary with the seasons—where dry months will result in lower inflow, and significant and extended rainfall events/wet season will result in higher inflow.

The predicted groundwater inflow to each aquifer during construction is shown on Figure 14.11 and the inflow to each tunnel feature is shown on Figure 14.12. The maximum inflow rates to each tunnel feature during construction are summarised in Table 14.18. Predicted inflows from each aquifer, by Water Plan, are included in Table 14.19 for construction phase and Table 14.20 for the operational phase of the Project.

The maximum inflow to the tunnel during construction is expected to be approximately 113.7 L/s (at 107 weeks). This comprises 79.7 L/s due to drainage in the MRV near the advancing face of the tunnel boring machine (TBM) portion of the tunnel (where permanent segments are not yet in place) and 34 L/s in the colluvium due to drainage of the mined tunnel.

The maximum predicted groundwater inflows are conservative estimates and do not include control measures that may be implemented during construction (conservative approach). This includes measures such as operating the TBM in closed mode or probing and grouting ahead of excavation.

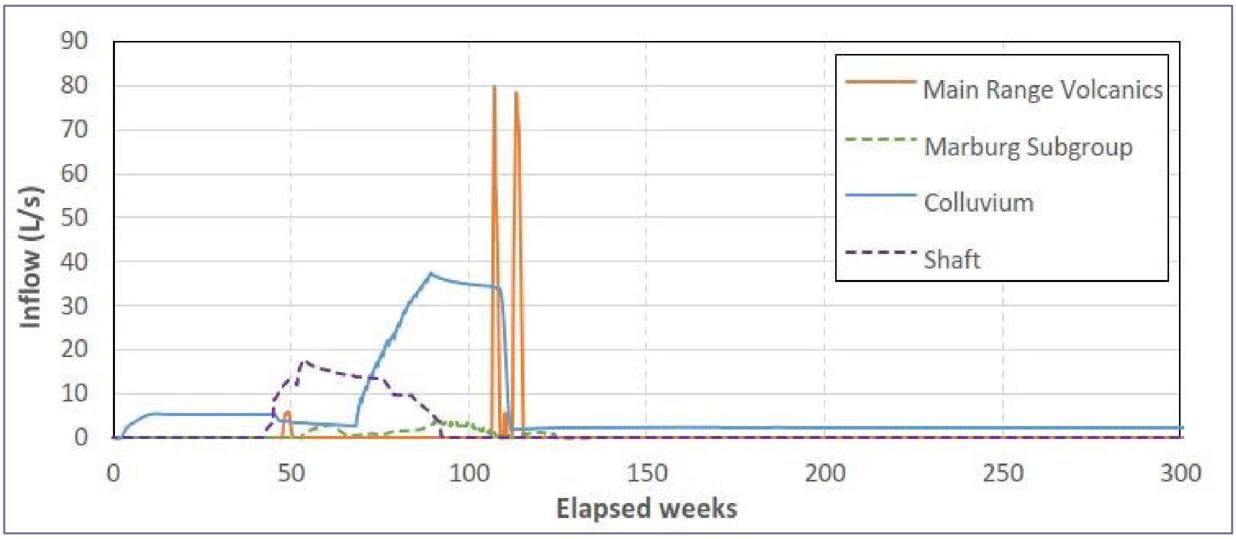

FIGURE 14.11 PREDICTED CONSTRUCTION PHASE GROUNDWATER INFLOW FOR EACH UNIT
Source: Golder (2020a)

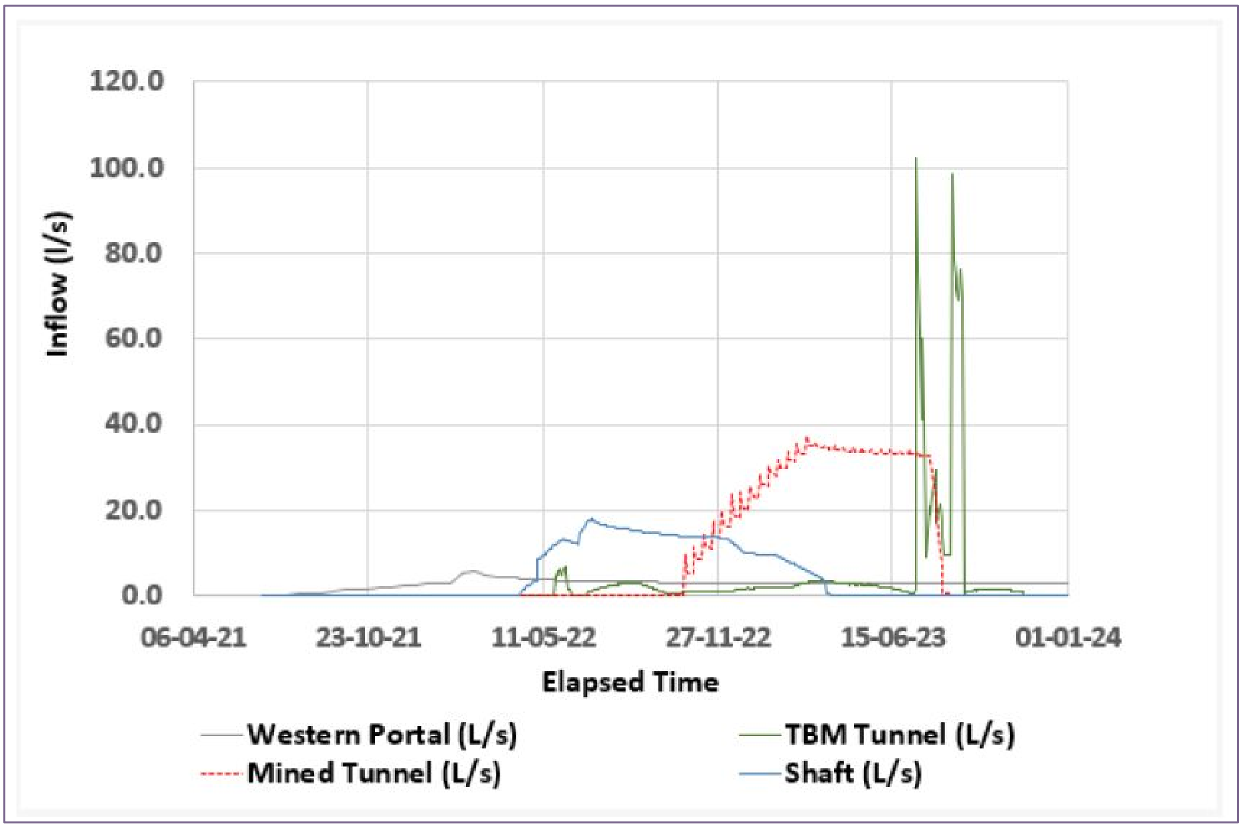

FIGURE 14.12 PREDICTED CONSTRUCTION PHASE GROUNDWATER INFLOW FOR THE MAIN PROJECT STRUCTURES
Source: Golder (2020a)

TABLE 14.18 PREDICTED MAXIMUM CONSTRUCTION PHASE GROUNDWATER INFLOW

Design feature	Chainage (km) Start	Chainage (km) Finish	Estimated maximum short-term groundwater inflow (L/s)[1]	Elapsed time of maximum inflow (since excavation commenced) in weeks
Western tunnel portal cut (drained)	3.7	4.1	6	31
Toowoomba Range Tunnel (TBM) (undrained)	4.1	9.76	100	107
Toowoomba Range Tunnel (mined) (drained)	9.76	10.235	37	88
Intermediate ventilation shaft (undrained)	6.83	6.83	17	58

Total predicted volumes of groundwater inflow for each aquifer have been estimated, for each Water Plan of relevance, to inform of impact on groundwater resources. Based on water entitlement data (Section 14.6.8.2), the Toowoomba City Basalts houses the largest volume of allocations in the groundwater study area (3,812.7 ML) compared to the Toowoomba North Basalts (13 ML) and Toowoomba South Basalts (95 ML). It is acknowledged that not all bores require a licence (e.g. domestic or stock use) and the true water allocation is unknown.

The construction phase predicted total volumetric take per aquifer, by Water Plan, and for the relevant sub-units, is presented in Table 14.19 and discussed in further detail in Appendix N: Groundwater Technical Report.

TABLE 14.19 PREDICTED INFLOW VOLUMES—CONSTRUCTION PHASE

Water Plan	Management area/ unit	Sub-area/unit	MRV inflow (ML)	Koukandowie Formation inflow (ML)	Colluvium inflow^ (ML)
Water Plan (GABORA) 2017	Hutton Groundwater Unit	Eastern Downs Marburg	-	169.1	-
		Murphys Creek Marburg	-		-
Water Plan (Condamine and Balonne) 2019	Condamine and Balonne Underground Water Management Area	Toowoomba South Basalts limitation area	379.9	-	-
		Toowoomba City Basalts Sub-area	349.0	-	-
Water Plan (Moreton) 2007	Lockyer Valley Groundwater Management Area	Implementation Area 2B (Groundwater unit 2)	96.8	-	688.4
Total predicted inflows			825.7	169.1	688.4

Table notes:
ML—megalitres
^ under the hydrogeology assessment colluvium infers shallow unconfined aquifer (Quaternary aquifer) and is a fully saturated for the purpose of the assessment.

The majority of the groundwater inflow is associated with the tunnel's construction using a TBM, though some of the groundwater inflow can be contributed to the construction of the western tunnel portal (e.g. Toowoomba South Basalts limitation area) and the intermediate ventilation shaft (Toowoomba City Basalts sub-area).

The large amount of groundwater inflow from the colluvium will occur in the eastern extent of the tunnel, which will be initially constructed as a drained tunnel (i.e. mined tunnel and cut cover tunnel) before the TBM finishes the tunnel. The groundwater inflows from the colluvium are also attributed to the eastern tunnel portal, which is also based on a drained design.

The seepage volumes for colluvium from the predictive model are calculated from the mined tunnel allowable permanent leakage rate (for construction and operation predictions) where the allowable permanent leakage rate = volume of ingress for the colluvium aquifer expected to be above the water table (simulating an undrained portal in a saturated aquifer) = 0.3 L/s (conservative approach).

It should be noted that these estimates are conservative and do not consider any water control mitigation techniques that are likely to be used for construction, such as the operation of the TBM in closed mode, or any probing and grouting ahead of the excavation. In addition, the totals do not include any inflows experienced following the completion of the construction; for example, inflows at the western tunnel portal are predicted to be 2.6 L/s (0.22 ML/day or 82 ML/year) once the portal is completed (around Week 32).

Groundwater inflow—operations

Predicted inflow into the Toowoomba Range Tunnel during the first 20 years of operations is outlined in ; noting that the tunnel design (including the ventilation shaft) is undrained, while the two portals are drained. The tunnel will be lined with precast concrete segments and aims for a class 3 water tightness rating (Haack, 1991). To achieve a class 3 rating, the allowable limit of leakage rate, assuming even distribution across the tunnel, is 0.3 L/s, while for the ventilation shaft it is assumed to be 0.0062 L/s. Predicted long-term groundwater inflow to the western tunnel portal, which is drained, is 2.6 L/s.

Predictive modelling indicates that total groundwater inflow could be up to 10 ML/yr during operations and approximately 82 ML/yr at the western tunnel portal. Total predicted volumes of groundwater inflow for each aquifer have been estimated, for each Water Plan of relevance, and are presented for a combined 20 years in Table 14.20. The undrained design of the tunnel predicts a significant decrease in groundwater inflow in all the relevant aquifers, compared to construction.

Further detail is included in Appendix N: Groundwater Technical Report.

TABLE 14.20 TOTAL PREDICTED INFLOW VOLUMES—OPERATIONAL PHASE (20 YEARS)

Water Plan	Management area/unit	Sub-area/unit	MRV inflow in ML/yr (ML/20 yrs)	Koukandowie Formation inflow in ML/yr (ML/20 yrs)	Colluvium inflow in ML/yr (ML/20 yrs)
Water Plan (Condamine and Balonne) 2019	Condamine and Balonne Underground Water Management Area	Toowoomba South Basalts limitation area	76.3 (1,524.8)	-	-
		Toowoomba City Basalts	6.9 (138.3)	-	-
Water Plan (GABORA) 2017	Hutton Groundwater Unit	Eastern Downs Marburg	-	8.8 (175.8)	-
		Murphys Creek Marburg			
Water Plan (Moreton) 2007	Lockyer Valley Groundwater Management Area	Implementation Area 2B	1.3 (25.6)	-	0.7 (13.5)
Total predicted inflows, ML/yr and (ML/20yrs) by aquifer type			84.5 (1,688.7)	8.8 (175.8)	0.7 (13.5)

Table note:
ML—megalitres

The water collected inside the tunnel (groundwater seepage, storm water carry-in, wash-down, firefighting, etc.) will be collected through a common tunnel drain and stored in a sump at the eastern tunnel portal. The groundwater inflow at the western tunnel portal will be diverted around the portal and away from the tunnel, directly into a tributary of Gowrie Creek, at Ch 3.4 km.

During detailed design, measures will be examined to reduce the inflow at the western tunnel portal, including tanking of the western portal below the average groundwater table or using an undrained design.

Groundwater inflow quality

The available groundwater quality data (including Project bores and the Queensland Globe database), the quality of inflows to the Toowoomba Range Tunnel, portals, and associated cuts during construction and operation is expected to be fresh to brackish, sodium-chloride dominant and neutral to slightly alkaline (refer Section 14.6.4).

The water quality of the MRV is considered acceptable to divert directly into the surrounding environment, which is supported by long-term groundwater monitoring and the monitoring undertaken for the Project, which indicated the water is generally good. This is also reflected in the MRVs use for potable (town water supply), domestic, stock and irrigation purposes in the groundwater study area.

Nine groundwater monitoring bores were established along the tunnel alignment in 2020 as part of the detailed geotechnical investigations. A summary of the groundwater salinity from these nine groundwater bores is provided below:

- MRV—has a median EC of 1,290 µS/cm and salinity of 637 mg/L and is generally considered good
- Koukandowie Formation—has a median EC of 2,150 µS/cm and salinity of 1,333 mg/L
- Gatton Sandstone—has a median salinity of 1,500 mg/L, similar to the Koukandowie Formation.

Water quality is expected to vary seasonally due to rainfall infiltration (dilution effect) and a first flush (higher concentrations of analytes) after the dry season. Further, the geology and hydrogeology of the Project area and key units being intersected (refer Section 14.6.3) are anticipated to comprise variable quality in at least the MRV.

The 14 monitoring bores that intersect the tunnel will provide a more accurate picture of the local groundwater resources, spatially and temporally; noting that there were few bores in the vicinity of the tunnel screened in the Koukandowie Formation, which is the main source of groundwater inflow during operations. As noted above, the salinity levels were twice as high as that for the MRV.

A second round of monitoring was recently completed, with the monitoring to continue up to and during construction (i.e. as part of the groundwater management and monitoring plan). The data will assist in identifying site-specific WQOs for the release of groundwater relevant to the local receiving environment, and will inform water management protocols during construction and operations, including the design of the water treatment plant.

Groundwater level drawdown

Groundwater level drawdown is the lowering of hydraulic head (pressure) in an aquifer due to construction activities, such as tunnelling and cutting, as part of the Project. While operational influences of groundwater-level drawdown can result from long-term groundwater inflow, as seepage, into the tunnel and shaft, localised groundwater level drawdown also occurs as a result of pumping by landholders. The groundwater level drawdown resulting from construction of the Toowoomba Range Tunnel and associated design features was estimated based on predicted groundwater inflow rates. Groundwater inflow to the tunnel is a loss to the groundwater unit and this causes the groundwater level in the unit to lower (groundwater drawdown). The modelled groundwater inflow or loss to the overall groundwater unit can provide an indication of groundwater drawdown as depth and extent.

Each groundwater unit responds differently due to the hydraulic properties of the aquifer and, as a result, the following groundwater units were assessed separately:

- Shallow MRV (typical value of hydraulic conductivity)
- Deep MRV (high conductivity layer)
- Koukandowie Formation (Marburg Subgroup).

The groundwater level drawdown figures show drawdown contours with registered groundwater bores and GDEs. The contour extent indicates these areas will potentially be impacted by groundwater-level drawdown. It is acknowledged that not all groundwater bores may be represented in these figures, as outlined in Section 14.6.8.1.

The predicted maximum groundwater inflow, during the construction phase, to the western tunnel portal occurs at 34 weeks and is within the shallow MRV; the predicted groundwater level drawdown is shown on Figure 14.13. Groundwater drawdown reaches 5 m and is expected to be localised to the Project disturbance footprint at the western tunnel portal. There is a registered bore at this location, which will be acquired as part of the land acquisition process.

The maximum groundwater inflow to the intermediate ventilation shaft occurs at 62 weeks, which intercepts all modelled aquifers (shallow and deep MRV and Koukandowie Formation). The resulting groundwater level drawdown is shown on Figure 14.14 to Figure 14.16. The results indicate groundwater level drawdown is localised at the shaft (Ch 6.83 km); however, drawdown of each unit at the tunnel portals is also anticipated at this the time of construction.

The maximum predicted groundwater level drawdown extent for tunnel construction (at 107 weeks) is shown on Figure 14.17 through Figure 14.19.

Groundwater level drawdown in the shallow MRV is limited to the construction of the shaft and portals at this time. The predicted groundwater drawdown for the deep MRV includes a drawdown of 5 m south of the tunnel in the groundwater study area; the 1 m predicted drawdown contour includes an area outside of the groundwater study area, south of the tunnel.

The groundwater drawdown predicted for the Koukandowie Formation is most significant, at depths of ~40 m at the tunnel. The drawdown reaches depths up to 5 m at the southern extent of the groundwater study area; similar to the deep MRV at this time, the 1 m predicted drawdown contour includes an area outside of the groundwater study area, south of the tunnel. Despite drawdown in the vicinity of Gowrie Creek being up to 25 m, the drawdown in this unit is not expected to impact on groundwater interaction with Gowrie Creek (i.e. groundwater interaction is likely to be from the Gowrie alluvium of the underlying shallow MRV).

The predicted 1-m drawdown contours are extensive in the model domain for week 107, such that they are considered to be an overestimation of the impact and unlikely to present in real life. ARTC have committed to refining these model predictions to better understand the impacts on groundwater and their significance; these predictions will be included in the Final EIS (see Section 14.7.2.2).

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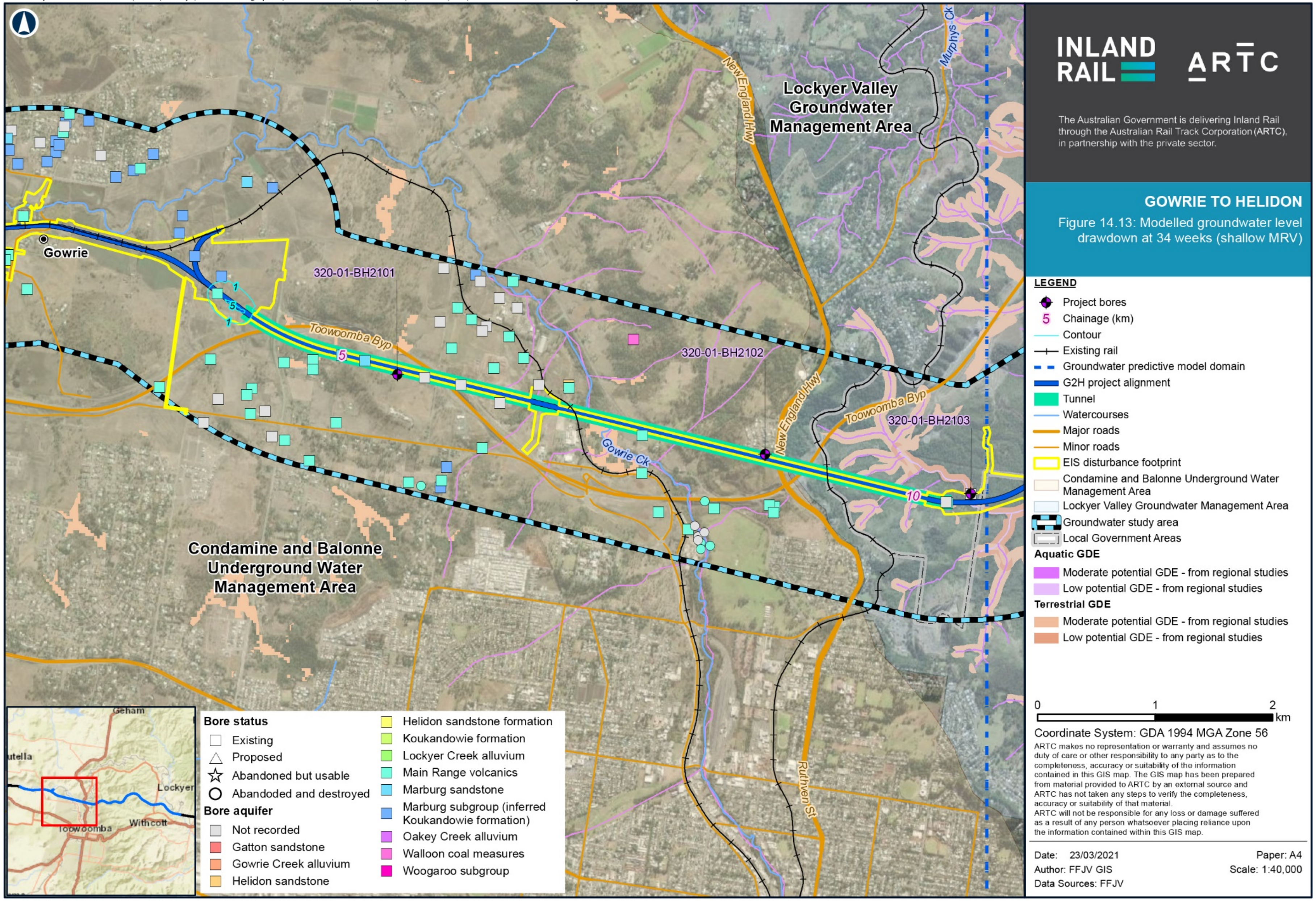

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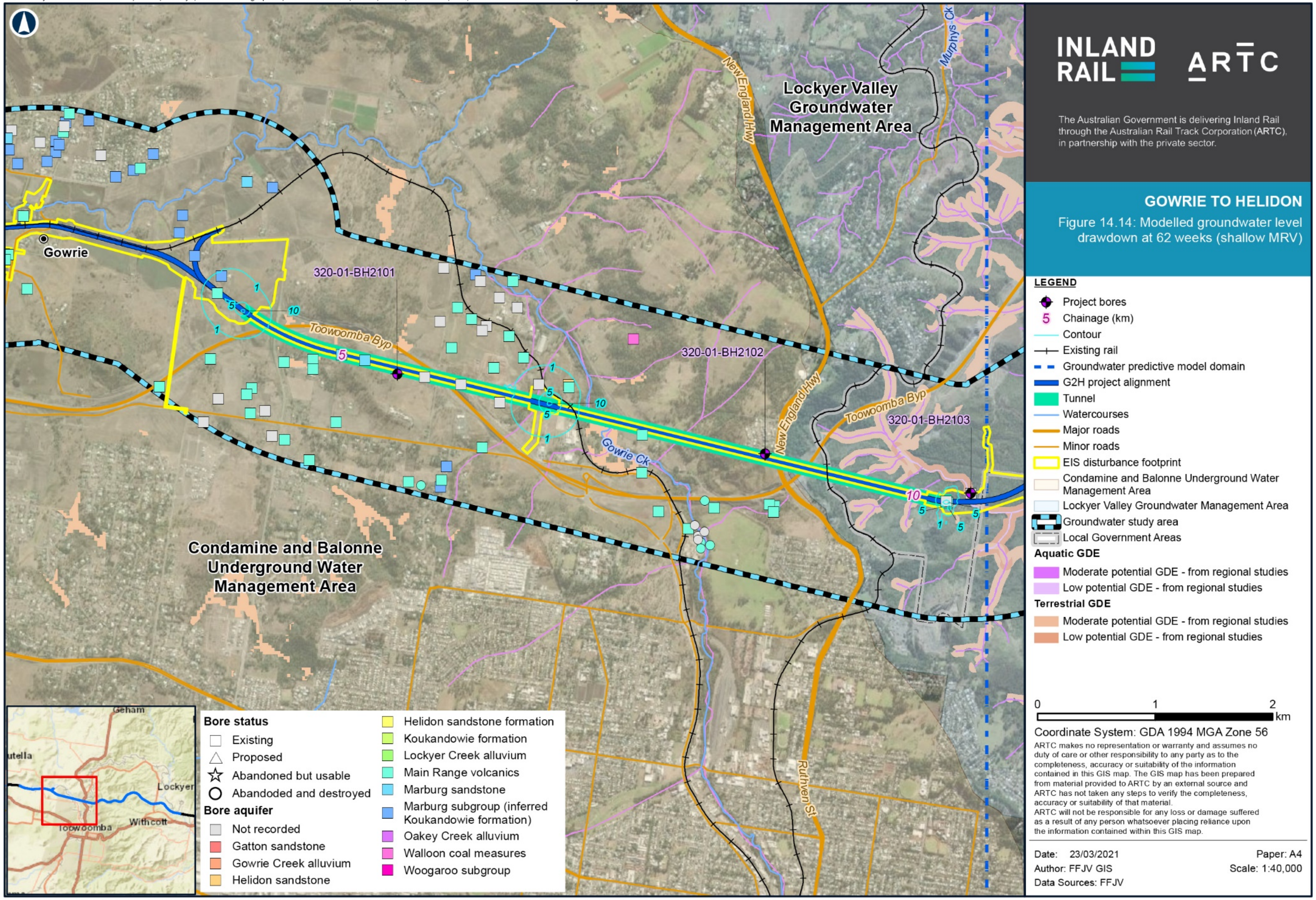

GOWRIE TO HELIDON
Figure 14.14: Modelled groundwater level drawdown at 62 weeks (shallow MRV)

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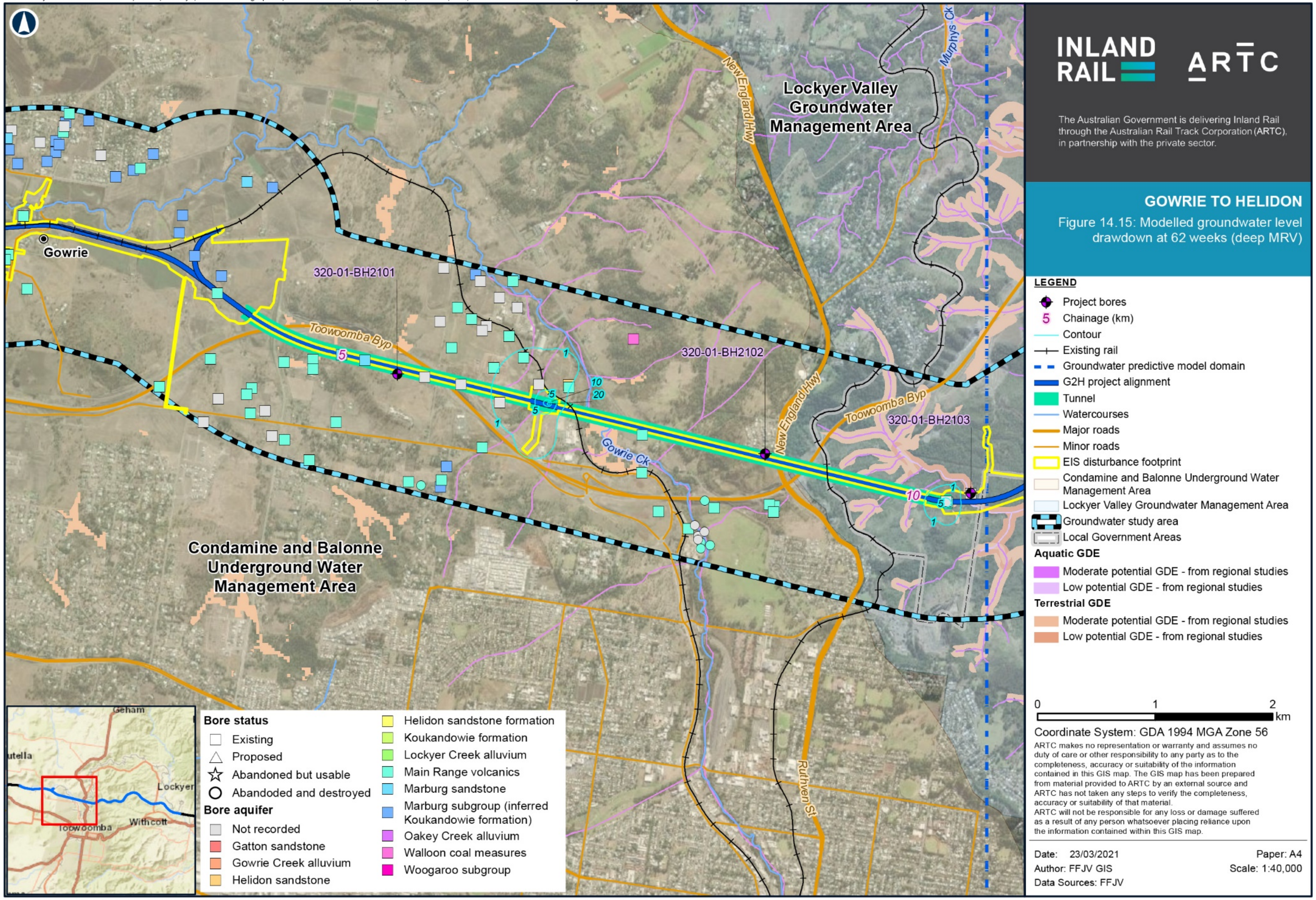

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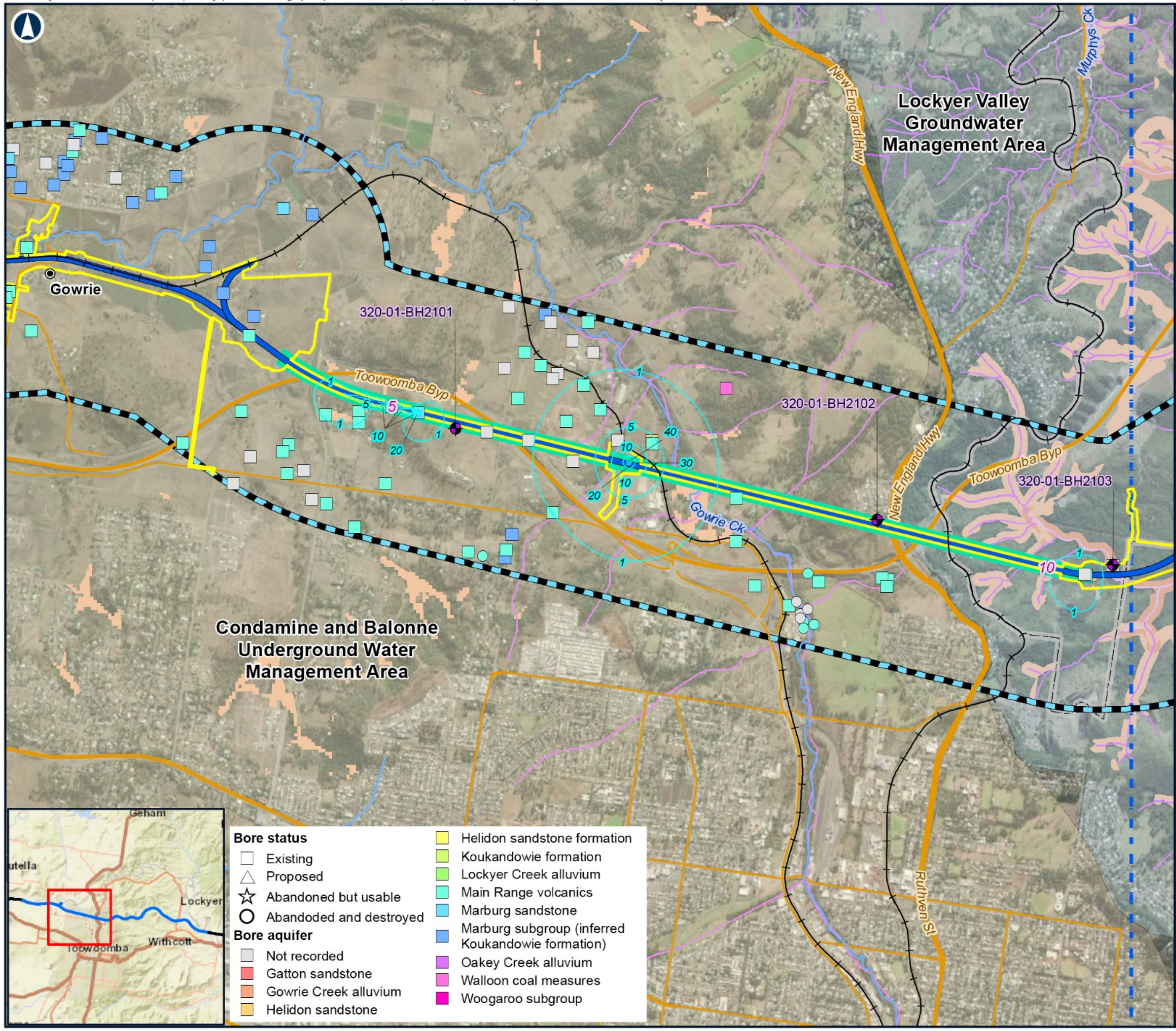

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GOWRIE TO HELIDON

Figure 14.16: Modelled groundwater level drawdown at 62 weeks (Koukandowie Formation)

LEGEND
- Project bores
- Chainage (km)
- Contour
- Existing rail
- Groundwater predictive model domain
- G2H project alignment
- Tunnel
- Watercourses
- Major roads
- Minor roads
- EIS disturbance footprint
- Condamine and Balonne Underground Water Management Area
- Lockyer Valley Groundwater Management Area
- Groundwater study area
- Local Government Areas

Aquatic GDE
- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Terrestrial GDE
- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Bore status
- Existing
- Proposed
- Abandoned but usable
- Abandoded and destroyed

Bore aquifer
- Not recorded
- Gatton sandstone
- Gowrie Creek alluvium
- Helidon sandstone
- Helidon sandstone formation
- Koukandowie formation
- Lockyer Creek alluvium
- Main Range volcanics
- Marburg sandstone
- Marburg subgroup (inferred Koukandowie formation)
- Oakey Creek alluvium
- Walloon coal measures
- Woogaroo subgroup

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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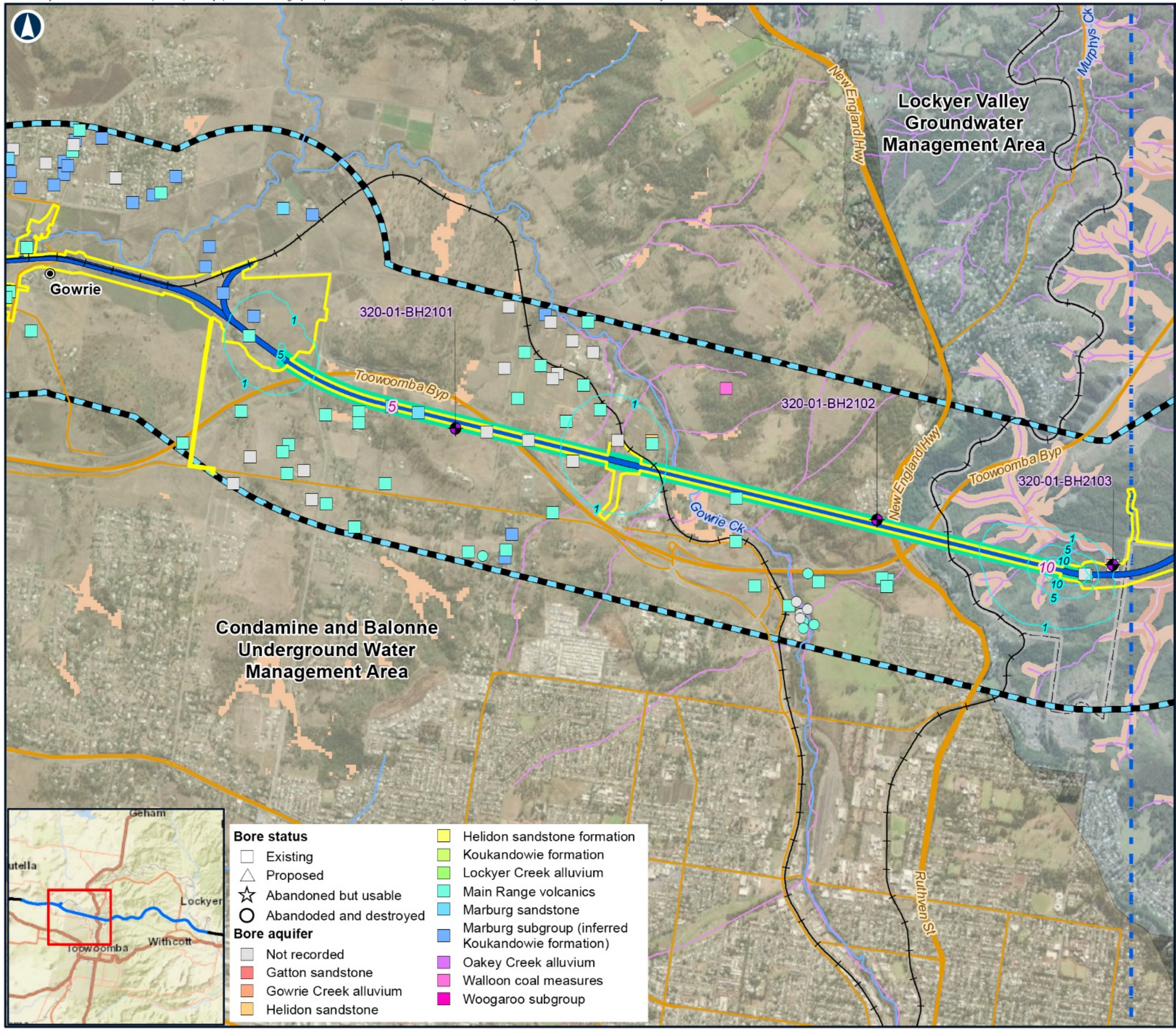

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GOWRIE TO HELIDON

Figure 14.17: Modelled groundwater level drawdown at 107 weeks (shallow MRV)

LEGEND

- Project bores
- Chainage (km)
- Contour
- Existing rail
- Groundwater predictive model domain
- G2H project alignment
- Tunnel
- Watercourses
- Major roads
- Minor roads
- EIS disturbance footprint
- Condamine and Balonne Underground Water Management Area
- Lockyer Valley Groundwater Management Area
- Groundwater study area
- Local Government Areas

Aquatic GDE

- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Terrestrial GDE

- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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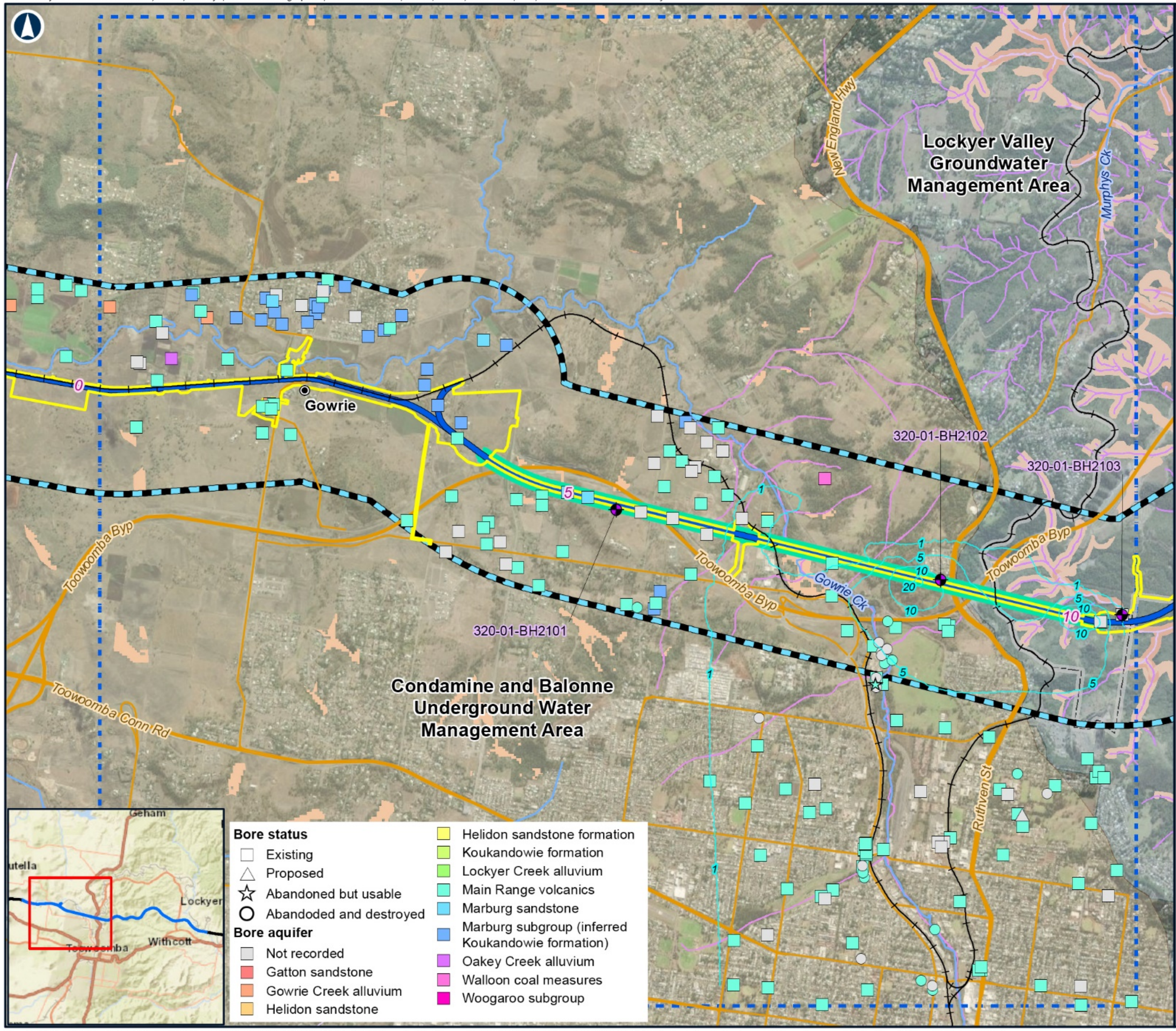

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GOWRIE TO HELIDON

Figure 14.18: Modelled groundwater level drawdown at 107 weeks (deep MRV)

Coordinate System: GDA 1994 MGA Zone 56

Date: 23/03/2021 Paper: A4
Author: FFJV GIS Scale: 1:52,000
Data Sources: FFJV

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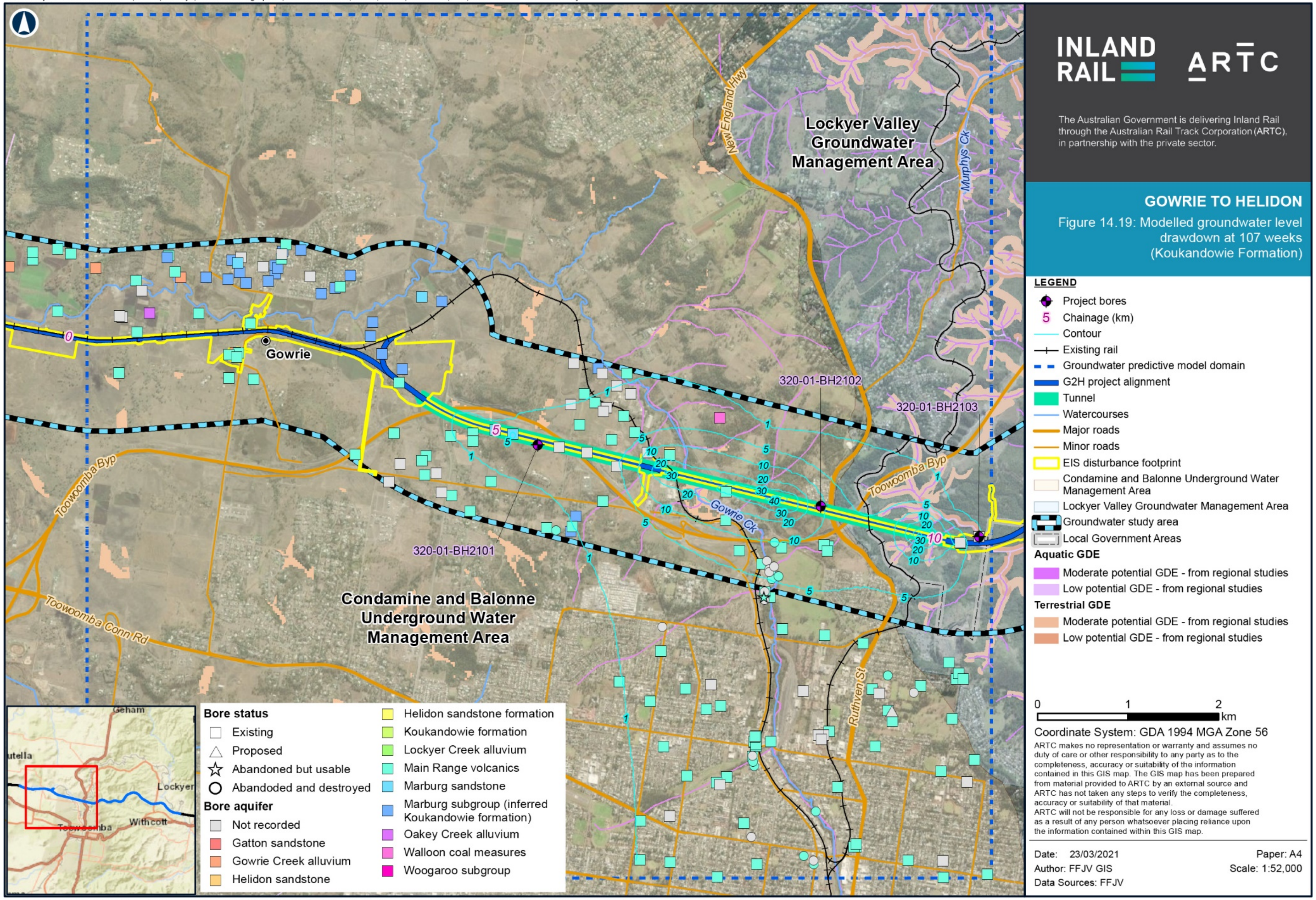

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Operational phase (20-years elapsed time) groundwater level drawdown is shown in Table 14.20 to Table 14.22 and is negligible across all groundwater units. The tunnel portals are drained structures, while the tunnel is designed as undrained.

The maximum predicted drawdown of 10 m during operations is predicted within the shallow MRV and is limited to the western tunnel portal (drained). A drawdown of up to 1 m is also predicted to occur outside of the Project disturbance footprint at the tunnel portals. There are no registered bores in these drawdown extents (refer Table 14.20).

No long-term impact on the deep MRV is predicted, no drawdown predicted for this unit during operation with this unit anticipated to recover after construction is complete (refer Figure 14.20). Modelling predicts drawdown impacts of up to 1 m within the Koukandowie Formation, along the tunnel alignment between Boundary Street and the New England Highway and at the eastern tunnel portal (refer Figure 14.21).

The long-term groundwater level drawdown is expected to recover along the tunnel alignment, except at the drained western portal, as the tunnel is designed as undrained.

14.7.2.2 Refinement of the predictive model

It is recognised that the existing numerical groundwater model was specifically developed to assess the feasibility design. The resultant Class 1 model was used to undertake an assessment of the potential groundwater impacts (related to the feasibility stage). This approach (model classification) was considered sufficient as a starting point for the Project based on the approach that a higher classification model would be developed as more site-specific data is collected and used (Barnett, et al., 2012).

To provide further confidence in ARTC's groundwater impact assessment, allowing for optimum impact avoidance, mitigation, or management, a robust approach for the refinement of the potential groundwater impact assessment of the Project has been developed. It is recognised that there are limitations to the existing model predicted 1-m drawdown contours that are extensive in the model domain for the 107-week scenarios such that they are considered to be an overestimation of the impact and unlikely to present in real life.

A staged approach has been developed to ensure the correct scientific development, refinement of model parameters (boundaries and layers), and peer review. This approach will promote a new integrated surface water–groundwater model that is fit-for-purpose to assess potential impacts on groundwater resources and users that can be updated as new information becomes available. See Appendix N: Groundwater Technical Report for details.

ARTC are working with DRDMW to ensure that their refined model predictions will be completed and included in the Final EIS to better understand the impacts on groundwater and their significance.

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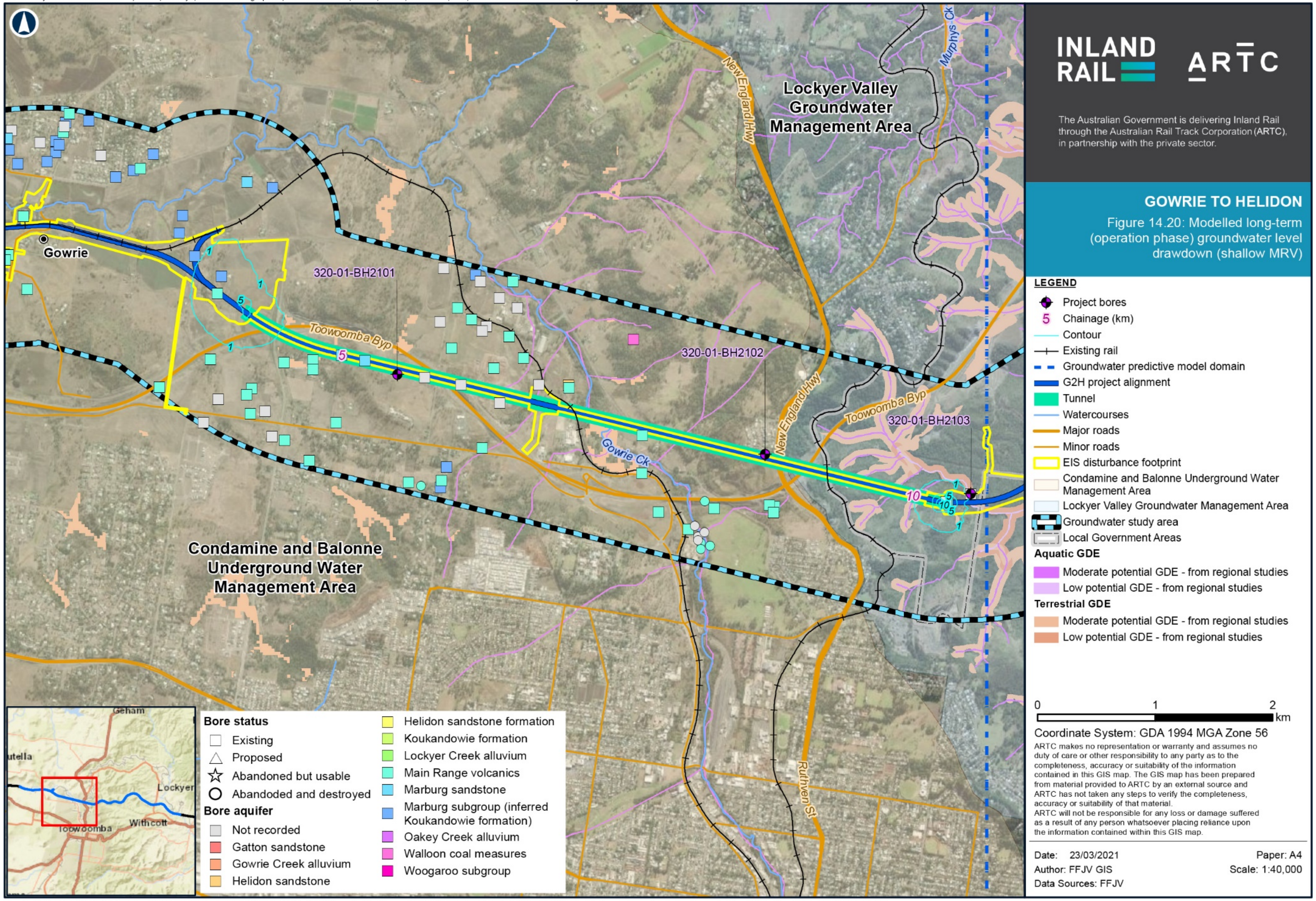

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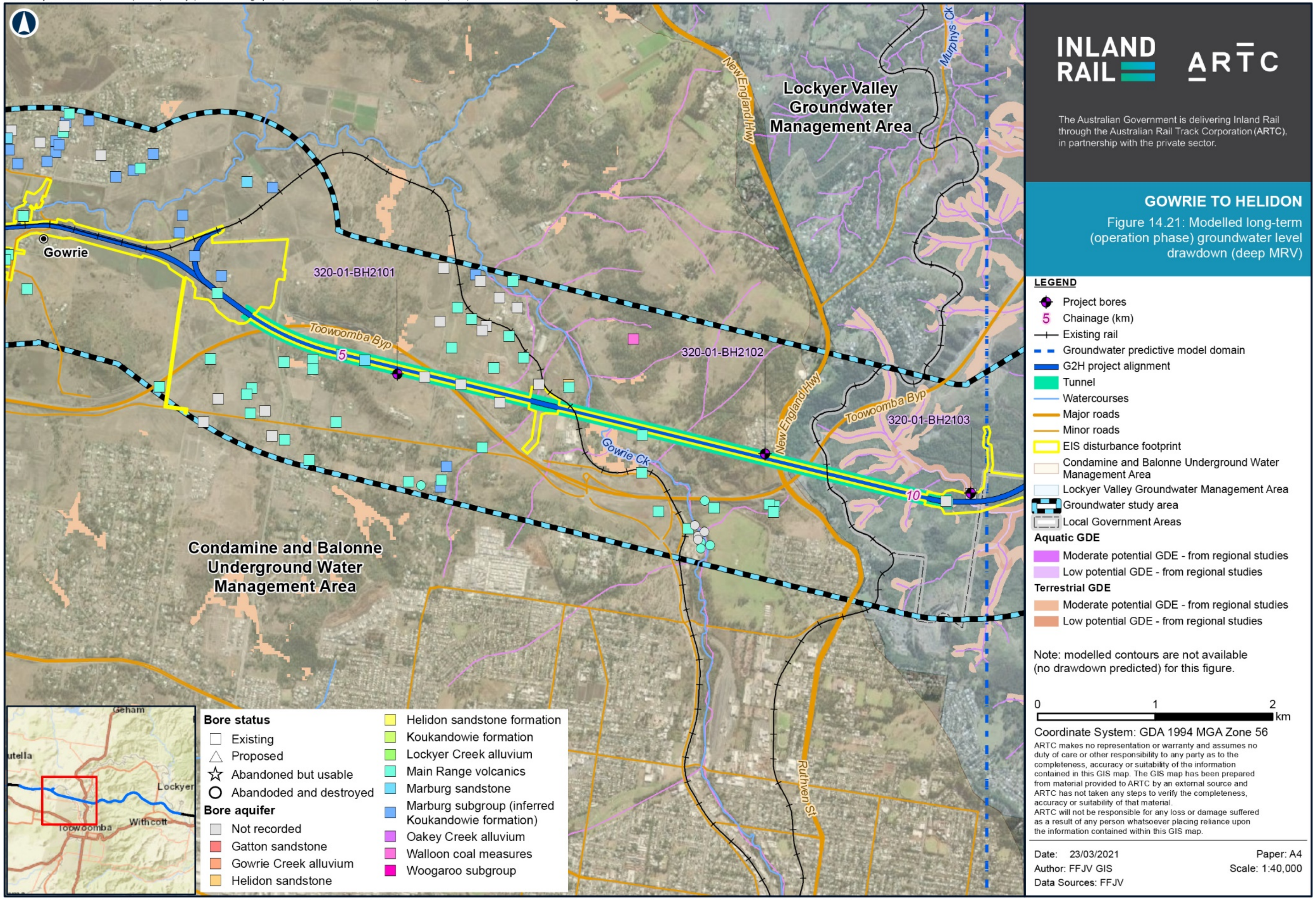

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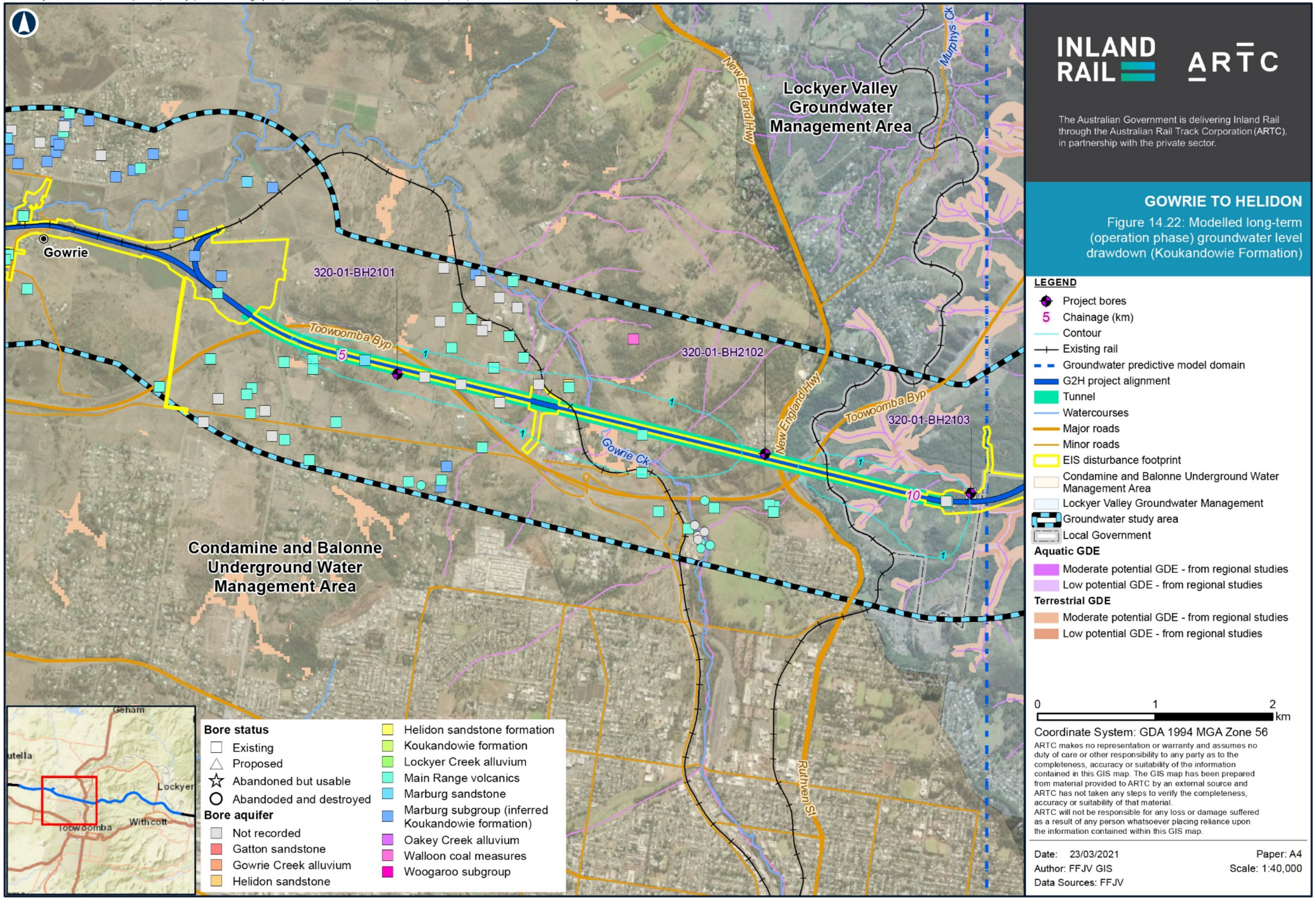

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14.7.2.3 Cuts along the alignment

There is a total of 14 proposed deep cuts (greater than 10 m deep) along the alignment and eight deep cuts are expected to intercept groundwater, as presented in Table 14.21. These cuts were modelled to predict groundwater seepage into the cuts.

TABLE 14.21 DESIGN DETAILS OF MODELLED CUTS

Cut ID	Location along Project (Ch km)	Median centreline elevation along cut (m AHD)	Average cut depth (m)	Maximum cut depth (m)	Median groundwater elevation at cut (m AHD)	Estimated depth of cut below the median groundwater elevation (m)
320-C3[1]	3.61	492.0	15.2	20.1	499.6	7.6
320-C4	10.25	393.6	20.6	70.1	410.7	17.1
320-C5	10.58	387.4	10.6	22.7	388.4	1
320-C6	11.17	377.3	14.7	31.6	388.7	11.4
320-C9	14.08	335.3	4.2	23.3	338.1	2.8
320-C10	14.33	321.9	15.1	28.0	330.4	8.5
320-C11	17.52	279.7	27.4	45.3	301.1	21.4
320-C12	19.35	251.7	11.7	24.3	257.3	5.6

Groundwater seepage from these cuts were estimated using the method described by Nguyen and Raudkivi (1983). The approach is based on a Laplace-type formulation based on the Dupuit–Forchheimer assumption and provides estimation of the phreatic surface and the flow rate as a function of time. The Laplace formulation is based on steady state boundary conditions in an aquifer. The Dupuit-Forchheimer assumption states that groundwater flows horizontally in an unconfined aquifer and that the groundwater discharge is proportional to the saturated aquifer thickness. This assumption requires that the water table be relatively flat and that groundwater is hydrostatic (equipotential lines are vertical). This work was published in the 1800s by Dupuit and Forchheimer. A schematic of the Dupuit-Forchheimer assumption is shown in Figure 14.. Seepage was calculated using inferred groundwater levels at 10 m intervals along the length of each cut. Further detail is provided in Appendix N: Groundwater Technical Report.

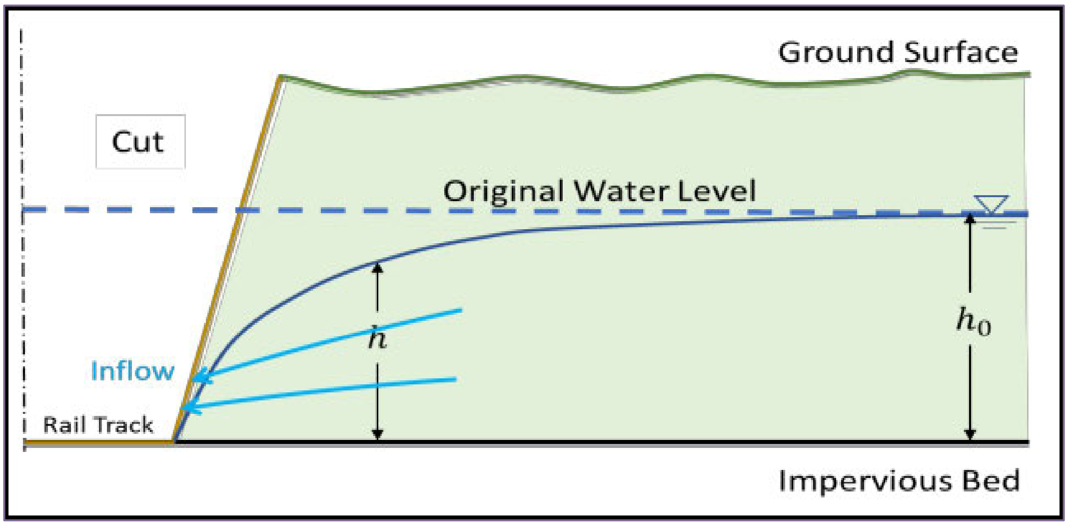

FIGURE 14.23 SEEPAGE FLOW ANALYTICAL MODEL FOR CUTS ALONG THE PROJECT WHERE H0 IS THE UNDISTURBED (AMBIENT) PIEZOMETRIC WATER LEVEL AND H IS THE PIEZOMETRIC HEAD

Table 14.22 presents the predicted seepage rate estimates for cuts along the alignment where groundwater is intercepted. Modelled seepage rates indicate there is limited seepage into deep cuts (less than 0.1 L/s). Seepage from cuts will likely report to cess drains, which are surface drains located to the side of the tracks.

TABLE 14.22 ESTIMATED SEEPAGE RATES FOR CUTS LIKELY TO INTERSECT GROUNDWATER

Cut ID	Cut length (m)	Geology	Total seepage rate: 1 year after construction (L/s)	Total seepage rate: long term (elapsed 20 years) (L/s)
320-C3	-	MRV	Modelled as part of the Toowoomba Range Tunnel	
320-C4 (eastern tunnel portal)	165	Colluvium	<0.1	<0.1
320-C5	376	Koukandowie Formation	<0.1	<0.1
320-C6	373	Koukandowie Formation	<0.1	<0.1
320-C9	317	Koukandowie Formation	<0.1	<0.1
320-C10	311	Koukandowie Formation	<0.1	<0.1
320-C11	295	Koukandowie Formation	<0.1	<0.1
320-C12	250	Gatton Sandstone	<0.1	<0.1

The median estimated groundwater level at each cut (refer Figure 14.20) is below the base elevation, excluding C12, where the median groundwater level is estimated to be approximately 1 m above the base of the cut.

Regional groundwater levels may rise temporarily above the base of the cut as a result of groundwater level fluctuations in response to rainfall patterns. In addition, water that infiltrates following large rainfall events may form temporary perched groundwater systems adjacent to cuts, which result in temporary inflows, particularly through rock joints in relatively more permeable horizons overlying lower permeability perching units. For cuts located in the Koukandowie Formation and the Gatton Sandstone, temporary inflows, as a result of either an increase in the regional groundwater level and/or the formation of temporary perched systems, are likely to be less than 1 L/s at their peak, with the duration of inflow from these temporary perched systems likely to be less than 1 month.

For the eastern tunnel portal and adjacent cut and cover tunnel, the excavation will be in the colluvium, within the Koukandowie Formation and the Gatton Sandstone units located at the base of the excavation or at shallow depth below the excavation. The colluvium is interpreted to have a significantly higher hydraulic conductivity than the Koukandowie Formation and the Gatton Sandstone, and, therefore, there is potential for greater inflow as a result of temporary increases in regional groundwater level than for cuts in less permeable formations. The groundwater level observed in the area of the eastern portal in borehole BH2216 was approximately 2 m below the base of the excavation between September and December 2018 (Golder, 2020b). The groundwater level during this period is likely to be below the long-term median groundwater level due to characteristically low rainfall received in this period.

Based on local topography and subsurface geology and likely high specific yield of the colluvium, it is predicted that the long-term median groundwater level is unlikely to be above the base of the excavation. As a result, the long-term inflow is expected to be low, despite the high hydraulic conductivity of colluvium. Temporary inflows following increases in groundwater level due to rainfall are estimated to be, at their upper limit, in the range of 2 to 5 L/s. These peak inflows would be of relatively short duration (potentially up to a month); however, temporary inflows are likely to continue at decreasing rates over longer periods than in formations with lower storage capacity, due to the relatively high specific yield of the colluvium.

14.7.3 Construction phase potential impacts

The Project includes several activities that have potential to impact on the groundwater regime. These activities include earthworks (cut-and-fill sections), drainage construction, haul-road and access-track construction, track laying, bridge and viaduct pilings, and tunnel and portal construction. The potential impacts of the Project on groundwater are discussed below in terms of impacts on groundwater resources and groundwater quality.

14.7.3.1 Water resources

Dewatering

Active 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 also occur passively during construction that includes seepage into cuts insufficient to require being pumped out. Dewatering may be required where sub-surface works encounter groundwater, primarily during construction. Reduced groundwater levels from dewatering during construction of cuts and the tunnel, has the potential to impact groundwater users, surface water flow and GDEs.

Cuts along the alignment

Reduced groundwater levels from dewatering during construction of cuts has the potential to impact groundwater users (e.g. registered bores and surface water flows). Dewatering has the potential to result in temporary drawdown of localised groundwater levels. This drawdown has the potential to temporarily affect the availability of groundwater from registered bores in proximity to the works, not otherwise decommissioned by the Project. Drawdown also has potential to affect surface water features and GDEs within the radius of influence, though there are few cuts near a watercourse.

Deep cuts with potential to intersect groundwater (bridges, viaducts and piling sections) may potentially result in drawdown of groundwater levels due to seepage into the cuts. Predictive modelling (refer Section 14.7.2) suggests the construction phase seepage resulting from the cuts is less than 0.1 L/s. Seepage from cuts will likely report to cess drains, which are surface drains located to the side of the tracks.

Construction design of cuts includes drainage measures to prevent degradation of the exposed rock face and ensure long-term stability. Cut-specific drainage measures that have been implemented include:

- Strip drains and weep holes to be applied in conjunction with any shotcrete facing
- Bunds (500 mm minimum, with catch drain) specified at the crest of the slope, where the existing topography is likely to cause run off into the cut face and the slope of the drain is between 1 in 100 and 1 in 200
- Sub-surface drainage, in the form of sub-horizontal drains, to control porewater pressures at the batter face. This will most likely apply for cuttings located in either the Koukandowie Formation or WCM, which may contain layers of extremely weathered mudstone, claystone or coal seams. Sub-horizontal drains have been nominated where the groundwater level is identified to potentially rise above the base of the cut.

Toowoomba Range Tunnel

Preliminary estimates of groundwater inflows and drawdowns have been undertaken to inform assessment of the potential to construct the Toowoomba Range Tunnel and portals as permanently undrained structures.

The predictive modelling of the Toowoomba Range Tunnel (refer Section 14.7.2) suggests the maximum tunnel seepage (inflow estimates) rates during construction are predicted to be 100 L/s for the TBM portion of the tunnel and 37 L/s for the mined tunnel portion (at 107 weeks). The intermediate ventilation shaft is expected to have a maximum seepage rate of 17 L/s during construction (at 62 weeks). The western tunnel portal is expected to see maximum inflows at 34 weeks. The resulting groundwater drawdown was then assessed for each unit (shallow MRV (typical value of hydraulic conductivity), deep MRV (high conductivity layer) and the Koukandowie Formation.

Increasing the permeability of the MRV and Koukandowie Formation for sensitivity analyses (refer Appendix N: Groundwater Technical Report) results in higher groundwater seepage rates and an increase in the drawdown extent. Ongoing and future geotechnical and hydrogeological investigations are anticipated, along with refinement of the predictive groundwater model (see Section 14.7.2.2) to confirm risks posed to groundwater drawdown impacts from increased permeabilities and on potential GDEs are acceptable. The increase in drawdown extents may impact additional groundwater bores and GDEs.

Loss or damage to existing landholder bores

There is a potential for existing landholder bores to be damaged, destroyed, or to become inaccessible as a result of the Project. Registered bores with potential to be impacted by construction of the Project are discussed in the subsections below.

Registered bores in the construction footprint

Sixteen registered bores in the Project disturbance footprint are summarised in Table 14.23. These bores are not within the predicted groundwater level drawdown extent. The potential exists for these bores to be damaged, destroyed or to become inaccessible, or more difficult to access, due to the Project.

It is likely that 14 of these bores will be decommissioned according to the *Minimum Construction Requirements for Water Bores in Australia – Edition 4* (National Uniform Drillers Licensing Committee, 2020) or will be used by the Project as monitoring bores.

There are two registered bores (RN117110 and RN117104) that are above the tunnel, at depths of 30 and 35 mbgl, respectively, while the tunnel is about 100 mbgl within the vicinity of these bores. The aquifer intercepted by these bores has not been identified; however, the bores are screened in basalt, which corresponds to the MRV observed in this area. The bores are unlikely to be decommissioned but the tunnel can potentially impact on bores above it by water level drawdown during construction and operations, along with potential impacts from vibration.

The number of registered boreholes to be decommissioned will be confirmed during detailed design, including whether the bore above the tunnel will need to be decommissioned or whether the purpose of the bores can be amended for monitoring purposes. No bores are anticipated to be decommissioned after the construction phase.

TABLE 14.23 EXISTING REGISTERED BORES WITHIN THE PROJECT DISTURBANCE FOOTPRINT

Bore	Chainage (km)	Lot/Plan	Bore role	Nearby Project feature
RN56783	2.0	122/AG3560	-	320-E2 and 320-E3
RN66497	3.6	2/RP192838	-	Western tunnel portal cut
RN71234	3.9	21/RP34896	-	Western tunnel portal cut
RN172858	3.9	2/RP192838	Sub-artesian monitoring	Western tunnel portal cut
RN107110	5.7	58/AG228	-	Toowoomba Range Tunnel
RN107104	6.1	172/RP220582	Water supply	Toowoomba Range Tunnel
RN173879	10.5	120/CC675	Sub-artesian monitoring	Eastern tunnel portal cut
RN106596	12.3	354/CH312304	Water supply	Bridge
RN173876	13.9	245/CC315	Sub-artesian monitoring	Bridge
RN173875	15.6	-	Sub-artesian monitoring	Cut (320-C10)
RN173799	19.8	213/SP200754	Sub-artesian monitoring	320-E12
RN173798	21.1	169/SP200753	Sub-artesian monitoring	Bridge
RN173154	21.5	4/SP200753	Water supply	Bridge
RN75289	23.6	18/SP105106	Water supply	Bridge
RN75335	23.9	18/SP105106	Water supply	Bridge
RN173801	24.8	452/SP117138	Sub-artesian monitoring	Bridge

Table note:
'-' Data not provided in the Queensland Globe database

Registered bores potentially impacted by groundwater level drawdown

After predictive modelling of the impacts of deep cuts and the Toowoomba Range Tunnel on groundwater resources (refer Section 14.7.2), the modelled impact area was assessed against licensed groundwater extraction bores and other registered bores in order to identify the areas (real property) potentially impacted by the Project. This has been undertaken to better understand the potential impacts on groundwater users. Predicted groundwater drawdown extents, along with registered bores, are mapped in Figure 14.13 to Figure 14.19. Table 14.24 summarises the registered bores (reported as existing) and their reported uses in the various drawdown extents within the groundwater study area. The table also includes bores in the drawdown extent resulting from the uncertainty analysis (refer Appendix N: Groundwater Technical Report for more information).

The bores predicted to be impacted by a 1 m drawdown of water levels for the deep MRV and Koukandowie Formation extend beyond the groundwater study area; these bores are included in Appendix N: Groundwater Technical Report.

Existing registered bores in the Koukandowie Formation groundwater drawdown extent are not screened in the Koukandowie Formation and are not likely to be impacted by groundwater drawdown. There are three shallow bores (RN94667, RN107104 and RN107105) that do not have aquifer information available (based on the Queensland Globe database). These bores are unlikely to be impacted by drawdown in the deep Koukandowie Formation as they are shallow bores (bore depth less than 15 m) not constructed within this formation.

TABLE 14.24 REGISTERED BORES IN THE PREDICTED GROUNDWATER DRAWDOWN EXTENTS (CONSTRUCTION PHASE)

Elapsed time since excavation commenced	Modelled aquifer	Drawdown depth (m)	Number of existing registered bores within the drawdown extent	Existing registered bore	Reported bore aquifer	Screened depth (m)	Reported bore use
34 weeks with increased conductivity in the MRV[1]	Shallow MRV	5	1	172858[a]	-	-	-
62 weeks	Koukandowie Formation	5	3	94667	-	12	-
				119852	Helidon Sandstone	5	Water supply
				137355	MRV	5	Water supply
62 weeks with increased conductivity in the MRV[1]	Shallow MRV	5	1	172858[a]	-	-	-
	Deep MRV	5	4	119498	MRV	67	Water supply
				94668	MRV	24	-
				107105	-	15	-
				38619	MRV	6.4	-
		> 5	3	94667	-	12	-
				119852	Helidon Sandstone	5	Water supply
				137355	MRV	5	Water supply
	Koukandowie Formation	5	7	107104	-	14	Water supply
				119498	MRV	67	Water supply
				107105	-	15	-
				38619	MRV	6.4	-
				94668	MRV	24	-
				94669	MRV	12	-
				172057	MRV	49	Water supply
		> 5	5	119852	Helidon Sandstone	5	Water supply
				137355	MRV	5	Water supply
				172118	MRV	64	Water supply
				94667	MRV	6.4	-
				38341	MRV	24	-

Elapsed time since excavation commenced	Modelled aquifer	Drawdown depth (m)	Number of existing registered bores within the drawdown extent	Existing registered bore	Reported bore aquifer	Screened depth (m)	Reported bore use
62 weeks with increased conductivity in the Koukandowie Formation[1]	Shallow MRV	5	1	94667	-	12	Sub-artesian monitoring
	Deep MRV	5	3	94667 119852 137355	- Helidon Sandstone MRV	12 5 5	- Water supply Water supply
	Koukandowie Formation	5	2	94668 107105	- -	5 5	Water supply Water supply
		> 5	3	94667 119852 137355	- Helidon Sandstone MRV	- 5 5	- Water supply Water supply
107 weeks	Deep MRV	> 5	4	172088 172183 172086 172087	MRV	31 24 30 36	Sub-artesian monitoring Water supply Sub-artesian monitoring Sub-artesian monitoring
	Koukandowie Formation	> 5	2	64098 172088	MRV	110 31	Unknown Sub-artesian monitoring
			3	172086 172087 172182	MRV	30 36 24	Sub-artesian monitoring Sub-artesian monitoring Great Artesian Basin monitoring
			1	172183	MRV	24	Water supply
			1	94667	Unknown	12	Unknown
			4	119497 119852 137168 137355	MRV Helidon Sandstone MRV MRV	40 5 12 5	Water supply Water supply Water supply Water supply

Table notes:

1 Refer to Uncertainty analysis, Section 9.3.8 in Appendix N: Groundwater Technical Report

a Bore is within the temporary and permanent footprint and likely to be decommissioned

Groundwater level drawdown in the shallow MRV, at the eastern portal, is expected to extend outside the construction footprint, as depicted in Figure 14.17, to an extent of approximately 200 m from the centre of the alignment; however, there are no existing registered bores within this extent.

The groundwater level drawdown within the deep MRV is predicted to extend outside the southern boundary of the groundwater study area, as depicted on Figure 14.18. There are four registered bores mapped within the predicted drawdown extent that are reported to be constructed to source water from this unit (located (within the study area; details of these bores are included in Table 14.24. The 1 m predicted groundwater drawdown in this unit includes an area outside the groundwater study area south of the tunnel.

Predicted groundwater drawdown in the Koukandowie (at 107 weeks) is anticipated to extend to the southern boundary of the groundwater study area at a depth of 5 m, (Figure 14.19). The 1 m predicted groundwater drawdown in this unit includes an area outside the groundwater study area south of the tunnel.

There are 82 registered bores located within the predicted 1 m drawdown contour extent, for both the deep MRV and the Koukandowie Formation, of which 66 are reported to exist. Of these 66 existing bores, 56 are reported to source groundwater from the MRV. One bore is reported to be existing but usable (MRV) and one proposed bore is reported to be located just south of the southern groundwater study area boundary.

The refinement of the predictive model will confirm the predicted drawdown contours, spatially as well as in time; that is, while the 1 m predicted drawdown contour is extensive, the actual timing and duration for a bore to be impacted by this drawdown can be estimated.

Registered bores potentially impacted by vibration

The main construction activities to cause vibration impacts include:

- Blasting
- Tunnel construction equipment
- Standard construction activities associated with site establishment, earthworks, drainage works, rail and road civil works, and construction of structures (e.g. use of earth moving machinery, vibratory rollers, piling rig, hydraulic hammers, etc.).

Noise and vibration impacts resulting from the Project have been assessed in Appendix O: Construction Noise and Vibration Technical Report. The assessment does not specially assess impacts to groundwater bores; however, they do reference buried services and prescribe the minimum setback distance of 5 m.

There are 16 existing registered bores in the construction footprint (summarised in Table 14.23) and of these bores there are seven bores (summarised in Table 14.25) near areas potentially impacted by vibration (including the western and eastern portal cuts, Toowoomba Range Tunnel and cut 320-C10). Bores within the construction footprint are likely to be decommissioned and, as such, they are of low risk.

There is potential for the two bores constructed above the tunnel (RN107110 and RN107104) to be impacted by vibration; however, the clearance between the top of the tunnel and bottom of the bore is greater than 60 m, which suggests potential vibration impacts are low.

TABLE 14.25 EXISTING REGISTERED BORES WITHIN THE CONSTRUCTION FOOTPRINT NEAR CRITICAL VIBRATION AREAS

Bore	Chainage (km)	Lot/Plan	Bore role	Nearby Project structure
RN66497	3.6	2/RP192838	-	Western portal cut
RN71234	3.9	21/RP34896	-	Western portal cut
RN172858	3.9	2/RP192838	Sub-artesian monitoring	Western portal cut
RN107110	5.7	58/AG228	-	Toowoomba Range Tunnel
RN107104	6.1	172/RP220582	Water supply	Toowoomba Range Tunnel
RN173879	10.5	120/CC675	Sub-artesian monitoring	Eastern portal cut
RN173875	15.6	-	Sub-artesian monitoring	Cut (320-C10)

Table note: '-' data not provided in the Queensland Globe database

Unregistered bores

While the potential for the Project to impact on licensed groundwater extraction bores and registered bores has been assessed, there is potential for unregistered landholder bores to be present in the groundwater study area and the predicted drawdown extents. Impacts are likely to be similar to those noted above for registered bores, based on depth and location from construction activities.

Unregistered bores will be identified in consultation with relevant landholders and stakeholders during detailed design. This will include the location of the bores, the date the bore was constructed, how the bore was constructed, the aquifer the bore intercepts, the primary use of the bore, and, where applicable, groundwater level and yields.

Once the unregistered bore is identified, ARTC will confirm what, if any, impacts are likely, including:

- As with the registered bores, unregistered bores located in the Project disturbance footprint will be decommissioned, with the expectation of any bore above the tunnel
- Whether the bore is within the predicted drawdown extents for the construction and operation of the tunnel.

Mitigation measures to prevent impact on such unregistered groundwater bores is presented in Section 14.8.

Groundwater dependent ecosystems and springs

The springs identified in Section 14.6.9 were mapped with the MRV drawdown extents, as the MRV is the primary source aquifer for springs in the groundwater study area. It is noted that no source aquifer is reported for the Helidon Spring (or anecdotally reported springs) east of the alignment. The springs are not within the predicted groundwater drawdown extent for the shallow or deep MRV aquifers.

The GDEs mapped within the groundwater drawdown contours are summarised in Table 14.26. The GDEs are associated with tributaries of Gowrie Creek and Rock Creek and are likely recharged by shallow alluvium units. It is unlikely the drawdown in the MRV and Koukandowie Formation will impact the mapped GDEs; however, there is potential connectivity between the shallow units and the MRV.

TABLE 14.26 SUMMARY OF GROUNDWATER DEPENDENT ECOSYSTEMS WITHIN GROUNDWATER DRAWDOWN CONTOURS DURING CONSTRUCTION

Duration	Unit	Drawdown contour depth (m)	GDEs within drawdown extent
34 weeks	Shallow MRV	5	None
	Deep MRV	5	None
62 weeks	Shallow MRV	5	Moderate potential GDE—terrestrial Tributary of Rocky Creek
	Deep MRV	5	Moderate potential GDE—terrestrial Tributary of Rocky Creek
	Koukandowie Formation	5–11	Moderate potential GDE—terrestrial Tributary of Gowrie Creek
107 weeks	Shallow MRV	5	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek
		5–10	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek
	Deep MRV	5	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek and Gowrie Creek
		5 - 6	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek
	Koukandowie Formation	5	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek and Gowrie Creek
		5–10	Moderate potential GDE—aquatic Moderate potential GDE—terrestrial Tributary of Rocky Creek and Gowrie Creek

Embankments

Potential for groundwater mounding at embankments was calculated using estimated current groundwater levels and an estimate of the potential increase in levels, based on records of groundwater-level variations from historical flood events (Golder, 2020a). Assessment of available records and calculations indicate embankments in the:

- MRV: fracture permeability and low effective porosity may result in potential groundwater level rise, between 1.2 m and 15.1 m, rapidly or delayed, dependent on connectivity of fractures following large rainfall/flood events
- Sedimentary units east of the GDR: low effective porosity may result in potential groundwater level rise, between 1.0 m and 3.5 m, likely delayed following large rainfall/flood events
- Flood plains overlying deep alluvium: potential groundwater level increase of up to 10 m is anticipated.

Three embankment locations (320-E1, 320-E2 and 320-E3) that overly the Gowrie Creek floodplain and are subject to inundation during flooding, are the most likely to see a rise in groundwater level (within 2 m of ground surface) (Golder, 2020a). Refer Appendix N: Groundwater Technical Report for further details of embankments, locations and design details.

Overall, there is the potential for embankments to effect groundwater levels and/or the hydraulic properties of the aquifer(s) locally across some sections of the alignment (as described above). It is anticipated that ongoing and further geotechnical investigations will confirm the potential risk and inform final design. This includes design measures and/or strategies to avoid, mitigate and manage impacts.

Subsidence/settlement

There is a limited potential for construction phase (more than 1 year after completion of slope cuts) localised drawdown to occur as a result of dewatering from cuts. Groundwater drawdown can result in settlement of compressible substrates and possible damage to adjacent structures, i.e. proposed bridges or embankments.

Early drawdown effects, due to seepage into cuttings and the tunnel, has the potential to cause settlement of compressible materials, and damage to buildings or other structures within areas of settlement. The greatest potential occurs where groundwater is shallow, soils are compressible, and buildings/structures are nearby; for example, areas close to the Gowrie Creek floodplain. In such locations, either viaducts or bridges are typically proposed.

In the area of the Toowoomba Bypass, subsidence potential is considered limited to the western portal of the Toowoomba Range Tunnel; all other Project crossing locations are to be either bridges or well below the bypass where impact is not anticipated.

Some locations for cuts are expected to be below the water table and eight deep cuts were selected for modelling to estimate the potential drawdown amount and lateral drawdown extent (refer Section 14.7.2.3). These deep cuts are located within competent substrate including basalt and sandstone where the likelihood of settlement is less probable than in unconsolidated substrates. Deep cuttings in high relief areas are typically in more competent bedrock sediments and so the risk of settlement is reduced. Reduced groundwater levels due to dewatering and/or seepage into the tunnel are not considered to present a risk of settlement due to the competent sedimentary bedrock material being tunneled (i.e. MRV and Koukandowie Formation).

Overall, the potential for settlement and damage to buildings and properties due to subsidence from drained cuttings and the undrained tunnel, appears to be low. It is anticipated that the potential for settlement will be confirmed as part of ongoing geotechnical investigations and will inform final design.

Vegetation removal and surface disturbance

A limited area is proposed to be cleared and graded for construction purposes when compared to the large aquifer extents due to the linear nature of the Project. The disturbance footprint considered negligible against the recharge surface area of the aquifers that underlay the Project. Consequently, vegetation removal and surface disturbance is likely to have little impact on the groundwater resources.

Bridge and viaduct pilings

Changes to groundwater levels may occur during installation of pilings for bridge construction. Any such changes will be temporary, localised and small, based on construction design (i.e. diameter, depth and spacing of piles). Impacts are likely to be in the alluvial aquifers of Gowrie Creek, Oaky Creek, Six Mile Creek and Lockyer Creek. Shallow MRV may also be intercepted in the Gowrie area and the eastern tunnel portal.

Construction water supply

Water supply for construction needs (e.g. construction and dust suppression) is to be confirmed in the detailed design; though, at this stage, groundwater is not envisaged to be the main water supply (apart from recycling groundwater that infiltrates into the tunnel), with a number of options available depending on the location along the Project alignment. There is potential for existing groundwater users to be affected due to drawdown effects of water supply bore(s) if groundwater supply, as a result of new groundwater bores (e.g. ARTC will acquire existing groundwater licences during the land acquisition and may also enter into an agreement with an existing licence holder to use their groundwater subject to licensing conditions and amendments), were to form a major part of the water supply solution (refer Appendix N: Groundwater Technical Report).

Construction water demand for the Project is estimated at 700 ML, with a detailed breakdown, including a water hierarchy provided in Chapter 6: Project Description.

Based on the groundwater inflow modelling (refer Section 14.7.2.1), if all the groundwater inflow into the tunnel could be captured, this is nearly 2.5 times the construction water demand. The majority of water from excavation of the tunnel will be collected and recycled for cooling the TBM, dust suppression, water for drilling, and compaction works to support the tunnel construction.

A water permit under the Water Act is likely for the groundwater inflow during construction. Water permits are issued for temporary projects having a foreseeable conclusion date and anticipated to have short-term impacts on the resource. Normally, water permits are granted up to a maximum timeframe of three years and cannot be renewed, transferred, or amended.

Where it is determined that construction water will be sourced from an existing bore (private or ARTC) an amendment under the Act may be required; that is, the current purpose of the bore (e.g. irrigation, domestic use) may not allow the water to be used for construction. Further, a water licence may be required for any new groundwater bores; though, as noted previously, groundwater allocations under the relevant water plan are predominantly exhausted.

Potential impacts to groundwater elevations may occur where bore water is sourced to supply water for construction activities; however, if groundwater is considered for sourcing of construction water, it will be sourced from existing registered and licensed bores. 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 registered bore.

Existing water entitlements

There are eight land parcels within the Project disturbance footprint that are linked to a water entitlement under the Water Act, refer to Table 14.27. These water entitlements will expire as a result of the land acquisition process (i.e. the water entitlement is linked to a land parcel being acquired (in full or part) for the Project). The landholder has 60 days to reinstate the water licence.

There is the potential for the water entitlements to be purchased by ARTC as part of the land acquisition process, or for compensation to be sought, due to the expiration of the water licence. There are also several water licences on adjacent properties to the Project, where construction water may also be sourced. This includes Lot 924 on SP154259, with the attached water licence (83456R) allowing for the take of groundwater for an urban purpose. The water allocation is for 3,800 megalitres per year (ML/yr) from the Main Range Volcanics (Toowoomba City Basalts) and is applicable to Toowoomba Regional Council.

TABLE 14.27 LAND PARCELS WITH WATER ENTITLEMENTS UNDER THE WATER ACT 2000 DIRECTLY IMPACTED (IN PART) BY THE PROJECT (IN BOLD)

Water source	Licence details	Water use	Associated land parcels	Annual allocation
Water Plan (Condamine and Balonne) 2019				
Groundwater	Licence to take water (404530)—Toowoomba South Basalts Groundwater, Upper Condamine Basalts, Main Range Volcanics	Irrigation	26/RP24609	35 ML
Groundwater	Licence to take water (4171R)—Toowoomba North Basalts Groundwater, Upper Condamine Basalts, Main Range Volcanics	Irrigation	2/RP138824	0 ML

Water source	Licence details	Water use	Associated land parcels	Annual allocation
Groundwater	Licence to take water (48082R)—Toowoomba South Basalts Groundwater, Upper Condamine Basalts, Main Range Volcanics	Stock intensive	35/AG4088	1 ML
Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017				
Groundwater	Licence to take water (48082R)—Eastern Downs Marburg, Hutton, Marburg subgroup	Irrigation	26/RP24609	5 ML
Groundwater	Licence to take water (48082R)—Eastern Downs Marburg, Hutton, Marburg subgroup	Irrigation	2/RP40070	10 ML
Water Plan (Moreton) 2007				
Surface water	Licence to take water (18927G)—Upper Lockyer Ck (Gat) Wac	Irrigation	1/CH3133; 111/CC794; 197/CH31508; 54/CA311531	15 ha
Surface water	Licence to take water (25397G)—Upper Lockyer Ck (Gat) Wac,	Irrigation	13/CH31259; 51/CC835	4 ha
Groundwater	Licence to take water (48322G)—Murphys Creek Marburg, Hutton	Domestic supply	153/CH31327	Unknown

14.7.3.2 Water quality

Contamination

During the construction phase, potential sources of contamination to groundwater could occur due to:

- Unintended spills and leaks of hydrocarbons (oils, fuels and lubricants) and other chemicals related to use of heavy plant and equipment, and fuel storages
- Water mixtures and emulsions related to washdown areas
- Upward seepage along piles/soil interfaces of saltier groundwater from the deeper confined aquifers into the fresher alluvium aquifers
- Discharge of groundwater seepage from tunnel and cuts
- Heavy metals entering waterways from rail grinding and welding
- Compounds leaching from ballast materials
- Salts mobilised from surface soils or shallow groundwater changes
- Disturbance of contaminated lands near waterways resulting in contaminated runoff entering watercourses and, potentially, to the local aquifers via recharge areas or due to surface and groundwater interaction
- Inadequately treated dewatering of tunnel infrastructure may result in hydrocarbons being introduced to the Gowrie Creek catchment at the western tunnel portal (Ch 3.4 km), and to the unnamed tributary of Rocky Creek at the eastern tunnel portal (Ch 10.4 km).

Direct infiltration of contaminants through the ground surface, in areas of low relief with shallow water levels, are likely to be reduced due to the dominant fine-grained sediments of the soil profile (clays and silts). This has potential to occur beneath the watercourses encountered by the Project, and at approximate Ch 10 km, Ch 12 km, and between Ch 19 and 24 km, which are underlain by alluvium, MRV, Koukandowie Formation or Gatton Sandstone.

Excessive amounts of water applied during construction phases of the Project have the potential to infiltrate past the root zone and contribute to rising water tables/levels in shallow aquifers. Leakage from water storage areas may also contribute to rising water levels.

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

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. 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.

Bridge and viaduct pilings

A rotary drill rig will be used to drill bored piers, with prefabricated reinforcement cages lowered into the pile before a wet concrete slurry is placed, via tremie or pumping. The alkaline wet concrete slurry may affect groundwater quality (for example pH and salinity) immediately adjacent to the piles, while curing occurs (i.e. drying and hardening of the concrete). Any such changes are likely to be temporary, localised and small, given the small contact areas of piling surfaces and groundwater compared to the scale of the groundwater flow systems.

Toowoomba Range Tunnel

Based on available groundwater quality data, groundwater quality of inflows to the Toowoomba Range Tunnel, and associated cuts during construction and operation is expected to be fresh to brackish, sodium-chloride dominant and neutral to slightly alkaline. Water quality values may vary seasonally due to rainfall infiltration and first-flush events.

During construction via the TBM, any water collected inside the tunnel (groundwater seepage, stormwater carry-in, wash-down, firefighting, etc.) will be collected and treated in a Water Treatment Plant (WTP) at the western tunnel portal to manage water quality. The treated water will be reused, where applicable, to support construction (subject to water quality requirements).

Any separated pollutants will be held for collection by a licensed waste contractor. Provision has been made for the collection and treatment of water from the tunnel. The extent of treatment of the water from the tunnel will depend on the tunnelling technique adopted, along with the quality of the groundwater ingress.

Cuts

The groundwater quality of seepage to the cuts is expected to be brackish and slightly alkaline. The estimated inflow rate to cuts in rock during construction is low (less than 0.1 L/s) and, consequently, evaporative deposition of salt could occur on batters and at the base of cuts. This would be more severe where the salinity is higher at the cut location, e.g. cuts into a localised area of reduced groundwater quality downstream of headwaters, where connectivity with Quaternary aquifers is expected to decrease.

Seepage from cuts will likely report to cess drains, which are surface drains located to the side of the tracks.

14.7.4 Operational phase potential impacts

This section provides a discussion of the potential impacts on groundwater resources and related environmental values as a result of operation of the Project.

14.7.4.1 Water resources

The operational phase will include maintenance activities for key infrastructure, including the Toowoomba Range Tunnel and bridges and structures. Numerical modelling (refer Section 14.7.2) indicates there is long-term seepage from the cuts and tunnel, which can potentially cause operational phase impacts.

Dewatering

Predictive modelling of the Toowoomba Range Tunnel (refer Section 14.7.2) suggests the long-term (operational) groundwater inflow to the tunnel is expected to be 0.3 L/s and 0.0062 L/s to the intermediate ventilation shaft. The resulting groundwater drawdown was then assessed for each major unit (shallow MRV (typical value of hydraulic conductivity), deep MRV (high conductivity layer) and the Koukandowie Formation).

Figure 14.20, Table 14.21 and Table 14.22 present the operational groundwater drawdown extents. Registered groundwater bores and GDEs have also been included in the figures.

These preliminary drawdown extents are considered a base case. There is potential for increased conductivity and permeability in the fractured MRV and Koukandowie Formation, which, when assessed in predicted modelling uncertainty analysis, the groundwater seepage rates into the tunnel may be higher rates and increased drawdown extents than those discussed above. Sensitivity analyses scenarios, undertaken as a component of the predictive modelling, indicate that an increase of the hydraulic conductivity in the MRV by one order of magnitude (Scenario 2, Appendix N: Groundwater Technical Report) has the most significant impact and increases inflow to the western tunnel portal by 77 per cent.

The predicted impacts will be refined via updated modelling, as described in Section 14.7.2.2, for the Final EIS.

Loss or damage to existing landholder bores

There is a potential for existing landholder bores to be damaged, destroyed, or to become inaccessible during operation. Registered bores were identified in the groundwater study area, in Section 14.6.8.1.

Registered bores potentially impacted by groundwater level drawdown

After predictive modelling of the impacts of deep cuts and the Toowoomba Range Tunnel on groundwater resources (refer Section 14.7.1), the modelled impact area was assessed against licensed groundwater extraction bores and other registered bores, in order to identify the areas (real property) potentially impacted by the Project. This has been used to better understand the potential impacts on groundwater users.

The predicted drawdown extent for the shallow MRV is limited to the portals due to their drained design—there is no predicted groundwater drawdown in the deep MRV. Predicted drawdown for the Koukandowie Formation is limited to within approximately 400 m from the tunnel.

Existing registered bores within the operation-phase groundwater drawdown extents are to be decommissioned to enable construction of the Project and are not considered to be impacted by the operation of the Project.

Registered bores in the Project disturbance footprint

There are 16 existing registered bores in the operation footprint are summarised in Table 14.23. With the exception of the two bores (RN117110 and RN117104) located above the tunnel, these bores will be decommissioned during construction. The predicted groundwater level drawdown extent indicates these bores are not expected to be impacted during operation.

Modelling of vibration in the tunnel (refer Chapter 15: Noise and Vibration) predicts a low risk of the railway operations impacting underground infrastructures. Further assessment will be required during detailed design in response to design and operational changes, along with the assumptions around the model(s).

Unregistered bores

While the potential for the Project to impact on licensed groundwater extraction bores and registered bores has been assessed, there is potential for unregistered landholder bores to be present within the Project disturbance footprint and/or the predicted groundwater drawdown impact extent. Impacts are likely to be similar to those noted above for registered bores, based on depth (source aquifer) and proximity to predicted groundwater drawdown during operation.

Mitigation measures to prevent impact on such unregistered groundwater bores is presented in Section 14.8.

Groundwater dependent ecosystems and springs

The springs identified in Section 14.6.9 were mapped with the MRV drawdown extents, as the MRV is the primary source aquifer for springs in the groundwater study area. It is noted that no source aquifer is reported for the Helidon Spring (or anecdotally reported springs) just east of the alignment. The operational groundwater drawdown extent for the shallow and deep MRV unit does not include any springs.

There are no GDEs mapped within the long-term (operational) groundwater drawdown contours.

Embankments

There is a potential for raised groundwater levels due to long-term surface loading of alluvial soils from embankments and other constructions along the Project, where groundwater is shallow. Possible areas for compressible alluvial soils include localised portions of Gowrie, Oaky, Rocky, Six Mile and Lockyer creeks. 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. Further, the main watercourse crossings are via viaducts and bridges rather than embankments.

Bridge and viaduct pilings

Pilings may change groundwater flow patterns. Such changes would be very localised and small given the diameter and spacing of pilings compared to regional flow patterns. Long-term impacts on groundwater flow are not anticipated, given the spacing of the pilings for the Project and that all footings will be established above the high water bank.

Operation water supply

The tunnel requires potable water for operation and maintenance activities. The main identified potable water requirements for the tunnel are listed below:

- Tunnel Control Centre amenities (1 L/s)
- Fire water tanks infill (6 L/s for 24-hour refill)
- WTP (2 L/s to be confirmed)
- Tunnel washdown (unknown although assumed to be non-determining).

Potable water is to be sourced from the TRC water network, via a dedicated pipeline from the western tunnel portal to the water work at Hermitage Road. This is the nearest located with the required flow and pressure for the fire management system.

Groundwater that infiltrates into the tunnel will be captured and piped to the eastern tunnel portal, where the water will be treated and reused (e.g. landscaping) or discharged to the local receiving environment (i.e. an unnamed tributary of Rocky Creek).

Groundwater has not been considered as a potable water source during operation and, therefore, there are no potential groundwater impacts associated with operation water supply.

14.7.4.2 Water quality

There is potential for water quality impacts during operation as a result of the following:

- Oil and grease spills (potential for oil and grease from rollingstock to enter the waterways after heavy rainfall events without appropriate controls)
- Heavy metals from maintenance (including rail grinding and welding)
- Compounds leaching from ballast materials
- Accidental spills from freight carriages during routine operation
- Infrastructure impacts—with the introduction of bridge or culverts in waterways, should these structures fail, there is the potential for impacts to water quality either from potential contaminants (debris) or from detained water flushing from collapsed structures
- General maintenance—maintenance of the rail line or machinery near waterways has the potential to mobilise sediments from disturbed areas and increase the potential for litter or rubbish to enter waterways. Furthermore, oils and greases, and other contaminants such as metals, have the potential to enter waterways from spills, and for impact from the use of environmental toxicants (such as use of inappropriate biocides) to maintain operating infrastructure areas. These activities have the potential to impact nearby waterways, through discharge points without appropriate mitigation.

In the instance a spill or leak occurs from normal operational activities, the impact is likely to be superficial in nature and not expected to impact on shallow aquifers. Spill kits and environmental response equipment will be stored at areas of heavy plant, e.g. a repair shop or plant/equipment storage shed.

Toowoomba Range Tunnel

Groundwater quality of inflows to the Toowoomba Range Tunnel, and associated cuts during operation, is expected to be fresh to brackish, sodium-chloride dominant and neutral to slightly alkaline. Water quality values may vary seasonally due to rainfall infiltration diluting levels. Estimated long-term (operation) inflow rates for the tunnel and shaft is low (inflow to the tunnel is expected to be 0.30 L/s and 0.006 L/s to the shaft).

The water collected inside the tunnel during operation (groundwater seepage, storm water carry-in, wash-down, firefighting, etc.) will be collected through a common tunnel drain and stored in a sump at the eastern tunnel portal. This water will be processed through a WTP, which includes hydrocarbon and first-flush separation. The treated water may be used onsite (e.g. washdown or landscaping) or discharged to a tributary of Rocky Creek. The later will be dependent on the relevant WQO and EVs relevant the receiving environment, along with any imposed conditions (refer Chapter 13: Surface Water and Hydrology). The constant release of water into this tributary, Ch 10.4 km, will impact on the environmental values of this system (i.e. change a water course from ephemeral to perennial), refer to Appendix L: Surface Water for further discussion on this matter.

Groundwater inflow at the western tunnel portal will be directed to the surrounding receiving environment (unnamed tributary of Gowrie Creek (Ch 3.4 km)). The source of the groundwater is from the MRV, which is considered to be of good quality, reflective of the water uses as a town water supply and for domestic purposes; however, the volume of water will impact on the local environmental values (i.e. change a water course from ephemeral to perennial), refer to Appendix L: Surface Water for further discussion on this matter.

Cuts

The groundwater quality of seepage to the cuts is expected to be brackish and slightly alkaline. Estimated operation inflow rate for cuts is low (less than 0.1 L/s) and, consequently, evaporative deposition of salt could occur on batters and at the base of cuts. This would be more severe where the salinity is higher at the cut location, e.g. cuts into a localised area of reduced groundwater quality downstream of headwaters, where connectivity with Quaternary aquifers is expected to decrease.

Seepage from cuts will likely report to cess drains, which are surface drains located to the side of the tracks.

14.8 Potential mitigation measures

14.8.1 Design considerations

The mitigation measures presented in Table 14.28 have been incorporated into the Project design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues. These design measures are relevant to both the construction and operational phases of the Project.

TABLE 14.28 INITIAL MITIGATION—DESIGN

Aspect	Initial mitigation
Water resources	The Project will use part of the rail corridor identified under the *Gowrie to Grandchester Rail Corridor Study* (Queensland Rail and Queensland Transport, 2003). This rail corridor is identified as 'future state transport corridor'. The alignment (both lateral and vertical) has been designed to minimise earthworks, reducing the potential to impact water resources (e.g. dewatering of cuttings and embankment placement). The use of cuts and embankments have been minimised to maintain gradient, by use of bridges and viaducts, and to minimise impacts to existing surface hydrology. This reduces the risk of altering shallow groundwater levels and recharge patterns. Undrained tunnel design to limit groundwater ingress into the tunnel and ensure the existing groundwater surrounding the tunnel is not drawn down during operation of the tunnel.
Water quality	The disturbance footprint defined in Project design has aimed to minimise clearing extents to that required to construct and operate the works. During construction and operation, any water collected inside the tunnel (groundwater seepage, stormwater carry-in, wash-down, firefighting, etc.) will be collected and treated in a WTP at either the western tunnel portal or the eastern tunnel portal. The water will be reused for construction activities or discharged to the surrounding environment (including the potential for reinjection), depending on volumes and receiving water quality. The target water quality for discharge to the surrounding environment will be suitable to not impact on the existing quality. With additional baseline data, appropriate environmental values and WQOs will be confirmed. Maintenance activities, refuelling and other tasks with potential to be spilled or released to ground surface will only be carried out at select designated areas at an appropriate distance from surface water bodies and other sensitive receptors. In the event of a spill, the risk of impacting on shallow groundwater is reduced.

14.8.2 Proposed mitigation measures

In order to manage and mitigate Project impacts on groundwater, a number of additional mitigation measures have been proposed for implementation in future phases of Project delivery, as presented in Table 14.29. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, address legislative requirements, accepted government plans, policy and practice.

A groundwater management and monitoring program (GMMP) will be developed to provide ongoing assessment of the potential impacts identified in Section 14.7 and the effectiveness of the proposed mitigation measures in Table 14.29. The GMMP incorporates principles of performance assessment and adaptive management—a structured, iterative process of decision making. The GMMP will be assessed and updated after each phase of works to include a:

- Baseline GMMP
- Construction GMMP
- Operation GMMP

Each phase of the GMMP will be based on the subsequent outcomes of the previous phase.

TABLE 14.29 PROPOSED MITIGATION MEASURES RELENT TO GROUNDWATER RESOURCES AND QUALITY

Delivery phase	Aspect	Proposed mitigation measures

Detailed design	Interaction with groundwater by elements of the Project	▸ Investigate solutions to reduce the volume of groundwater inflow at the western tunnel portal and, where applicable, the tunnel, during construction and operations:
		  ▸ Probe drilling ahead of the tunnel face
		  ▸ Identification of high permeability features
		  ▸ Installation of grout curtains
		  ▸ Use of gaskets in areas of high inflow to minimise seepage to the tunnel
		  ▸ Tanking of the western portal below the average groundwater table.
		▸ Continue to work with DRDMW regarding the groundwater impacts from the different phases of the Project, to ensure the correct approval pathways are implemented and that the necessary data is available to inform a decision under the Water Act (e.g. groundwater modelling and measures to mitigate impairment to bores)
		▸ Further geotechnical and hydrogeological investigations will be undertaken in parallel to the detailed design process to ensure site-specific conditions are reflected in the final design solution. Investigations will be targeted to specific locations, such as:
		  ▸ Toowoomba Range Tunnel, portals, and shaft
		  ▸ Deep cut sections
		  ▸ Locations of significant fill
		  ▸ Fault/dyke/fracture structures
		  ▸ Koukandowie Formation of the Marburg Subgroup, WCM, and colluvium deposits, to better understand the hydraulic conductivity
		▸ Additional aquifer permeability tests are ongoing prior to final design, to understand the structural elements, hydraulic connectivity between units, and aquifer characteristics (compartmentalisation) that may result in cut/tunnel inflow seepage rates higher than expected, increased regional or localised groundwater drawdown and/or impacts on EVs. Specifically, to continue collection and assessment of baseline groundwater monitoring data (levels and quality) along the tunnel alignment to confirm seasonal variation and inform detailed design (groundwater levels) and the WQOs for the GMMP. There is limited local data along the Toowoomba Range Tunnel aspect—groundwater levels in the Marburg Subgroup/Koukandowie Formation may be higher than estimated. Additional monitoring bores along the tunnel alignment (~400 m intervals) and at every cut identified to intersect groundwater and inclusion into the baseline monitoring program (levels and quality) will establish groundwater levels prior to final design (and may identify perched aquifers). Continuous collection of groundwater levels in monitoring bores along the tunnel alignment, at each cut location anticipated to intersect groundwater, will allow for assessment of recharge rates, to better understand the hydrogeological regime's response to large rainfall events in highly conductive zones. This data will limit risks to over/under designing the tunnel and cuts.
		▸ Site inspections of proposed cut locations will be conducted to visually examine surface outcrops for sulfide minerals or remnant products indicative of sulfide mineralisation. This would inform the need for management of potential ARD from cuttings in sedimentary units prior to construction works.
		▸ Predictive numerical modelling will be refined using additional information obtained from further geotechnical and hydrogeological investigations, and updates to the sensitivity analyses and hydraulic conductivity parameters, in addition to finalised cut dimensions. This revised modelling will be completed for the Final EIS to better understand seepage estimates and groundwater level variation, resultant from the tunnel, portals and cuts. Seepage analysis will be used to advise of construction of the tunnel, drainage blanket specifications, or alternative design controls, for deep cuts into hard rock.

Delivery phase	Aspect	Proposed mitigation measures
Detailed design [continued]	Interaction with groundwater by elements of the Project [continued]	▸ As an outcome of baseline groundwater monitoring and predictive modelling, confirm the water treatment facility required for the construction and operation of the Project (source relevant approval where applicable) ▸ Investigate measures to harvest the groundwater inflow during construction for reuse by the Project (currently estimated to 2.5x the volume required for construction) or by other projects in the area. Alternatively, consult with DES and DRDMW regarding the release of the water into the surrounding environment.

	Impacts to bore users	▸ Undertake a landholder bore survey to verify the number of bores within, and directly adjacent to, the Project disturbance footprint, bores above the Toowoomba Range Tunnel and, where applicable, the drawdown extents modelled for the Project. The survey may include a bore assessment with due consideration of the Queensland Government's Guideline Bore Assessments (Queensland Government, 2017). The assessment will aim to:
		  ▸ Provide a measure of security for ARTC and the bore owners by providing information about the current condition and pumping capacity for a water bore
		  ▸ Provide a reference point for comparison with subsequent bore assessments to assist in the negotiation of make-good arrangements and assist in the development of groundwater data modelling
		▸ Assist in resolution of any future disputes that may arise between bore owners and ARTC following a bore assessment or in the negotiation of a make-good arrangement. Landholders affected by the Project will be consulted to confirm the location of registered bores and to establish the presence of any unregistered bores in 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 landholder and may include monetary compensation developed on a case-by-case basis.
		▸ Procure access agreements to existing registered groundwater bores included in the GMMP (refer Table 14.30).

	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, specifically DRDMW Water Services, 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 impacted by the Project. Sources of construction water will be finalised as the construction approach is refined during the detailed 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 landholders under private agreement
		  ▸ Confirmation of access agreement with local governments for sourcing of mains water.
		▸ 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. Discussions with private water owners may include an accompanying officer from DRDMW Water Services and amendments to existing water authorisations.

Delivery phase	Aspect	Proposed mitigation measures

Detailed design [continued]	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 detailed design process, in accordance with the Baseline GMMP (refer Section 14.8.3.1). 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. Continuous and repeated quality sampling of groundwater along the portals, tunnel and deep cuts will provide site-specific quality with respect to magnesium, dissolved oxygen (DO), calcium concentrations, groundwater aggressivity and scaling potential, prior to final design.
		‣ Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines, such as *Monitoring and Sampling Manual* (DES, 2018a) 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 14.8.3.1). 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 future revisions of the GMMP, which will be subject to approval from DRDMW and DES prior to implementation.
		‣ A Contaminated Land Management Sub-plan will be developed and incorporated into the Construction Environmental Management Plan (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 (refer Chapter 9: Land Resources)
		‣ Confirm that groundwater inflow at the western and eastern tunnel portals can meet the relevant WQO for discharge into the surrounding environment without treatment. If treatment is required, confirm the nature of the treatment and use of the treated water and waste material.
		‣ Refine the design of the WTP, including the target water quality of treated water disposal, based on additional groundwater quality (baseline) data.

Pre-construction	Impacts to bores	‣ There are 16 registered bores in the Project footprint for the reference design, two of which are located above the Toowoomba Range Tunnel. With the exception of the bores above the tunnel, these bores, plus unregistered bores that also occur in the Project footprint, are likely to be decommissioned for the progression of the Project. Bores identified within the construction footprint will be decommissioned in accordance with the *Minimum Construction Requirements for Water Bores in in - Edition 4* (National Uniform Drillers Licensing Committee, 2020). 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 landholder and may include monetary compensation developed on a case-by-case basis. ‣ Confirm vibration impacts to existing registered bores that are not planned to be decommissioned (refer Table 14.25). The high-risk bores are RN107110 and RN107104 (above the Toowoomba Range Tunnel). The construction team will need to undertake vibration monitoring to assess whether the vibration from the works meet the criteria.
	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).

Delivery phase	Aspect	Proposed mitigation measures
Pre-construction [continued]	Groundwater quality	▸ Confirm the construction methodology for the tunnel including measures to capture and treat groundwater inflow into the tunnel. Where applicable, confirm whether the groundwater can be reused (treated or untreated) onsite for other activities or whether the water can be discharged to the surrounding environment (e.g. tributary of Gowrie Creek) or the water is to be managed and disposed of as wastewater.
Construction	Water resources	▸ The Construction GMMP will be implemented (refer above and Section 14.8.3.2) ▸ Opportunities to re-use/recycle water during construction will be identified and implemented where feasible ▸ Implement the relevant measures agreed with the individual bore owners regarding make-good measures ▸ Continue to engage with the community and the bore owners regarding the construction schedule; in particular, the tunnelling activities.
	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 in 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 onsite chemical- and hydrocarbon-absorbent socks/booms and spill kits. ▸ 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).

Delivery phase	Aspect	Proposed mitigation measures
Construction [continued]	Groundwater quality [continued]	▸ 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 materials in 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* (Standards Australia, 2006a) ▸ AS 1940:2017 *Storage and Handling of Flammable and Combustible Liquids* (Standards Australia, 2017) ▸ AS 3780:2008 The *Storage and Handling of Corrosive Substances* (Standards Australia, 2008) ▸ 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 onsite 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 that is suspected to contain sulfides will be stockpiled, lined and covered, and managed, to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to offsite 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 (Appendix T: Spoil Management Strategy).
	Encountering PASS and/or ARD	▸ All excavated material that is suspected to contain sulfides will be stockpiled, lined and covered, and managed, to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse is preferred to offsite 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 (refer Appendix T: 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 onsite 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	Proposed mitigation measures
Operation	Impacts to 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 14.8.3.3). The need for monitoring during operation will be informed by groundwater observations and data collected during construction of the Project.

	Groundwater quality	▸ Before a train travels on the Inland Rail network, operators must make sure that the classes of dangerous goods, and the identification numbers of vehicles carrying dangerous goods, are recorded in the train consist documentation. Dangerous goods must be loaded, labelled, and marshalled in accordance with the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (National Transport Commission, 2018).
		▸ Groundwater infiltration into the Toowoomba Range Tunnel, and associated ventilation shaft, will be captured and treated in the WTP at the eastern tunnel portal, prior to release, in accordance with relevant approval conditions
		▸ Potential deep-cut seepage water will be monitored and discharged in accordance with the Surface Water Sub-plan, as confirmed during detailed design
		▸ Groundwater quality will be monitored in accordance with the Operation GMMP, assessed against trigger and threshold levels, and contingency measures followed (as required)
		▸ 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. These procedures will be in accordance with ARTC's *Work Instruction for Chemicals* (WHS-WI-214) and *Emergency Management Plan* (RLS-PR-044) (available on ARTC's extranet).
		▸ The ARTC's *Work Instruction for Chemicals* (WHS-WI-214) will be applied for all maintenance activities requiring the transport of dangerous goods within the rail corridor. The Work Instruction includes the following control measures to reduce the risk associated with dangerous goods storage:
		  ▸ Where practical, dangerous goods must be transported in their original packaging and stored separately from one another on the vehicle, specifically detonators
		  ▸ All dangerous goods must be adequately restrained within the vehicle's confines to prevent movement during transit, e.g. gas bottles restrained to headboard or in designated ventilated storage compartments
		  ▸ The combined (aggregate) quantity of dangerous goods must not exceed 1,000 L or kg
		  ▸ Any individual receptacle used for transporting dangerous goods must have capacity less than 500 L or kg, or dangerous goods licencing for both the vehicle and driver will apply
		  ▸ All vehicles carrying mixed loads of dangerous goods must display the appropriate mixed class placard at least on the front and rear of the vehicle
		  ▸ The vehicle must be fitted with appropriate safety equipment for the load, as per ARTC operation procedures, including double-sided triangle reflector signals, fire extinguisher(s) and personal protection equipment.

	Water resources	▸ Groundwater levels will be monitored in accordance with the Operation GMMP, assessed against trigger and threshold levels, and contingency measures followed (as required).

The program will establish groundwater sampling locations, frequency of sampling and the analytical program. Roles and responsibilities will be set out to clearly establish the review and approval process that will be used to evaluate the data collected as part of the monitoring program.

The baseline (background) groundwater monitoring program will be ongoing so as to account for natural (seasonal) or anthropogenic fluctuations of groundwater levels prior to construction. This is pertinent for the alluvial sediments, in particular, as the water levels in these sediments are key to the design, construction and operation of the Project.

In addition, the baseline groundwater level dataset will allow for identification of outside influences on groundwater levels. This information is important to capture to allow for discernibility between the impacts of the Project and those from non-Project influences.

Details of the GMMP are presented in Section 14.8.3 and includes an indicative monitoring network (to be finalised post-EIS).

14.8.2.1 Groundwater bore impairment

It is recognised that requirements for make good agreements are well described under Part 3 of the Water Act for the mining and coal seam gas industry but are unclear for a Project of this nature; however, ARTC are proposing to adopt some of the make-good obligations under the Act to ensure that the bore holder is properly compensated for any impacts from the Project and that any impairment caused by the Project is 'made good'.

The measures will be on a case-by-case basis and will be confirmed during detailed design, once the construction and design is confirmed, with the groundwater model to be updated to reflect any changes to the construction methodology and design, along with the detailed geotechnical data, groundwater monitoring data and the bore assessment data. Any required legal agreements, along with securing relevant water authorisations for the Project, which may trigger the requirements for make-good measures and/or as a result of these measures will also be confirmed during detailed design.

Scenarios where 'make good' arrangements may be required include:

- There are 14 registered bores in the Project disturbance footprint and the compensation for the loss of these assets will be determined on a case-by-case basis as part of the land acquisition process, to be undertaken by the constructing authority. This process would also apply to any unregistered bores in the Project disturbance footprint. The drilling of a new bore would be the responsibility of the landholder, including any required approvals under the Water Act for the works; noting that water licences will automatically expire as a result of the land acquisition process, as the licences are linked to a land parcel, with the landholder having up to 60 days to reinstate the water licence.
- Where the Project severs direct access to a registered or unregistered bore (or other water infrastructure) compensation may also be sought as part of the land acquisition process; alternatively, where the impact is temporary, ARTC may provide alternative water supply
- The Project changes the integrity of a registered or unregistered bore as a result of the construction and/or operation of the borehole (e.g. due to vibration). ARTC will work with the impacted landholder to rectify the issue, including changes to the work program or providing compensation for the reconditioning of the water bore to improve its hydraulic efficiency, or the drilling of a new bore. It should be noted that, based on the current vibration modelling, no bores are likely to be impacted, with the Project meeting the desired criteria (25 mm/s) at a setback distance of 5 m.

In addition to above, there is the potential for the Project to impact groundwater users because of groundwater drawdown (refer Section 14.7.2.1). ARTC plan to make-good impairments (e.g. water level decline impairing the bore's ability to provide a reasonable quantity or quality of water for the bore's authorised use or purpose) resulting from the construction and/or operation of the Project, on a case-by-case basis.

Measures to ensure that a bore owner has access to a reasonable quantity and quality of water for the water bore's authorised use or purpose vary, with the likely scenario being compensation (monetary or otherwise) for the bore's impaired capacity.

ARTC is proposing a threshold level of 5-m drawdown for consolidated aquifers and 2-m drawdown for unconsolidated aquifers, which aligns with Part 3 of the Water Act. Based on the 5-m drawdown threshold, a total of 20 registered bores are located in the construction drawdown extents, while only 10 are in the operation drawdown extents (though none of these bores are within the Koukandowie Formation).

A landholder bore survey is planned as part of the Project (refer Appendix F: Proponent Commitments) which will aim to verify the number of bores within, and directly adjacent to, the Project disturbance footprint, bores above the

Toowoomba Range Tunnel and, where applicable, the drawdown extents modelled for the Project (refer Section 14.7.2.1).

The survey requirements will be confirmed during detailed design and, where necessary, in consultation with DRDMW.

The bore assessment will be undertaken with due consideration of the Queensland Government's *Guideline Bore Assessments* (Queensland Government, 2017). The assessment will aim to:

- Provide a measure of security for ARTC and the bore owners by providing information about the current condition and pumping capacity for a water bore
- Provide a reference point for comparison with subsequent bore assessments to assist in the negotiation of make-good arrangements and assist in the development of groundwater data modelling
- Assist in resolution of any future disputes that may arise between bore owners and ARTC following a bore assessment or in the negotiation of a make-good arrangement.

The outcome of the assessment, including whether or not the bore is impaired as a result of the Project will be provided to the landholder and, where applicable, the relevant government agencies. If the bore assessment shows that the Project has not materially contributed to the impairment of the bore, a make good is not required.

14.8.3 Groundwater management and monitoring program

The GMMP provides for an ongoing assessment of the potential groundwater impacts discussed in Section 14.7. The GMMP incorporates principles of performance assessment and adaptive management; a structured, iterative process for decision making. The GMMP will be dynamic to ensure the network will allow for validation of the updated predictive groundwater model.

The GMMP will be assessed and updated in consultation with DRDMW 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 in Figure 14..

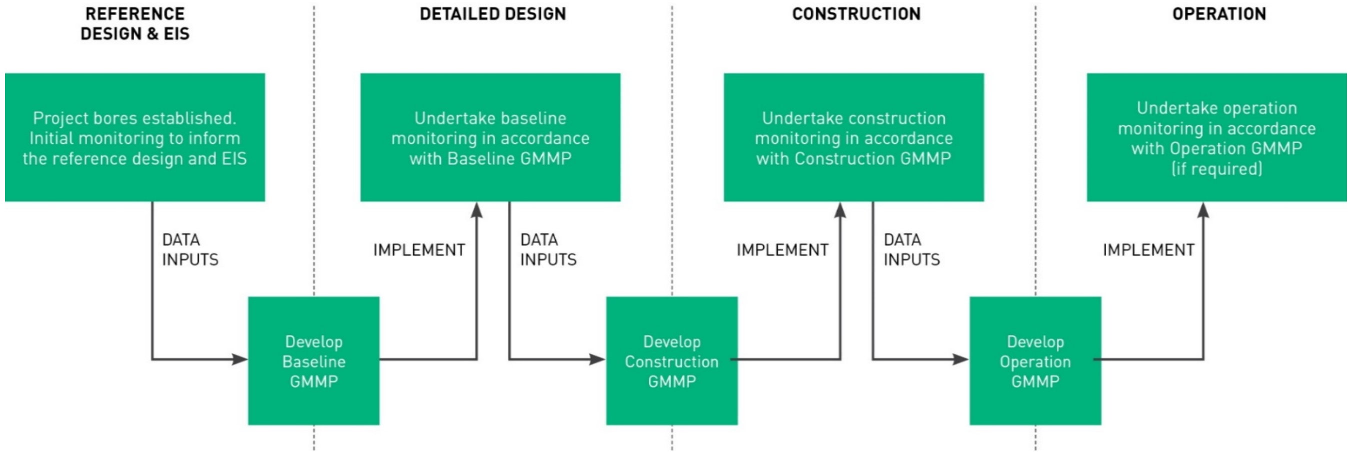

FIGURE 14.24 DEVELOPMENT AND IMPLEMENTATION OF THE GROUNDWATER MANAGEMENT AND MONITORING PROGRAM OVER SEQUENTIAL PROJECT PHASES

14.8.3.1 Baseline Groundwater Management and Monitoring Program

The Baseline GMMP's primary objective is to develop a robust and comprehensive 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 and groundwater-level thresholds. The baseline GMMP will be developed and implemented during the detailed 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.

An indicative network of monitoring bores for the baseline GMMP is summarised in Table 14.30. The indicative network is subject to landholder negotiations and access, and will be refined during the detailed design phase. As noted in Section 14.5.2.2, another nine groundwater monitoring bores were established along the Toowoomba Range Tunnel, with these bores to be also included as part of the GMMP. Data loggers were also installed in the monitoring bores, with the bores associated with the tunnel linked to a telemetry station. Groundwater monitoring of these bores will be ongoing, with a second round of monitoring occurring in January 2021.This data will inform baseline conditions along the tunnel alignment that will assist to refine the predicted groundwater inflow volumes and the quality of the water and required level of treatment, if any.

Groundwater monitoring is currently focused on the nine monitoring bores above the tunnel with the program to be expanded in consultation with DRDMW, subject to access agreements, once the groundwater model is refined.

If bores specified in Table 14.30 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 better understand the heterogeneity of the MRV aquifer. Further, additional monitoring bores along the tunnel alignment will establish groundwater levels to inform the final design (and may identify perched aquifers). The indicative monitoring bore network will be re-assessed on completion of refinement of the predictive model to ensure the network is comprehensive such that predicted impacts, along with early warning monitoring points, can be identified prior to construction.

The baseline dataset will be compiled, and the Construction GMMP developed, based on this information, prior to commencement of the construction of the Project. There is sufficient time prior to construction of the tunnel commencing to collect a robust baseline dataset to inform WQO and future groundwater monitoring activities, along with the design of any proposed water treatment measures for both construction and operations (e.g. swales, water treatment plant).

The Baseline GMMP may also incorporate bores where drawdown has been predicted to occur (i.e. the bore assessment).

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

TABLE 14.30 INDICATIVE MINIMUM GROUNDWATER MONITORING NETWORK

Project feature	Chainage (km)	Length (m)	Maximum depth (m)	Bore	Bore screened aquifer	Screened depth top (m)	Screen depth bottom (m)	Reason for monitoring
Bores within predicted impact areas								
320-E1	-1.76	1,180	2.6	RN94161	Marburg Subgroup	101	133	Predicted rise in groundwater level (refer Section 14.7.3.1)
320-E2	-0.34	2,560	3.2	RN56783	MRV	22.5	24.4	
320-E3	2.33	1,280	3.7	RN56783	MRV			
Western portal cut (320-C3)	3.61	490	21.6	RN66497	Marburg Subgroup	43	49	Predicted seepage/drawdown (refer Section 14.7.2.3)
				RN71234	Marburg Subgroup	63	68	
				RN172858 (BH2103)	MRV	14	20	
				BH2101	Koukandowie Formation	105	117	
Eastern portal cut (320-C4)	10.34	60	15.5	RN173879 (BH2103)	Koukandowie Formation	17	26	
				BH2102	MRV	VWP		
320-C5	10.57	310	23.5	RN173879 (BH2103)	Koukandowie Formation	17	26	Predicted seepage (refer Section 14.7.2.3)
320-C6	11.16	430	31.6	RN173879 (BH2103)	Koukandowie Formation	17	26	
				BH2201	Koukandowie Formation	14	20	
320-C9	14.07	30	23.1	BH2203	Koukandowie Formation	12	20	
320-C10	14.33	1,390	28.5	RN173875 (BH2301)	Koukandowie Formation	11	20	
				BH2203	Koukandowie Formation	12	20	
320-C11	17.56	260	45.7	RN106018	Unknown	Not reported	Not reported	
320-C12	19.41	260	29.4	BH2209	Gatton Sandstone	14	35	
Toowoomba Range Tunnel	4.10	6,240	NA	RN107110	MRV	15	30	Predicted seepage/ drawdown (refer Section 14.7.2.3)
				RN107104	MRV	14	35	

Project feature	Chainage (km)	Length (m)	Maximum depth (m)	Bore	Bore screened aquifer	Screened depth top (m)	Screen depth bottom (m)	Reason for monitoring
Bores within predicted groundwater level drawdown extent								
Intermediate ventilation shaft (predicted impact at elapsed 62 weeks)	6.83	NA	100	RN119498	MRV	52	67	Predicted groundwater level drawdown due to the shaft (refer Section 14.7.2)
				RN107104	Unknown	14	35	
				RN38619	MRV	6.4	79.9	
				RN94668	MRV	24	30	
				RN94669	MRV	12	30	
				RN172057	MRV	37	49	
				RN172118	MRV	48	64	
				RN38341	MRV	6.4	49.4	
Toowoomba Range tunnel (predicted impact at elapsed 107 weeks)	4.10	6,240	NA	RN172088	MRV	25	31	Predicted groundwater level drawdown in the deep MRV (refer Section 14.7.2)
				RN 172183	MRV	84	95	
				RN 172086	MRV	24	30	
				RN 172087	MRV	30	36	
				RN 64098	MRV	110		Possible groundwater level drawdown in the Koukandowie Formation (refer Section 14.7.2)
				RN 172088	MRV	25	31	
				RN 172086	MRV	24	30	
				RN 172087	MRV	30	36	
				RN 172182	MRV	72	83	
				RN 172183	MRV	84	95	
				RN 94667	Unknown	12	30	
				119497	MRV	10	40	
				119852	Helidon Sandstone	564	657	
Project bores (operated by ARTC)								
320-E10	15.72	1,840	33.7	BH2207	Koukandowie Formation	7	10	Project bores
320-E14	20.66	110	13.9	BH2212	Gatton Sandstone	11.4	20.9	
320-E14	20.66	110	13.9	BH2215	Gatton Sandstone	11	20	
320-E14	20.66	110	13.9	BH2216	Gatton Sandstone	14	20	
320-E14	20.66	110	13.9	BH2217	Gatton Sandstone	11.5	20.5	
320-E14	20.66	110	13.9	BH2218	Gatton Sandstone	14	20	

Project feature	Chainage (km)	Length (m)	Maximum depth (m)	Bore	Bore screened aquifer	Screened depth top (m)	Screen depth bottom (m)	Reason for monitoring
Optional additional bores within the construction footprint								
Bridge	12.3	N/A	N/A	RN106596	Marburg Subgroup	11	88	Registered bores within construction footprint
Bridge	21.5	N/A	N/A	RN173154	Gatton Sandstone	127	139	
Bridge	23.6	N/A	N/A	RN75289	Helidon Sandstone	21.3	43.9	
Bridge	23.9	N/A	N/A	RN75335	Helidon Sandstone	12.8	37.8	

Groundwater level monitoring

Groundwater levels for bores in the indicative minimum monitoring network are to be monitored using automated pressure transducers (groundwater level loggers), to record measurements at least every six hours. This is particularly required to establish the baseline groundwater dataset from which potential impacts can be assessed and threshold levels developed for the construction and operation of the Project.

Data loggers were installed in the monitoring bores along the tunnel as part of the recent geotechnical investigations, with the bores linked to a telemetry station.

Manual measurements on all bores in the indicative minimum monitoring network is proposed monthly during establishment of the baseline dataset to allow for quality control checks against the pressure transducers, as this will be the basis for comparison for the Project. Pressure transducer data will be downloaded on a bimonthly basis, during the baseline monitoring program, 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 MRV aquifer, as the water levels in this unit are key to the design, construction and operation of the Project, and 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. It is important to capture this information 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, which will include groundwater level drawdown thresholds for construction.

Groundwater quality monitoring

Groundwater quality samples will be collected from bores in the indicative monitoring network on a bimonthly basis to coincide with the groundwater level monitoring program (refer Section 14.8.3). 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 TDS
- Major anions (bicarbonate, chloride, sulfate)
- Major cations (calcium, magnesium, sodium, potassium and silicon)
- Dissolved and total metals (aluminium, arsenic, boron, cadmium, chromium, copper, manganese, lead, nickel, selenium, molybdenum, silver, zinc, iron, and mercury)
- Nutrients (ammonia, nitrite, nitrate, total nitrogen, total phosphorus).

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 used 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, 2018a) 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.

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.

14.8.3.2 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 14.7. 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, as appropriate. For example, where construction activities are surficial in nature and localised, monitoring of deep aquifers may not 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 aim of the monitoring will be to ensure that the relevant WQOs are being met (in tunnel and in the local groundwater network) and that the proposed treatments are sufficient. The Construction GMMP will also aim to verify the predictive groundwater modelling through the monitoring of landholder bores within the relevant groundwater extents (refer Section 14.7.2.1); alternatively, the Construction GMMP will have protocols to undertake monitoring in response to landholder complaints.

The surface water monitoring program for the Project will be used to inform and complement 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 the construction phase, this may trigger a groundwater sample to be procured from the local alluvial aquifer to inform of any impacts. If surface water quality results are within/below acceptable values, however, sampling of the alluvial aquifers in this area may not be warranted—construction-task, WQO-, and residual-significance dependent.

14.8.3.3 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.

The Operation GMMP will also aim to verify the predictive modelling that currently predicts drawdown impacts within the Koukandowie Formation, along the tunnel alignment between Boundary Street and the New England Highway, and at the eastern tunnel portal (refer Figure 14.); noting that there are no bores in the predicted drawdown extents for the Koukandowie Formation aquifer. No long-term impacts are predicted on the shallow and deep MRVs during operations.

14.9 Impact assessment

As discussed in Section 14.5.4, a qualitative impact assessment using the significance assessment approach has been adopted for evaluating potential impacts to groundwater resources from the Project, as described in Section 14.7. A summary of the significance assessment is provided in Table 14.31.

For each of the potential impacts discussed in Section 14.7, the initial significance assessment was undertaken on the assumption that the design considerations (or initial mitigation) factored into the design phase (refer Table 14.31) have been implemented.

TABLE 14.31 SIGNIFICANCE ASSESSMENT SUMMARY FOR GROUNDWATER

Potential impact	Phase	Initial significance[1]			Application of proposed mitigation measures presented in Table 14.29, by aspect[2]	Residual significance[3]	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Loss of registered and potentially unregistered bores (through destruction or loss of access)	Construction	Moderate	Moderate	Moderate	Water resources (preconstruction and construction)	Low	Low
	Operations		Moderate	Moderate		Low	Low
Altered groundwater levels (increase or decrease) affecting groundwater users (bores and GDEs) due to embankments and seepage to cuts/portals	Construction	High	Moderate	High	Water resources (detailed design, preconstruction, construction)	Moderate	Moderate
	Operations		Low	Moderate		Moderate	Moderate
Subsidence/consolidation due to groundwater extraction, dewatering/seepage or loading	Construction	Moderate	Moderate	Moderate	Water resources (detailed design, preconstruction, construction) Water quality (preconstruction)	Low	Low
	Operations		Low	Low	-	Low	Low
Reduced groundwater levels affecting groundwater users (bores and GDEs) due to the Toowoomba Range Tunnel	Construction	High	Moderate	High	Water resources (detailed design, preconstruction, construction)	Moderate	Moderate
	Operations		Low	Moderate		Moderate	Moderate

Potential impact	Phase	Initial significance[1] Sensitivity	Initial significance[1] Magnitude	Initial significance[1] Significance	Application of proposed mitigation measures presented in Table 14.29, by aspect[2]	Residual significance[3] Magnitude	Residual significance[3] Significance
Contamination or water quality degradation of groundwater resources requiring remediation from spills or induced flow, bore hole intersections. Upwards leakage along pile/soil interfaces	Construction	Moderate	High	High	Water quality (detailed design, preconstruction, construction)	Moderate	Moderate
	Operations		Low	Low	-	Low	Low
Acid rock drainage (ARD) from cuts and tunnel impacts on environmental values (i.e. GDEs)	Construction	Moderate	Moderate	Moderate	Water quality (preconstruction, construction)	Low	Low
	Operations		Low	Low	-	Low	Low
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Construction	Moderate	Moderate	Moderate	Water resources (preconstruction)	Low	Low
	Operations		Low	Low	-	Low	Low

Table notes:

1 Includes implementation of initial mitigations specified in Table 14.28

2 Proposed mitigation and controls, as identified in Table 14.29

3 Assessment of residual significance once the initial and additional mitigation measures have been applied.

Proposed mitigation measures, including those listed in relevant sub plans (including the GMMP), were then applied, as appropriate, to the relevant phase of the Project to reduce the level of potential impact, and are detailed in Section 14.8.

The residual significance level of the potential impacts was then reassessed after mitigation and management measures were applied. The pre-mitigated significances were compared to the residual significance for each potential impact on groundwater values, to assess the effectiveness of the mitigation and management measures.

14.9.1 Temporary impacts

Many of the potential impacts with respect to groundwater are considered temporary in nature and associated with the construction phase of the Project, with the likelihood of a material impact on current groundwater conditions and users considered to be moderate (loss of registered bores, groundwater level decreases due to dewatering for construction) to low (groundwater flow patterns).

Final construction design, engineering controls and monitoring are generally considered to adequately mitigate potential impacts to groundwater; however, it is noted that additional investigations and assessment of potential drainage/dewatering impacts associated with the Toowoomba Range Tunnel and deep-cut sections are proposed to further refine the current models and knowledge of the local hydrogeology (as described in Appendix N: Groundwater Technical Report) and inform detailed design. Additional geotechnical and hydrogeological investigations have been completed with the data to be used to verify and/or further inform the models, the EIS and the design, when available.

14.9.2 Long-term impacts

The main potential long-term impacts identified beyond the construction stage are:

- Changes to groundwater levels and flow, associated with groundwater mounding near embankments and ongoing dewatering/draining of the Toowoomba Range Tunnel, and deep cuts
- Management of discharge from dewatering/drainage of the tunnel and deep cuts
- Final construction design, engineering controls and monitoring are generally considered to adequately mitigate potential impacts to groundwater; however, additional investigations and assessment is proposed to further refine current understanding (as described in this groundwater technical report) and inform final design, with respect to:
  - Potential drainage/dewatering impacts of the tunnel and deep cuts
  - Potential loading impacts near significant embankments.

14.9.3 Cumulative impacts

Cumulative impacts are the successive, incremental and combined impacts of an activity when added to other existing or planned projects and activities (World Bank International Finance Corporation, 2013). For the Project, a CIA was undertaken where potential groundwater impacts of the Project were assessed together with existing or planned surrounding activities (as outlined in Section 14.9.3.1). Cumulative impacts to groundwater are most likely to occur where multiple projects intersect and/or take groundwater from the same aquifer units.

There are 18 existing registered bores within the predicted construction phase drawdown groundwater extent (62 weeks is the maximum drawdown for shaft construction (3 bores) and 107 weeks is the maximum drawdown during tunnel construction (15 bores)), as included in Table 14.24; however, predicted drawdown extents are highly localised. There are no registered groundwater bores within the predicted operational groundwater drawdown area.

For a full assessment of cumulative impacts refer Chapter 22: Cumulative Impacts.

14.9.3.1 Surrounding projects and timeline relationships

Projects and operations surrounding the groundwater study area are depicted on Figure 14.. Due to the localised potential groundwater impacts associated with the alignment, only applicable projects and operations (with potential impacts on groundwater) in Table 14.32 have been considered for this CIA. Other projects are considered too distant compared to the localised nature of potential groundwater impacts, and/or the scope of the surrounding projects were such that there is negligible potential to impact on groundwater.

TABLE 14.32 APPLICABLE PROJECTS AND OPERATIONS CONSIDERED FOR THE CUMULATIVE IMPACT ASSESSMENT

Project and proponent	Location	Description	Project status	Timeline	Relationship to the Project
NSW/QLD Border to Gowrie (ARTC)	Rail alignment from NSW/QLD Border to Gowrie	▶ 216 km single-track freight railway as part of the ARTC Inland Rail Program ▶ Establishment of approximately 145 km of new rail corridor and use of approximately 71 km of existing rail corridor ▶ Construction of rail infrastructure, culverts, bridges, viaducts and crossing loops ▶ Five crossing loops, each 2,200 m in length ▶ Ancillary works including road and public utility crossings and realignments.	EIS being prepared by ARTC	Construction: 2021 to 2026 Operation: >50 years	Potential overlap of construction finalisation of B2G and commencement of G2H
Helidon to Calvert (ARTC)	Rail alignment from Helidon to Calvert	▶ 47 km single-track dual-gauge freight rail line to accommodate double-stack freight trains up to 1,800 m long ▶ 850 m tunnel through the Little Liverpool Range ▶ Construction of rail infrastructure, culverts, bridges, viaducts and crossing loops ▶ Connection to the existing West Moreton System railway Line ▶ Ancillary works, including road and public utility crossings and realignments.	EIS being prepared by ARTC	Construction: 2021 to 2026 Operation: >50 years	Potential overlap of construction finalisation of G2H and commencement of H2C
Defence Housing Australia Mount Lofty Development	Mount Lofty	▶ Former rifle range redeveloped into a master-planned residential community comprising of 342 lots. Some lots will be retained by DHA, on which homes will be built for Defence members and their families, with remaining lots available for public purchase.	Lodged DA on 12 June 2018 (DA reference number MCUI/2018/2861) and is a controlled action (EPBC referral (2018/8198))	Currently on hold	Potential groundwater drawdown impacts. The 5 m drawdown extent within the deep MRV and Koukandowie Formation during construction is approximately 1 km from the western boundary of the proposed development.

Project and proponent	Location	Description	Project status	Timeline	Relationship to the Project
InterLinkSQ	Global Logistics Centre and Industrial Park	- 200 hectares of land area - 24-hectare intermodal facility with rail, hardstand and industrial land - 24/7 operations with residential buffers - Zoned medium impact industry - Intermodal, transport, logistics and warehousing	Approval has been granted for the development	2017 to 2037	The development is located at Ch 1.0 km. There is limited potential for impacts at this location as there is no proposed tunnelling or cuts.
Asterion Medicinal Cannabis Facility	Wellcamp, Queensland	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	The development adjoins the Project footprint 1 km south of Toowoomba–Cecil Plains Road. The source of the water supply for the facility is unable to be confirmed. The projected size of the facility is anticipated to require large volumes of water that, if sourced from bores/municipal supplies that draw from the Water Plan (Condamine and Balonne) 2019, may overlap with the Project.

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

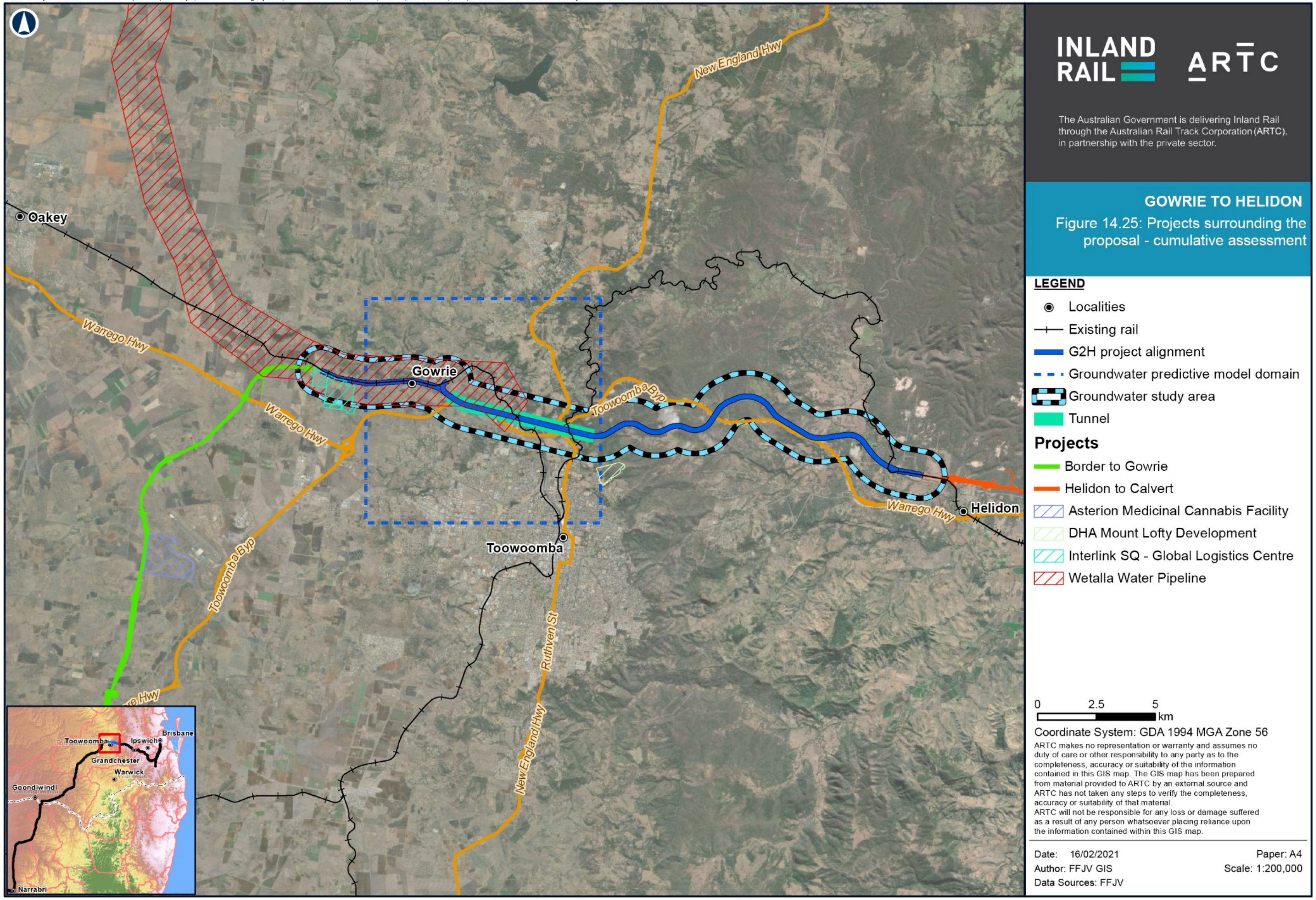

Figure 14.25: Projects surrounding the proposal - cumulative assessment

Map by: NCW/MEF/DTH/MF/GN Z:\GIS\GIS_3200_G2H\Tasks\320-EAP-201909051619_G2H_Groundwater_Figures\320-EAP-201909051619_ARTC_Fig14.27_Cumulative_v7.mxd Date: 16/02/2021 08:27

14.9.3.2 Assessment of potential cumulative impacts

Cumulative impacts to groundwater would most likely occur where multiple projects intersect and/or abstract groundwater from the same shallow aquifer units. Key cumulative impacts for consideration are provided in Table 14.33.

TABLE 14.33 SUMMARY OF POTENTIAL CUMULATIVE IMPACTS

	Potential cumulative impact	
Project	**Groundwater levels**	**Groundwater quality/ contamination**
NSW/QLD Border to Gowrie to (ARTC)	Potential overlap of impacts from dewatering and cuttings that intersect shallow aquifers (MRV). Potential to overlap is primarily at the start and end of construction activities of the projects, where the Project abuts these other ARTC projects. Possible subsequent impacts on groundwater users.	Potential cumulative impacts on shallow aquifers from derailments and tunnel incidents, spills/leaks from heavy machinery, drill rigs and storage of fuels, etc.
Helidon to Calvert (ARTC)		
Defence Housing Australia Mount Lofty Development	Potential for groundwater drawdown to cause settlement at the proposed development. Groundwater drawdown can result in settlement of compressible substrates and possible damage to adjacent structures. The 5-m drawdown extent (construction phase), within the deep MRV and Koukandowie Formation, is approximately 1 km from the western boundary of the proposed development. The potential for settlement and damage to buildings and properties, due to subsidence from drained cuttings and the undrained tunnel, appears to be low. It is anticipated that the potential for settlement will be confirmed as part of ongoing geotechnical investigations and will inform final design.	
InterLinkSQ	Limited potential for impacts at this location as there is no proposed tunnelling or cuts.	
Asterion Medicinal Cannabis Facility	There may be a brief overlap in 2021 between the conclusion of construction for the Asterion Medicinal Cannabis Facility and the commencement of early works activities for the Project. Water source for this facility has not been identified. Potential overlap of impacts from dewatering, if Asterion is using bore water under a new licence/allocation or municipal water supplies sourced from the MRV (that have increased licensed volume where the predicted drawdown from additional allocations has increased). Possible subsequent impacts on groundwater users.	No impact anticipated

A qualitative significance assessment has been applied for evaluating cumulative impacts from the Project and surrounding projects. The qualitative assessment assigns a relevance factor of 1 (low), medium (2) or 3 (high) to the potential cumulative impacts for each of the following aspects:

- The probability of the impact
- The duration of the impact
- The magnitude/intensity of the impact
- The sensitivity of receiving environment.

The significance of the cumulative impact is then determined by summing the relevance factors. The impact categories are as follows:

- Low (relevance sum 1–6): Negative impacts should be managed by standard environmental procedures. Special approval conditions are unlikely. Monitoring required as part of the general Project monitoring.
- Medium (relevance sum 7–9): Mitigation measures likely required and specific management practices to be applied. Specific approval conditions are likely.
- High (relevance sum 10–12): Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Specific approval conditions are likely and targeted monitoring is required.

Based on the above methodology, the cumulative groundwater impacts for the Project are summarised in Table 14.34.

TABLE 14.34 SUMMARY OF THE CUMULATIVE IMPACT ASSESSMENT

Cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments	Mitigation measures
Change in groundwater levels	Probability of impact	1	6	Low	Localised impacts on shallow groundwater levels considered unlikely to be compounded in the vicinity of where the Project interfaces with B2G and H2C. Overlap of construction activities at either end of the Project with the B2G and H2C projects exist. The Project predicted 5-m drawdown extent (construction phase) in the deep MRV and Koukandowie Formation is approximately 1 km from the western boundary of the proposed Mt Lofty development. No anticipated impacts with the InterLinkSQ project, due to no deep cuts or tunnel in proximity. Potential overlap of construction activities from G2H with commencement of operations for Asterion. The operation of this facility is expected to require significant volumes of water.	Adherence to dewatering and water supply mitigation measures discussed in Section 14.8. Adherence to the CEMP/GMMP to respond effectively to groundwater level drawdown triggers. The potential for settlement and damage to buildings and properties of the proposed Mt Lofty development due to subsidence from drained cuttings and the undrained tunnel appears to be low. It is anticipated that the potential for settlement will be confirmed as part of ongoing geotechnical investigations and will inform final design. Confirm water source for Asterion and any predicted groundwater impacts, if any.
	Duration of the impact	2				
	Magnitude/intensity of the impact	1				
	Sensitivity of receiving environment	2				

Cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments	Mitigation measures
Groundwater quality and contamination	Probability of impact	1	6	Low	Primarily related to the shallow alluvial aquifer where potential intersections by excavations and contaminant spills can impact water quality for all identified projects. Overlap of construction activities at the ends of the Project alignment with either ARTC projects exist.	Implementation of the GMMP to identify and respond to triggers being breached. Adherence to the CEMP to prevent and respond effectively to spills and leaks.
	Duration of the impact	2				
	Magnitude/intensity of the impact	1				
	Sensitivity of receiving environment	2				

14.10 Conclusions

To meet the study scope and objectives outlined in the ToR (refer Table 14.1), the groundwater impact assessment provides a description of the existing hydrogeological environment and an assessment of the potential impacts of the Project on that environment. A staged approach was adopted for development of the groundwater study, including: a desktop study; review of geotechnical site investigation information and reports; a groundwater impact assessment; and a significance assessment.

The potential impacts of the Project on groundwater levels, flow and quality were discussed in Section 14.7 and a significance assessment carried out (refer Section 14.9); with the key conclusions, being:

- A moderate residual significance risk was identified for the potential of reduced groundwater levels to impact groundwater users (bores and potential GDEs) due to the Toowoomba Range Tunnel and associated cuts and portals:
    - Ground-truthing of GDEs is required to confirm GDEs exist within predicted drawdown extents
    - Continued baseline groundwater level monitoring will confirm groundwater levels at the tunnel and inform additional investigations and modelling.
- A moderate residual significance risk during the construction phase was identified for potential contamination, or degradation, of groundwater quality, including from spills and uncontrolled releases, water mixtures and emulsions from washdown areas, and wastewater from construction sites
- Low residual significance risks were identified as being low for all other potential impacts, including loss of registered bores due to destruction or loss of access, changes to groundwater levels due to loading from embankments (i.e. upstream mounding and damming, and downstream groundwater level reductions), and ARD from cuts and vegetation removal. Proposed additional geotechnical works, including investigation and monitoring of groundwater levels at deep cuttings, Toowoomba Range Tunnel and areas of foundation treatment in low lying floodplain areas will further inform detailed design.

An indicative groundwater monitoring program (refer Section 14.8.2) is proposed to provide an ongoing assessment of the potential impacts of the Project on the identified groundwater EVs and WQOs. The program includes an indicative monitoring bore network (refer Table 14.30) for periodic water-level and groundwater-quality monitoring.

A CIA was undertaken (refer Section 14.9.3) that considered the adjoining ARTC rail alignments and surrounding developments. The CIA identified a low significance due to adoption and implementation of mitigation measures.