CHAPTER 19

Groundwater

ALBURY TO ILLABO ENVIRONMENTAL IMPACT STATEMENT

Contents

Figures

Tables

19. Groundwater

This chapter is a summary of the potential impacts of the Albury to Illabo (A2I) section of the Inland Rail program (the proposal) on groundwater. The full assessment is in Technical Paper 12: Groundwater.

19.1 Summary

The proposal would have limited interaction with groundwater during construction across most enhancement sites. The key potential impact to groundwater would occur where track lowering and/or excavations are proposed that intersect saturated and permanent aquifers at three enhancement sites—Riverina Highway bridge, Pearson Street bridge, and Kemp Street bridge.

During construction, dewatering at Riverina Highway bridge and Kemp Street bridge would result in an estimated take of 0.7 megalitres (ML) and 11.4 ML within one water calendar year respectively. Subject to the confirmation of predicted groundwater take during detailed design, ARTC or its contractor would obtain a relevant water access licence for the groundwater take. Due to the radius of influence on groundwater levels, distance to registered bores and groundwater dependent ecosystems and the temporary nature of any inflows, the works at the two enhancement sites would have a negligible to low risk to registered bores and groundwater dependent ecosystems, except at one water supply bore located 7.5 m away from the Kemp Street bridge enhancement site. However, significant impacts to the bore are unlikely.

At Pearson Street bridge enhancement site, the required depth of excavation would be above the monitored groundwater level and under the current climatic conditions groundwater interception and take is not expected. Under wetter climatic conditions or changed pumping conditions, potentially elevated groundwater levels may be intersected during bulk excavation. This impact could result in groundwater take; however, the duration of works at this site would be limited and any impact to groundwater dependent ecosystems or registered bores would be low.

Potential groundwater take resulting from the proposal would have a low risk of impact on the current water balance of the Billabong Creek alluvial, Wagga Wagga alluvial, or Lachlan Fold Belt Murray–Darling Basin groundwater sources. Further groundwater investigations and monitoring would inform design and construction methodology to further reduce and avoid impacts to groundwater resources during construction. The quality of groundwater taken during excavation works would be assessed for the suitability for re-use during construction (or by others) or disposed of accordingly.

Groundwater is not predicted to be impacted during operation of the proposal given its depth and because the operational use as a rail corridor is comparable to existing land use activities. There remains a low to moderate risk of groundwater rising to the elevation of the track and potentially entering the surface water drainage network (known as groundwater seepage) at the Pearson Street bridge enhancement site under wetter climatic conditions. As any such seepage would be intermittent and limited in extent, impacts to GDEs and registered water supply bores in the vicinity of this enhancement site is assessed as low. The proposal has been designed to accommodate this potential seepage.

The assessment of the proposal's impacts on aquifers and GDEs in regard to the minimal impact considerations of the NSW Aquifer Interference Policy (Department of Primary Industries (DPI), 2012a) indicates the proposal complies with Level 1 criteria, which considers the potential impacts acceptable.

19.2 Approach

19.2.1 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (SEARs) related to groundwater, and where in the environmental impact statement (EIS) these have been addressed, are detailed in Appendix A: Secretary's Environmental Assessment Requirements.

19.2.2 Relevant legislation, policies and guidelines

The assessments were undertaken in accordance with the SEARs and with reference to the requirements of relevant legislation, policies and/or assessment guidelines, including:

- *Water Act 2007* (Cth)
- *Murray–Darling Basin Plan 2012* (including water resource plans and water quality management plans) (Murray–Darling Basin Authority, 2012) (the Basin Plan 2012)
- *National Water Quality Management Strategy* (Australian and New Zealand Environment and Conservation Council (ANZECC), 2018)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Governments, 2018) (the Water Quality Guidelines)

- *Water Management Act 2000* (NSW)
- The following water sharing plans:
  - *Murray Alluvial Groundwater Sources 2020*
  - *Murrumbidgee Alluvial Groundwater sources 2020*
  - *NSW Murray–Darling Basin Fractured Rock Groundwater sources 2020*
- *NSW Aquifer Interference Policy* (Department of Primary Industries, 2012a)
- Water Management (General) Regulation 2018
- *NSW State Groundwater Policy Framework* (Department of Land and Water Conservation (DLWC), 1997a), which includes:
  - *NSW Groundwater Quality Protection Policy* (DLWC, 1998)
  - *NSW Groundwater Dependent Ecosystems Policy* (DLWC, 2002a)
  - *NSW Groundwater Quantity Management Policy* (DLWC, 1997b)
- *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (NSW Office of Water, 2012).

19.2.3 Methodology

Study area

The study area is defined by the groundwater systems that underlie the proposal site (as defined by water sharing plans). This regional scale was assessed to characterise the hydrogeological conditions and potential area of influence of any potential impacts. Within this study area, areas within 2 kilometres (km) of each enhancement site were assessed in more detail in this impact assessment.

Key tasks

Desktop assessment

A desktop review of available data was undertaken to develop an understanding of the hydrogeological environment within the groundwater study area and to identify sensitive receptors including waterways, GDEs and registered groundwater bores.

The desktop assessment involved:

- reviewing existing survey information from previous geotechnical investigation at the proposal sites
- reviewing geological data from the *Seamless Geology Project* (Colquhoun, Hughes & Deyssing et al., 2019) and information from geotechnical investigations and regional maps
- reviewing relevant proprietary databases detailing the existing groundwater, geological, climate and hydrogeological environments including:
  - GDE information from the BOM GDE Atlas (2021)
  - climate data including rainfall and evapotranspiration from the Bureau of Meteorology (BOM) (refer to Chapter 25: Climate change adaptation and greenhouse gas and section 4.2 of Technical Paper 12: Groundwater)
  - registered groundwater bore data including groundwater levels, quality and yield, from the BOM National Groundwater Information System (NGIS) and WaterNSW
- reviewing publicly available reports and databases further detailing the existing groundwater, soil (refer to Chapter 20: Soils and contamination), geological (refer to section 19.3.1 of this EIS and section 4.3 of Technical Paper 12: Groundwater), topographical (refer to section 20.2.1 of this EIS), and hydrogeological environments (see to section 19.3.1), including surface water and groundwater interaction, and climate (refer to section 25.1.2). Sources include background aquifer descriptions documented in water resource plans (WRP) and water sharing plans, local council management plans and reports
- reviewing information provided by Wagga Wagga City Council regarding local monitoring bores within their Urban Salinity Management Plan.

A preliminary risk assessment was then undertaken to determine the requirement for further site investigations. The risk assessment was based on a review of the construction and operation activities during the preliminary design stages, particularly ground disturbance works such as track lowering and other work requiring excavation or other work with the potential to impact existing groundwater conditions, based on the available hydrogeological desktop information.

Field investigations

Field investigations included the drilling, monitoring well installation, water level monitoring and water quality monitoring at six locations where the preliminary risk ratings identified the high potential for impact or where a data gaps existed. These locations were:

- Albury precinct (Albury Yard clearances and Riverina Highway bridge enhancement sites)
- Wagga Wagga precinct (Uranquinty Yard clearances, Pearson Street bridge and Edmondson Street bridge enhancement sites)
- Junee precinct (Olympic Highway underbridge enhancement site).

Three groundwater monitoring events (GMEs) were completed in 2–5 February (GME1), 29–31 March (GME2) and 26–27 May (GME3). GMEs involve monitoring water levels and water quality in groundwater monitoring wells. The location of the groundwater monitoring wells and further details of the field investigation methodology is included in Technical Paper 12: Groundwater.

Hydrogeological concept model

Based on findings of the desktop assessment and field investigations, hydrogeological conceptual models were developed at each of the proposal enhancement sites.

Impact assessment

A qualitative assessment of the potential groundwater impacts from the construction and operation of the proposal was undertaken; the assessment considered:

- the existing hydrological environment
- potential impacts to the hydrological environment, including the risk of penetrating the groundwater table
- estimation of dewatering volumes and the radius of influence at sites assessed to be high risk. The radius of influence estimate was calculated using the Bear (1979) equation using a specific yield value of 20 per cent (refer to section 3.8.2 of Technical Paper 12: Groundwater)
- potential changes to the availability of and water quality for sensitive receivers
- quantification of dewatering requirements.

For the purpose of the assessment, four potential impact rating categories were assessed with respect to the proposal. The potential impact rating categories are outlined in Table 19-1.

TABLE 19-1 GROUNDWATER ASSESSMENT IMPACT RATINGS

Impact Rating	Description
Negligible	Indicates the impact is considered to cause no perceptible change to the local or regional hydrogeological environment.
Low	Indicates a low potential for limited (in extent and/or time) impact to the hydrogeological environment may exist. However, the potential impact would cause no permanent perceptible change to the regional hydrogeological environment, including GDEs and registered bores.
Moderate	Indicates a potential for permanent, but limited impact to the local hydrogeological environment may exist. However, the potential impact would cause no perceivable change to the regional hydrogeological environment.
High	Indicates a potential for permanent impact to the hydrogeological environment at both the local and regional scale. The potential impact could cause significant changes to groundwater availability or quality.

Outcomes of the impact assessment were used to develop mitigation measures to inform future stages of the design, construction and operation of the proposal.

19.2.4 Key risks

An environmental risk assessment was undertaken for the proposal (refer Appendix E: Environmental risk assessment). Groundwater risks with an assessed level of medium or above, identified by the environmental risk assessment, included:

- potential for bulk excavations and piling to intersect the water table and lead to groundwater level drawdown and changes to quality and quantity, impacting nearby groundwater bores, GDEs and watercourse base flow.

The groundwater assessment considered the potential risk identified by the environmental risk assessment in addition to potential risk and impacts identified by the scoping report, the SEARs and relevant guidelines and policies (as appropriate).

19.3 Existing environment

19.3.1 Groundwater systems

Four groundwater systems were identified that underlie the study area:

- Upper Murray (Alluvium)—Albury precinct
- Billabong Creek (Alluvium)—Greater Hume, Lockhart precinct
- Wagga Wagga alluvial—Wagga Wagga precinct
- Lachlan fractured rock—all precincts.

These groundwater systems are delineated as per the groundwater sources listed within the water sharing plans. Groundwater systems are shown on Figure 19-1. Groundwater systems are defined as geological material of similar hydrogeological properties. Groundwater systems are generally based on stratigraphic units, although units of similar groundwater storage and transmissive properties are often classified together as a single system.

An aquifer is a rock or sediment in a formation, group of formations or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs. A confined aquifer is bounded above and below by impervious (confining) layers. In a confined aquifer, the water is under sufficient pressure so that when wells are drilled into the aquifer, measured water levels rise above the top of the aquifer. Perched groundwater that is a system separated from the underlying main body of groundwater (base aquifer). The regional permanent groundwater system is conceptualised noting that perched temporary systems can be locally present (see section 19.3.8)

Upper Murray (Alluvium)—Albury precinct

The Albury precinct is underlain by alluvial deposits of sand, silt, clay and gravel in flood and soil plain areas that form the Upper Murray (alluvium) groundwater system. A summary of the characteristics is provided in Table 19-2.

Billabong Creek (Alluvium)—Greater Hume, Lockhart precinct

The Wagga Wagga precinct is generally located on alluvium deposits comprising of gravel, sand, silty and clay that form the Billabong Creek (alluvium). A summary of the characteristics is provided in Table 19-2.

Wagga Wagga Alluvial—Wagga Wagga precinct

The Wagga Wagga precinct is underlain by deep alluvium comprising of gravel, sand, silty and clay and forms the Wagga Wagga Alluvial groundwater system. A summary of the characteristics is provided in Table 19-2.

Lachlan fractured rock—all precincts

The Lachlan fractured rock groundwater system underlies all precincts and is formed by colluvium and alluvium consisting of gravel, sand silt and clay. The underlying rock units are divided by the Gilmore Fault Zone, separating the granite with siltstone, sandstone, shale, conglomerate and minor felsic volcanic rocks. A summary of the characteristics is provided in Table 19-2.

TABLE 19-2 GROUNDWATER SYSTEMS THAT UNDERLIE THE PROPOSAL SITE

Groundwater system/proposal site precinct	Aquifers	Encountered depth (mBGL)[1]/flow direction	Characteristics
Upper Murray (alluvium) *Albury precinct*	Shallow	0–20 Groundwater flow is generally southeast to northwest.	Unconfined to semi-confined aquifer consisting of water bearing sands and gravels. Shares a hydraulic connection with major rivers, creeks, irrigation channels and other water bodies and is considered a gaining system at Albury.
	Deep	20–80 Groundwater flow is generally southeast to northwest.	Semi confined aquifer consisting of water bearing sands and gravels. Considered the more productive Upper Murray alluvium aquifer with bores containing yields of up to 10 ML/day. Assumed limited with the overlying aquifer.
Billabong Creek (alluvium) *Greater Hume precinct*	Shallow	0–50 Groundwater flow is generally east to west	Unconfined to semi-confined aquifer of poorly sorted sands and gravel with interbedded clay. Bore yields are generally less than 0.5ML/day. Shares a hydraulic connection with Billabong Creek and is considered a gaining system at Culcairn.

Groundwater system/proposal site precinct	Aquifers	Encountered depth (mBGL)[1]/flow direction	Characteristics
	Deep	50–100 Groundwater flow is generally east to west.	Unconfined to semi confined aquifer of poorly sorted sands and gravel with interbedded clay. Bore yields are generally less than 0.5 ML/day. Shares a hydraulic connection with Billabong Creek and is considered a gaining system at Culcairn.
Wagga Wagga Alluvial *Wagga Wagga precinct*	Shallow	0–40	Consisting of water bearing sands and fine gravel. Considered the more productive Billabong Creek alluvium aquifer with bore yields of up to 5 ML/day.
	Deep	40–90 Groundwater flow is generally east to west.	Semi-confined aquifer consisting of water bearing sands and gravels of the Lachlan Formation. Considered the more productive Wagga Wagga alluvial aquifer with bore yields of up to 13 ML/day. Shares a hydraulic connection with the overlying shallow aquifer. Flow is locally altered due to groundwater depression cones in areas of heavy extraction around Wagga Wagga and further upstream.
Lachlan fractured rock *All precincts*	Shallow	Variable—Groundwater flow is generally controlled by topography but would be influenced by localised fracture systems and regional geological structures	Unconfined to confined aquifer depending on location and overlying geology. Groundwater is stored and moves through fractures, joints, bedding plains, faults and cavities within the rock mass or weathered zone (for the shallow aquifer). Hydraulic connectivity between surface water features, other overlying aquifers and between the shallow and deep Lachlan fractured rock aquifers is limited to the degree of fracturing extending between the aquifers or the bed of the surface water features.

1. mBGL = metres below ground level

19.3.2 Groundwater levels

Groundwater data used to guide this assessment included a range of sources including water resource plans, data from registered groundwater bores, Wagga Wagga City Council monitoring networks (near proposed enhancement sites), site-specific monitoring data where inflow was encountered during geotechnical investigations and site-specific monitoring as part of the site investigations.

Groundwater levels vary significantly across the study area depending on the groundwater source present at each enhancement site, local topographical conditions, influences such as climatic conditions impacting inflow and the hydraulic conductivity between surface water features.

The elevation of the enhancement sites located within the study area generally range from an elevation of around 150 metres Australian Height Datum (mAHD) within the Albury precinct to an elevation of around 360mAHD within the Junee precinct. Mean annual rainfall across the proposal sites range from 526 millimetres at Junee (BoM Station #073019) to 610 millimetres at Albury (BoM Station #072160). Refer to Chapter 25: Climate change risk adaptation and greenhouse gas) for further discussion on climate.

Groundwater levels were manually measured at six installed monitoring bores during GMEs (2021). These results are presented in Table 19-3. No groundwater-level statistics are available for BH219 (Uranquinty Yard clearances enhancement site) as the bore was ‘dry’ during the monitoring period.

Data captured from the same locations via data loggers, with a summary of groundwater level statistics (minimum, maximum and median), is included in Table 4.11 of Technical Paper 12: Groundwater.

TABLE 19-3 GROUNDWATER LEVELS RECORDED BY MANUAL DIP MEASUREMENTS DURING GMES

			GME 1 (Feb 2021)		GME 2 (March 2021)		GME 3 (May 2021)	
Bore ID	Enhancement site	Groundwater source	SWL[1] (mBGL)	SWL[1] (mAHD)	SWL[1] (mBGL)	SWL[1] (mAHD)	SWL[1] (mBGL)	SWL[1] (mAHD)
BH201	Albury Yard clearances	Upper Murray—shallow	8.11	152.53	8.38	152.26	8.49	152.15
BH204	Riverina Highway bridge	Upper Murray—shallow	7.48	153.91	7.72	153.67	7.66	153.73
BH206	Pearson Street bridge	Lachlan fractured rock shallow	2.22	184.25	1.98	184.49	2.49	183.98
BH210	Edmondson Street bridge	Lachlan fractured rock shallow	10.75	172.93	10.45	173.23	11.14	172.53
BH215	Olympic Highway underbridge	Lachlan fractured rock shallow	9.99	299.56	9.85	299.70	9.72	299.83
BH219	Uranquinty Yard clearances	Lachlan fractured rock shallow	Dry (>30.00)	Dry (<168.36)	Dry (>30.00)	Dry (<168.36)	Dry (<30.00)	Dry (<168.36)

1. Surface water level (SWL)

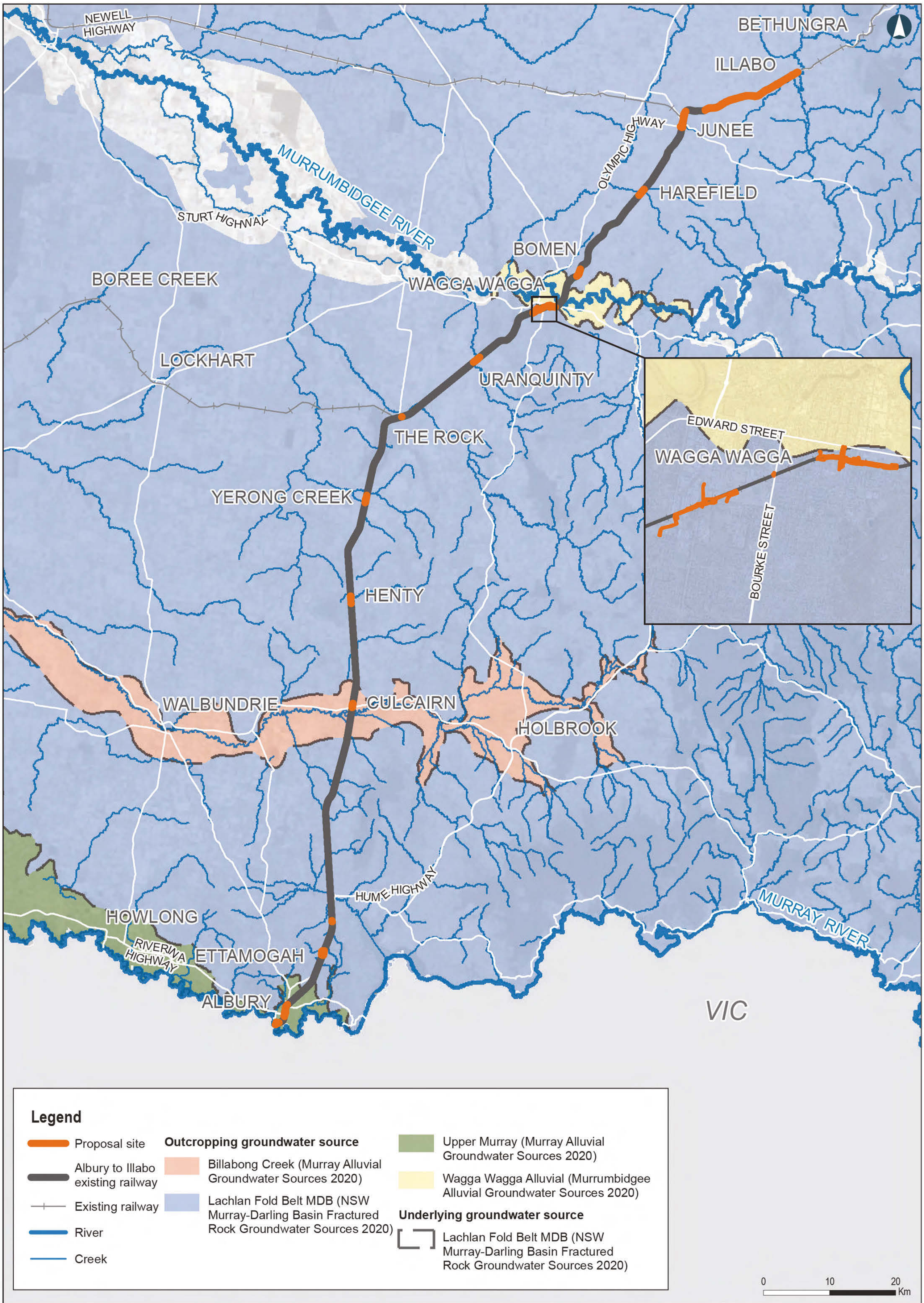

Figure 19-1 Water sharing plans and groundwater source

Data Sources: ARTC, NSWSS

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:70,000
Paper size: A3
Date: 19/09/2021

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19.3.3 Groundwater quality

Groundwater quality describes the condition of water within the groundwater source and its suitability for different purposes, such as whether it can be used for town water, stock and domestic supply or irrigation. One way of assessing groundwater quality is by the salinity of the water resource.

Beneficial use categories are general groupings of groundwater uses based on water quality; primarily based on salinity and the absence or presence of contamination but can include water quality indicators or sodium absorption ration, nutrients and pathogens. The overriding principle is that groundwater quality should be maintained within its beneficial use category. Beneficial use is the equivalent of environmental value (ANZECC, 2000). Beneficial use categories:

- were adopted in the *NSW Groundwater Quality Protection Policy* (Department of Land and Water Conservation (DLWC), 1998)
- have been adopted in the *NSW Aquifer Interference Policy*
- are used in the relevant WRPs.

Beneficial use categories included in Table 19-4 are based on salinity for this assessment. Salinity levels are separated into classes A1 to D dependent on the total dissolved solids which determine the beneficial use category.

TABLE 19-4 BENEFICIAL USE CATEGORIES ADOPTED FOR THE ASSESSMENT

	Salinity (Total Dissolved Solids (TDS) mg/L)[1]						
	A1	A2	A3	B	C1	C2	D
Beneficial use	0–600	600–900	901–1,200	1,201–3,000	3,001–6,000	6,001–10,000	>10,000
Aquatic ecosystem protection	✓	✓	✓	✓	✓	✓	✓
Primary industries—irrigation	✓	✓	✓	✓			
Primary industries—stock drinking water	✓	✓	✓	✓	✓	✓	
Recreation and aesthetics	✓	✓	✓	✓	✓	✓	✓
Raw drinking water	✓	✓	✓				
Industrial water	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual	✓	✓	✓	✓	✓	✓	✓

1 Conversion from mg/L to µs/cm (conversion factor of 0.67) is A1 = 0-896, A2 = 897-1,343, A3 = 1,344-1,791, B = 1,792-4,478, C1 = 4,479-8,955, C2 = 8,956-14,925 and D = >14,925.

As discussed in section 19.2.3 information on groundwater quality within the study area has been compiled from a range of sources including groundwater resource descriptions (published by the then Department of Planning, Industry and Environment (DPIE)), data from registered groundwater bores, Wagga Wagga City Council monitoring networks (near proposed enhancement sites), site-specific monitoring as part of the site investigations. Table 19-5 provides a summary of regional groundwater quality (DPIE, 2019a, 2019b and 2019c).

TABLE 19-5 INDICATIVE REGIONAL GROUNDWATER QUALITY (DPIE, 2019A, 2019B AND 2019C)

Groundwater system	Aquifer	Quality—Salinity (Electrical Conductivity (EC))
Upper Murray (Alluvium)	Shallow	Fresh, generally less than 800 µS/cm.[1] Higher values (up to 5,000 µS/cm[1]) have previously been recorded. No distinction has been made between shallow or deep aquifer groundwater quality due to limited information.
	Deep	
Billabong Creek (Alluvium)	Shallow	Varies from 200 to 12,000 µS/cm[1], with groundwater in the eastern part of the aquifer fresher and in regions with direct river recharge.
	Deep	Typically fresh, 300 to 2,000 µS/cm[1]
Wagga Wagga Alluvial	Shallow	Can vary with the freshest groundwater occurring proximal to the Murrumbidgee River. The EC is generally below 1,660 µS/cm[1]
	Deep	Fresh, around 950 µS/cm[1]
Lachlan fractured rock	Shallow	Significantly varies from fresh to saline based on rock type, fracture density, aquifer depth and climate.
	Deep	

1. µS/cm = microseimens per centimetre

A review of registered groundwater bores, located within one kilometre of enhancement sites (specifically the Murray River bridge, and Albury Yard clearances, and Culcairn Yard clearances) indicate lower EC values (233µS/cm)—classified as fresh (A1) in the upper Murray groundwater system, and similar quality in the Billabong Creek (shallow and deep) groundwater system—classified as brackish and fresh-brackish (A1-C1 and A1-B, respectively).

A review of Wagga Wagga City Council monitoring network for select bores near enhancement sites indicates a range of groundwater quality ranging from marginal (A2) to moderately saline (D). All bores in this monitoring network were within shallow areas of the Lachlan fractured rock groundwater system.

Groundwater quality results obtained from locations with installed monitoring bores during GMEs are presented in Table 19-6 and the full analytical results are provided in Appendix C of Technical Paper 12: Groundwater. No groundwater quality samples were collected at BH219 (Uranquinty Yard clearances) as the bore was dry during each GME. This indicates that the groundwater levels in the targeted aquifer would be below the base of the bore. The results of the GMEs are consistent with the indicative groundwater quality outlined in Table 19-5, with the field readings within the ranges (microseimens per centimetre (µS/cm)) of the four groundwater systems.

TABLE 19-6 GROUNDWATER QUALITY REORDERED DURING GMES

	Groundwater quality	BH201[4]	BH204[4]	BH206[4]	BH210[4]	BH215[4]
GME 1	Field reading (EC µS/cm)[1]	2,031	1,688	729	547	2,442
	Classification[2]	Brackish	Brackish	Fresh	Fresh	Brackish
	Category[3]	B	A3	A1	A1	B
GME 2	Field reading (EC µS/cm)[1]	1,374	1,591	566	577	2,148
	Classification[2]	Marginal	Marginal	Fresh	Fresh	Brackish
	Category[3]	A3	A3	A1	A1	B
GME 3	Field reading (EC µS/cm)[1]	1,616	1,499	631	580	2,662
	Classification[2]	Marginal	Marginal	Fresh	Fresh	Brackish
	Category[3]	A3	A3	A1	A1	B

1. µS/cm = microseimens per centimetre
2. Based on calculated median value and classification ranges provided in Hounslow (1995)
3. Refer to Table 19-4 for water quality category descriptions
4. BH201 is located at Albury Yard clearances in the Upper Murray—shallow groundwater system; BH204 is located at Riverina Highway bridge in the Upper Murray—shallow groundwater system; BH206 is located at Pearson Street bridge in the Lachlan fractured rock—shallow groundwater system; BH210 is located at Edmondson Street bridge in the Lachlan fractured rock—shallow groundwater system; BH215 is located at Olympic Highway underbridge in the Lachlan fractured rock—shallow groundwater system.
5. Note: refer to Table 19-2 for depths of each of the four groundwater systems.

The beneficial use categories of the groundwater assessed in Table 19-6 indicate that the existing groundwater can be used for all beneficial uses with the exception of category B, which is not suitable to be used as raw drinking water.

19.3.4 Groundwater contamination

The assessment of impacts associated with groundwater contamination are included in Chapter 20: Soils and contamination and Technical Paper 13: Contamination. Table 19-7 provides a summary of groundwater contamination for each precinct from Technical Paper 13: Contamination.

TABLE 19-7 SUMMARY OF GROUNDWATER CONTAMINATION

Precinct	Comment
Albury	A review of historical assessments indicates there is potential for hydrocarbon and metal contamination at Albury Yard clearances enhancement site.
Greater Hume, Lockhart	A review of historical assessments did not identify any groundwater contamination.
Wagga Wagga	A review of historical assessments indicates there is a low potential for herbicide contamination at Bomen Yard clearances, potential hydrocarbon contamination from underground storage tanks at Edmondson Street bridge, Wagga Wagga Station pedestrian bridge and Wagga Wagga Yard clearances enhancement sites.
Junee	A review of historical assessments indicates there is a low potential for herbicide contamination at Harefield Yard clearances.

19.3.5 Hydraulic conductivity

Hydraulic conductivity is a fundamental aquifer hydrogeological property that assists in understanding the potential for drawdown and its associated effects. Hydraulic conductivity is measured in metres per day (K value) and is a calculation of how quickly groundwater flows through a porous medium (soil matrix or rock mass) under natural conditions. The higher the value of hydraulic conductivity, the greater the movement of groundwater expected.

Hydraulic conductivity was assessed at all monitoring bore locations where groundwater was present during site investigations to provide an estimate for inflow and drawdown assessments, if required. The results can be summarised as:

- bores screened in the Murray Alluvial groundwater system recorded K values of 0.88–0.97 me per day at Albury Yard clearances and 0.078 m per day at Riverina Highway bridge, which is within the representative range of silts to fine sands from Domenico and Schwartz (1990)
- BH206 at Pearson Street bridge, screened within residual soils of the Lachlan fractured rock—shallow groundwater system recorded a K value of 0.08 m per day, which is within the representative range of silts from Domenico and Schwartz (1990)
- BH215, screened across the extremely weathered granite profile of the Lachlan fractured rock—shallow groundwater system recorded a K value of 0.11 m, which is within the representative range of weathered granite from Domenico and Schwartz (1990).

19.3.6 Water allocation and availability

The groundwater sources identified in the previous sections, are close to or fully allocated, except for the Lachlan Fold Belt groundwater system, which was under-allocated but typically has variable water quality and yields. Licensing restrictions through either full allocation or over utilisation could limit the availability of groundwater as a source for construction water supply.

A more detailed summary of water allocation and availability is included in Technical Paper 12: Groundwater.

19.3.7 Sensitive receivers

Registered groundwater bores

A total of 469 registered groundwater bores are located within the study area with only one located within an enhancement site—registered bore (GW402492) (refer to Figure 19-2 to Figure 19-6).

Most of registered bores are for monitoring or observation purposes (305) followed by water supply (including industry, aquaculture, commercial and household water supply) (91), unknown purpose (32), recreation (15), stock and domestic (11), drainage (11) and exploration (4).

Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) rely on a supply of groundwater to support the species composition, structure and function of the ecosystem. A GDE may be either entirely dependent on groundwater for survival or may use groundwater opportunistically or as a supplementary source of water.

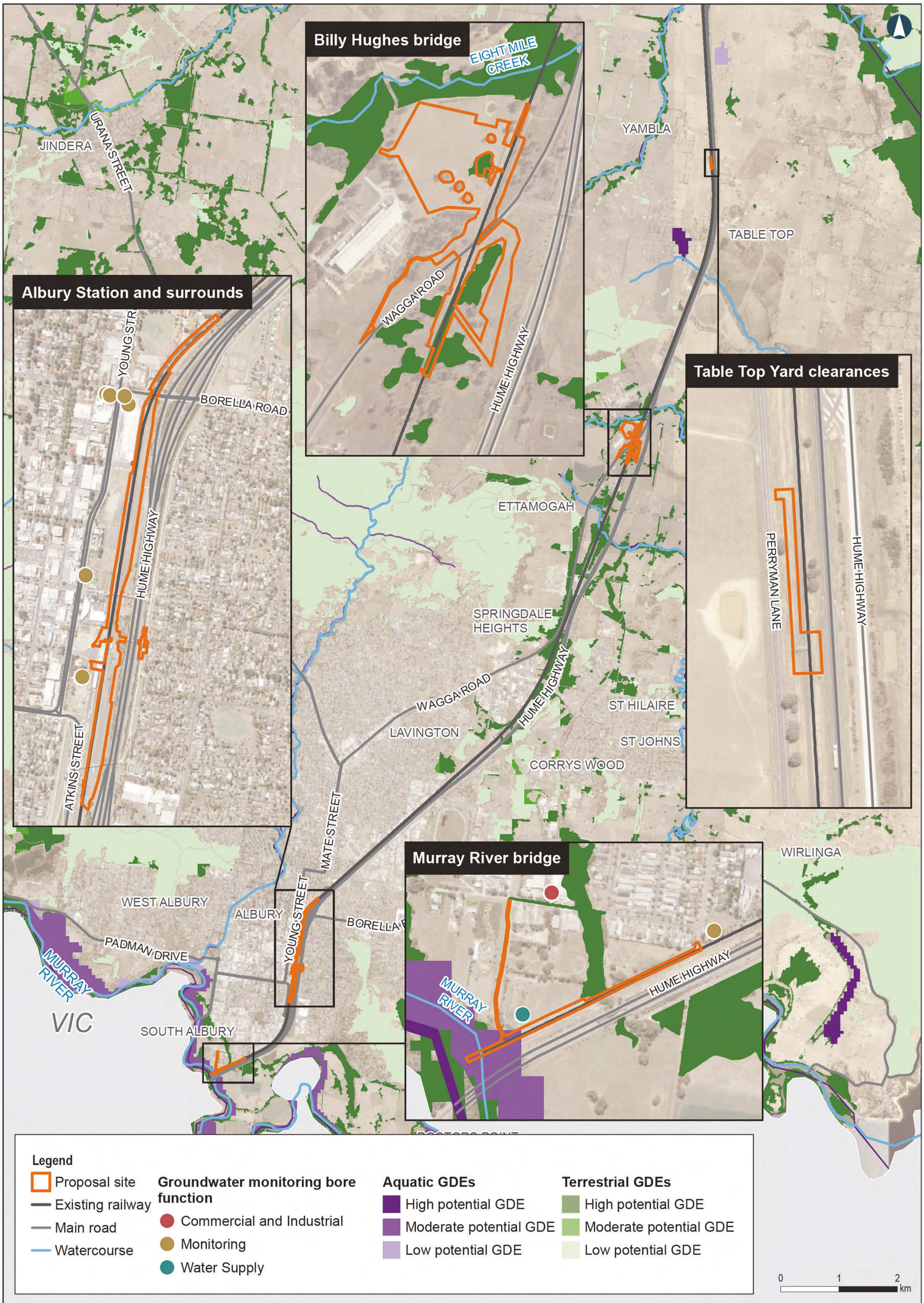
The *NSW DPI Water Risk Assessment Guidelines* for GDEs (NSW Office of Water, 2012) adopts the definition for GDEs as:

'*Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater.'*

The GDE Atlas (BOM, 2021) defines GDEs according to their potential to interact with groundwater (being high, moderate and low potential) as shown in Figure 19-2 to Figure 19-6. The GDE Atlas further categorises GDEs as aquatic for surface water bodies or terrestrial.

Groundwater discharge can be important in maintaining baseflow in rivers and streams, and ecosystems associated with these discharge areas may have a high dependency on groundwater for their water requirements. It should be noted, however, that some of these ecosystems rely on perched aquifer systems that are shallow, surficial and are largely not connected to the deep regional groundwater system, and, as such, would not be additionally interfered with by construction works (beyond that impacted by typical excavation cutting disturbance). That is, these ecosystems are largely sustained by recharge-in/recharge-out processes associated with rainfall infiltration, which typically characterise the behaviour of shallow perched water systems. Within the groundwater study areas, this relates to GDEs that are located overlying colluvial or residual soils associated with Lachlan fractured rock groundwater system.

A total of 31 ecosystems (16 aquatic and 15 terrestrial) that potentially rely on the surface expression of groundwater have been identified across all groundwater study areas in the GDE Atlas. The location of these GDEs relative to the proposal are shown in Figure 19-2 to Figure 19-6; additional details on the types of GDEs are presented in the Technical Paper 12: Groundwater.



Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:85,000
Paper size: A4
Date: 14/12/2021

Figure 19-2 Groundwater Dependent Ecosystems and registered bore locations of Albury precinct

Data Sources: ARTC, NSWSS

210_EAP_F1902_GDEs_Albury_r1v4.mxd

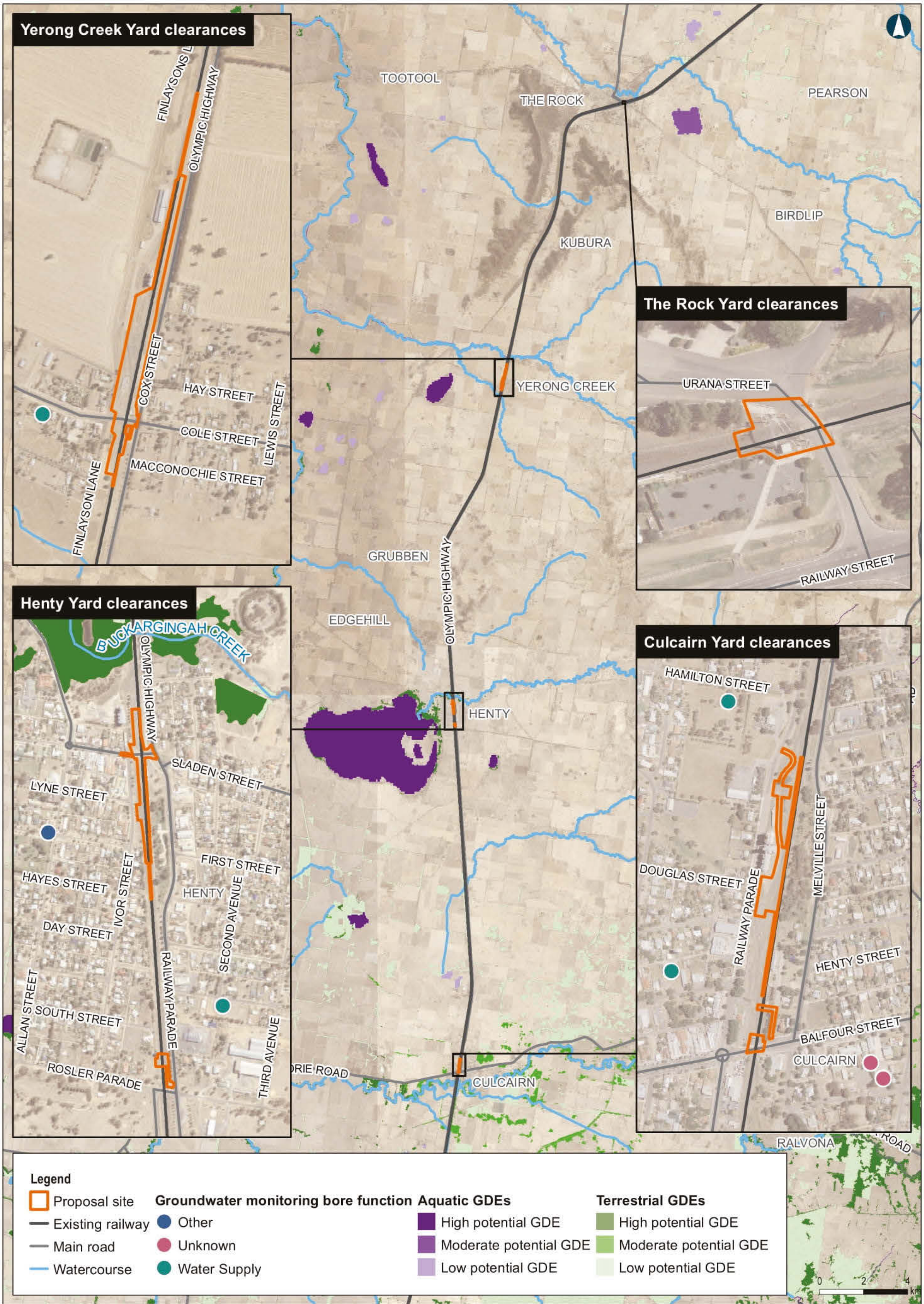
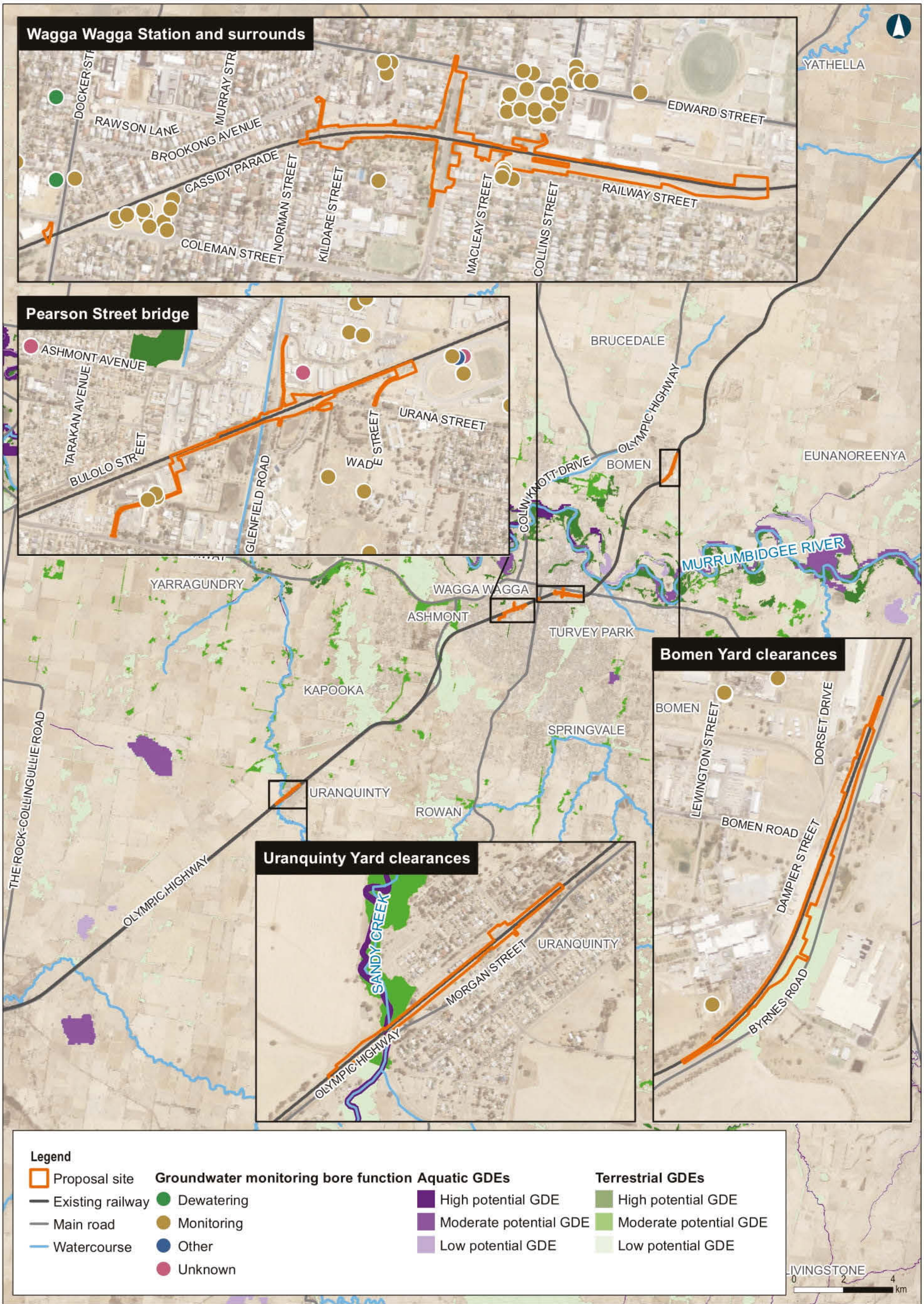


Figure 19-3 Groundwater Dependent Ecosystems and registered bore locations of Greater Hume-Lockhart precinct

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:225,000
Paper size: A4
Date: 4/11/2021

Data Sources: ARTC, NSWSS

210_EAP_F1903_GDEs_LGH_r1v3.mxd



Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:200,000
Paper size: A4
Date: 14/12/2021

Figure 19-4 Groundwater Dependent Ecosystems and registered bore locations of Wagga Wagga precinct

Data Sources: ARTC, NSWSS

210_EAP_F1904_GDEs_Wagga_r1v4.mxd

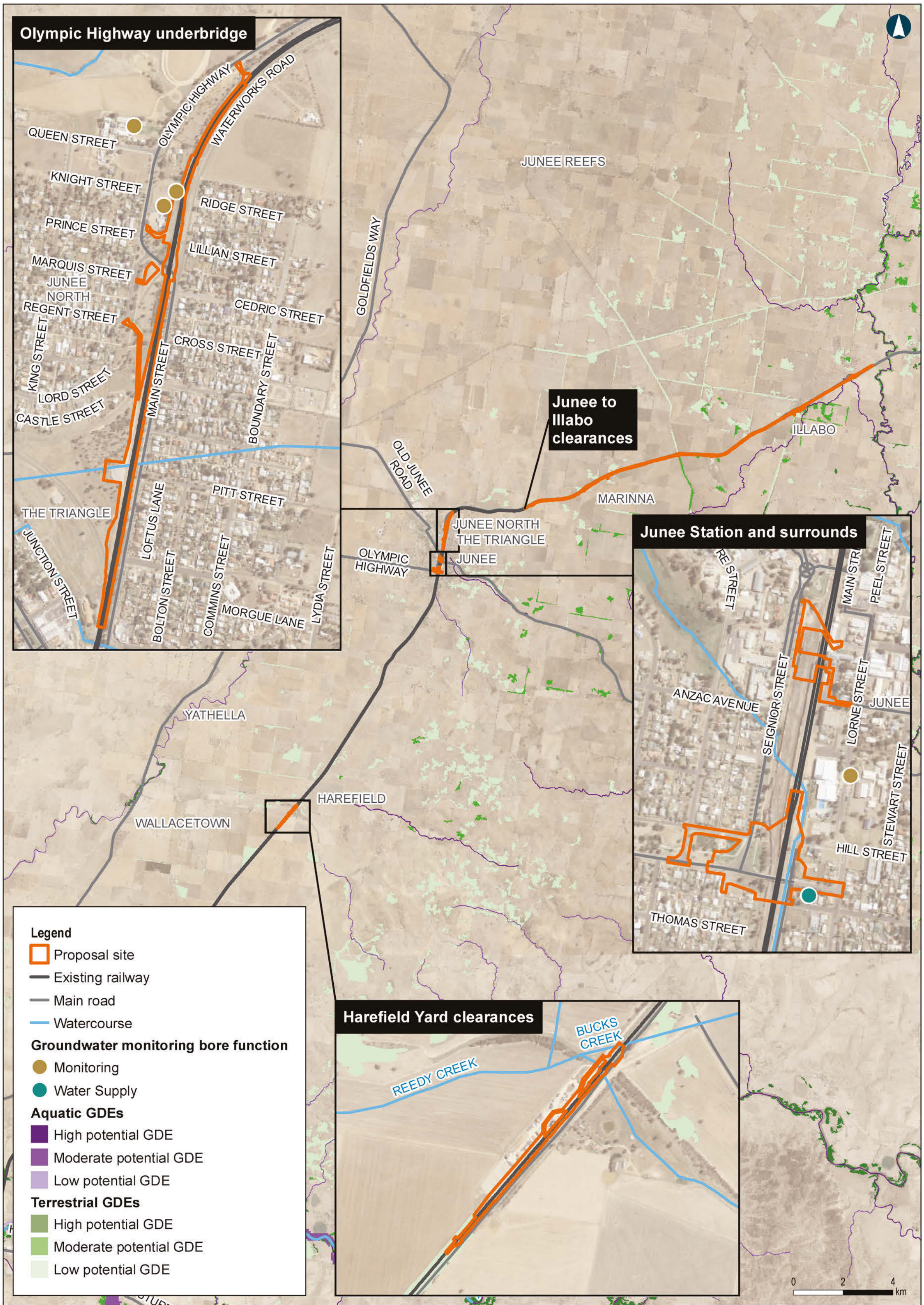


Figure 19-5 Groundwater Dependent Ecosystems and registered bore locations of Junee precinct

Data Sources: ARTC, NSWSS

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:200,000
Paper size: A4
Date: 19/02/2022

210_EAP_F1905_GDEs_Junee_r1v5.mxd

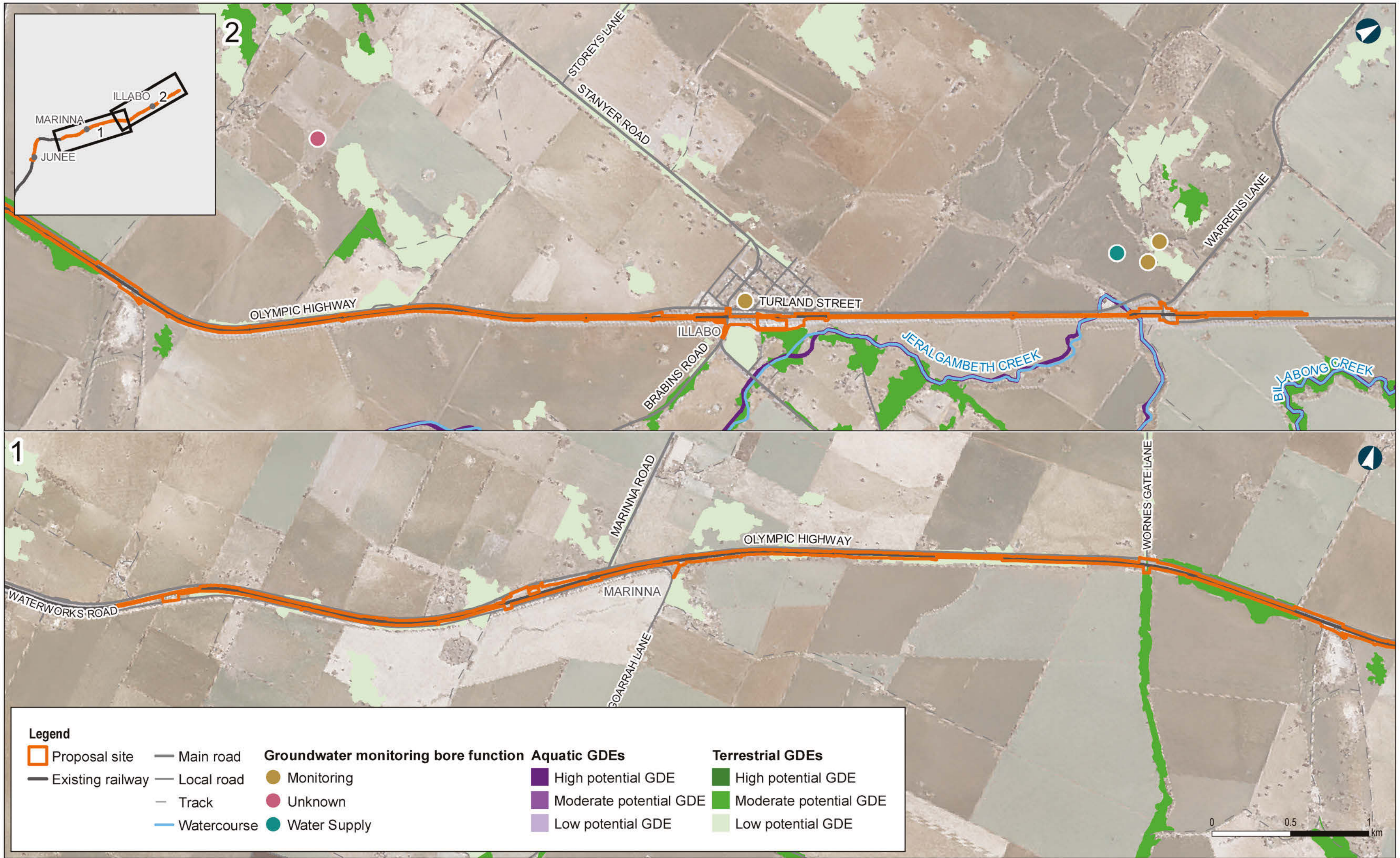


Figure 19-6 Groundwater Dependent Ecosystems and registered bore locations of Junee to Illabo clearances

Data Sources: ARTC, NSWSS

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:32,000
Paper size: A4
Date: 1/06/2022

210_EAP_F1906_GDEs_Junee_r1v4.mxd

19.3.8 Conceptual hydrological model

Conceptual hydrogeological models have been generated for each enhancement site. These models are useful tools that capture the existing groundwater and surface water conditions, and illustrate the interaction between the two. To inform the development of this conceptual hydrogeological model, information was obtained from the following sources (as relevant to each enhancement site):

- regional groundwater levels from WRP groundwater resource descriptions published by the then DPIE outlined in section 19.3.2.
- groundwater bore searches outlined in section 19.2.3
- groundwater monitoring networks maintained by Wagga Wagga City Council (1994–2021) outlined in section 19.3.3
- information gathered during site geotechnical investigations (2016 and 2021) (refer to Chapter 20: Soils and contamination)
- data collected during GMEs from bores installed through field investigations in February, April and May 2021 outlined in section 19.3.3

Detailed summaries of each data source are included in Technical Paper 12: Groundwater.

As identified in Table 19-2, deeper groundwater systems are located between 20–80 mBGL in the Upper Murray (Alluvium) groundwater system, 50–100 mBGL in the Billabong Creek (Alluvium) groundwater system, 40–90 mBGL in the Wagga Wagga Alluvial groundwater and variable in the Lachlan fracture rock groundwater system. Considering the maximum depth of bulk earthworks (up to 7 m below ground level) required for the proposal, deeper groundwater systems have been excluded from assessment in the hydrological model. Refer to section 8.2 for further information on the proposed construction activities.

Albury

Table 19-8 provides a summary of the groundwater conditions within enhancement sites based on available information.

TABLE 19-8 CONCEPTUAL HYDROLOGICAL MODEL—ENHANCEMENT SITES (ALBURY PRECINCT)

Enhancement site	Groundwater source/details	Groundwater levels	Groundwater quality[1]/hydraulic conductivity[2]	Nearby sensitive receivers
Murry River bridge	▸ Upper Murray (Alluvium) groundwater system ▸ Groundwater recharge is likely dominated by the Murray River, which shares a hydraulic connection to the alluvial aquifer.	▸ Groundwater would be of a similar elevation to the water level of the Murray River.	▸ Strongly influenced by the SWL, flow and quality of the Murray River.	▸ GDEs, including Murray River (aquatic) and River Red Gums (terrestrial)
Albury yard clearances and Albury Station pedestrian bridge	▸ Upper Murray (Alluvium) ground water system ▸ Groundwater recharge is likely dominated by the Murray River, which shares a hydraulic connection to the alluvial aquifer.	▸ Between 8.1–8.5 m below ground level (mBGL).	▸ Quality: marginal to brackish ▸ Salinity category: A3 to B (see Table 19-4 for beneficial uses) ▸ Hydraulic conductivity: 0.88–0.97 m/day.	▸ Registered bores situated close to the Murray River ▸ GDEs, including Murray River (aquatic) and River Red Gums (terrestrial)
Riverina Highway bridge	▸ Upper Murray (alluvium) groundwater system ▸ Groundwater recharge is likely dominated by the Murray River, which shares a hydraulic connection to the alluvial aquifer. ▸ Groundwater flow towards the Albury yard clearances is plausible based on limited information regarding groundwater level differences between Albury Yard clearances and Riverina Highway bridge.	▸ Between 7.3–7.7 mBGL.	▸ Quality: marginal to brackish ▸ Salinity category: A3 (see Table 19-4 for beneficial uses) ▸ Hydraulic conductivity: 0.08 m/day.	▸ Registered bores for water supply purposes ▸ GDEs situated closer to the Murray River or its tributaries.
Billy Hughes bridge	▸ Lachlan fractured rock groundwater system ▸ Recharge would primarily be from surface water infiltration and localised flows from neighbouring topographic highs ▸ Perched water may exist, groundwater flow would generally follow local topography, which regionally dips towards the south.	▸ Below observable groundwater investigation depths of 7.2 mBGL (211.7 mAHD).	▸ No information regarding groundwater quality is available.	▸ Anticipated to be at depth within the weathered fractured rock and be unsuitable for a resource due to predicted low yields ▸ GDEs within the groundwater study area and enhancement site.

1. Groundwater quality relates to the condition of groundwater within a groundwater source and its suitability for different purposes.
2. Hydraulic conductivity measures the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (metres per day).

Lockhart–Greater Hume

Table 19-9 provides a summary of the groundwater conditions at the Lockhart–Greater Hume precinct enhancement sites based on available information.

TABLE 19-9 CONCEPTUAL HYDROLOGICAL MODEL—ENHANCEMENT SITES (LOCKHART–GREATER HUME PRECINCT)

Enhancement site	Details	Groundwater levels	Groundwater quality[1]/hydraulic conductivity[2]	Nearby sensitive receivers
Table Top Yard clearances	▶ Lachlan fractured rock groundwater system ▶ Due to the proposed works (gantry signal works) requiring minimal excavation, no site investigations were conducted.	▶ No groundwater level information is available, but groundwater is not anticipated within 0.5 m of the surface within the enhancement site.	▶ No groundwater quality information is available ▶ Groundwater yields of 0.1 litres per second (L/s) from current bore.	▶ One registered bore (GW505149) ▶ Nearest GDEs approximately 350 m and 850 m from the enhancement site.
Culcairn Yard clearances	▶ Billabong Creek (alluvium) groundwater system ▶ Recharge would occur through rainfall infiltration overlying alluvium soils and discharge from Billabong Creek ▶ Groundwater flow is predicted to generally flow east to west due to connection with Billabong Creek.	▶ Recorded groundwater levels of 4.0–34.0 mBGL ▶ Median groundwater level calculated from nine bores was 13.7 m.	▶ Groundwater quality is anticipated to be fresh to brackish (WaterNSW, 2021).	▶ GDEs clustered around the riparian corridor of Billabong Creek.
Henty Yard clearances	▶ Lachlan fractured rock groundwater system. ▶ Recharge from rainfall infiltration is considered the dominant recharge mechanism ▶ Urbanisation around the proposal site may impact localised responses to rainfall events ▶ Groundwater flow is anticipated to follow topography, east to west.	▶ The shallow permanent groundwater system is predicted to be greater than 2.2 m within the enhancement site.	▶ No groundwater quality information is available.	▶ GDE populations of the topographically low-lying Doodle Corner Swamp, a high-potential GDE located approximately 1.6 km west of the enhancement site.
Yerong Creek Yard clearances	▶ Lachlan fractured rock groundwater system ▶ Recharge from rainfall infiltration is anticipated to be the dominant recharge mechanism ▶ Groundwater flow is anticipated to generally follow topography, generally south-east to north-west.	▶ Below observable groundwater depths of 2.2 mBGL.	▶ No groundwater quality information is available.	▶ Yerong Creek is the only mapped GDE within the groundwater study area for this site.
The Rock Yard clearances	▶ Lachlan fractured rock groundwater system ▶ Recharge from discharge from Burkes River during high flow and flooding conditions and infiltration from rainfall are anticipated to be the dominant recharge mechanisms ▶ Groundwater flow most likely follows regional river topography towards the north west.	▶ Below observable groundwater depths of 5.4 mBGL.	▶ No groundwater quality information is available.	▶ Burke River is the only mapped GDE within the groundwater study area.

1. Groundwater quality relates to the condition of groundwater within a groundwater source and its suitability for different purposes.
2. Hydraulic conductivity measures the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of 1 m^2 under a unit hydraulic gradient at right angles to the direction of flow (m/day).

Wagga Wagga

Table 19-10 provides a summary of the groundwater conditions at the Wagga Wagga precinct enhancement sites based on available information.

TABLE 19-10 CONCEPTUAL HYDROLOGICAL MODEL—ENHANCEMENT SITES (WAGGA WAGGA PRECINCT)

Enhancement site	Details	Groundwater levels	Groundwater quality[1]/hydraulic conductivity[2]	Nearby sensitive receivers
Uranquinty Yard clearances	▸ Wagga Wagga Alluvium groundwater system.	▸ Likely deeper than the observable groundwater depth (8.5 mBGL) recorded during site investigations ▸ A deeper aquifer is likely in excess of 30 m.	▸ No information available.	▸ GDEs associated with Sandy Creek ▸ One bore approximately 1.7 km north-east of the enhancement site.
Pearson Street bridge	▸ Lachlan fractured rock groundwater system ▸ Wagga Wagga Alluvial groundwater system ▸ Recharged by direct rainfall, or rainfall in areas of topographic highs to the south east ▸ Groundwater flow would be controlled by localised topography, towards the north–north west.	▸ Monitored groundwater ranged from 184–185.2 mAHD ▸ Groundwater levels (based on long-term data) show strong correlation to climatic conditions, with a strong variability close to the enhancement site.	▸ Quality: fresh ▸ Salinity category: A1 (see Table 19-4 for beneficial uses) ▸ Hydraulic conductivity: 0.10 m/day ▸ Groundwater quality may be influenced by dewatering to manage localised groundwater salinity issues within its vicinity.	▸ Nearest GDE is located around 300 m to the north of the enhancement site.
Cassidy Parade pedestrian bridge, Edmondson Street bridge, Wagga Wagga Yard clearances	▸ Lachlan fractured rock groundwater system ▸ Recharged by direct rainfall, or rainfall in areas of topographic highs to the south ▸ Groundwater flow would be controlled by localised topography, and flow towards the north.	▸ BH210: between 10.9–11.1 mBGL at BH210 ▸ Wagga Wagga Council monitoring bore 20: ranged from 4.5 mBGL to greater than 14.9 mBGL.	▸ BH210 quality: fresh ▸ BH210 salinity category: A1 (see Table 19-4 for beneficial uses) ▸ Monitoring bore 20 salinity: B to C2 (see Table 19-4 for beneficial uses) ▸ Groundwater quality may be influenced by dewatering to manage localised groundwater salinity issues within its vicinity.	▸ None identified.
Bomen Yard clearances	▸ Lachlan fractured rock groundwater system ▸ Recharge from rainfall infiltration is considered the dominant recharge mechanism ▸ Groundwater flow likely to follow topography, towards the west to north west.	▸ Between 12–15 mBGL ▸ Perched water may exist at soils and weathered rock interface ▸ Shallow permanent groundwater table is predicted to be greater than 2.1 mBGL.	▸ No information available.	▸ Bore GW402633 ▸ Low potential GDEs of Blakely's Red Gum and Yellow Box grasses.

1. Groundwater quality relates to the condition of groundwater within a groundwater source and its suitability for different purposes.
2. Hydraulic conductivity measures the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of 1 m^2 under a unit hydraulic gradient at right angles to the direction of flow (m/day).

Junee

Table 19-11 provides a summary of the groundwater conditions at the Junee precinct enhancement sites based on available information.

TABLE 19-11 CONCEPTUAL HYDROLOGICAL MODEL—ENHANCEMENT SITES (JUNEE PRECINCT)

Enhancement site	Details	Groundwater levels	Groundwater quality[1]/hydraulic conductivity[2]	Nearby sensitive receivers
Harefield Yard clearances	▸ Lachlan fractured rock groundwater system ▸ Recharge from rainfall infiltration is considered the dominant recharge mechanism ▸ Additional recharge likely provided through hydraulic connection with Reedy Creek during high-flow conditions ▸ Groundwater flow is predicted to follow topography, towards the north-west.	▸ Recorded groundwater levels between 15.0–25.0 mBGL ▸ The shallow permanent groundwater table is predicted to be greater than 2.0 mBGL under non-flooding or high-flow creek conditions.	▸ Qualitative statement of 'very good' in the records for bored GW019704 (WaterNSW, 2021).	▸ Three registered water supply bores within groundwater study area ▸ Low potential GDEs of yellow box are located adjacent to the southern end of the enhancement site.
Kemp Street bridge	▸ Localised depression filled with minor alluvial and colluvial sediments from the surrounding Lachlan fractured rock groundwater system ▸ Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs located to the east and west, which would influence the groundwater quality and likely be similar to the groundwater quality monitored at Olympic Highway underbridge, Junee (brackish, beneficial use category B) ▸ Indication of a non-permanent groundwater source (perched system) dominated by evaporation, or a limited hydraulic conductivity and yields exists above Lachlan fractured rock groundwater system ▸ Groundwater flow would follow topography and flow towards the north to north-west.	▸ No site investigations were completed ▸ Conditions predicted to be similar to conditions at Kemp Street bridge and Olympic Highway underbridge enhancement sites.	▸ No information available ▸ Groundwater quality and hydraulic conductivity likely to be similar to Olympic Highway underbridge.	▸ One bore within 20 m (GW064614) ▸ Limited connectivity with GDEs.
Junee Yard clearances	▸ Localised depression filled with colluvial sediments from the surrounding Lachlan fractured rock groundwater system ▸ Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs ▸ Groundwater flow is anticipated to follow topography, generally towards the north-west.	▸ No site investigations were completed ▸ Conditions predicted to be similar to conditions at Kemp Street bridge and Olympic Highway underbridge enhancement sites.	▸ No information available ▸ Groundwater quality and hydraulic conductivity likely to be similar to Olympic Highway underbridge.	▸ Limited connectivity with GDEs.

Enhancement site	Details	Groundwater levels	Groundwater quality[1]/hydraulic conductivity[2]	Nearby sensitive receivers
Olympic Highway underbridge	▸ Localised depression that overlies colluvial and residual deposits of the Lachlan fractured rock groundwater system ▸ Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs ▸ Groundwater flow is predicted to follow topography, flow towards the south along the enhancement sites then towards the west.	▸ BH215 between 9.5–10 mBGL ▸ Perched, temporary water may be present at fill, soil and shallow rock interfaces ▸ Groundwater is predicted to be greater than 9.5mBGL.	▸ Quality: brackish ▸ Salinity: B (see Table 19-4 for beneficial uses) ▸ Hydraulic conductivity: 0.11 m/day.	▸ Limited connectivity with GDEs.
Junee to Illabo clearances	▸ Lachlan fractured rock groundwater system ▸ Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs ▸ Groundwater flow is predicted to follow topography, flow to the northeast.	▸ Limited registered bores drilled into the Lachlan fractured rock deep groundwater system ▸ No reviewed records contained groundwater level information, one bore (GW401369) identified water bearing zones starting from 19 mBGL ▸ Groundwater is predicted to be greater than 2.0 mBGL.	▸ Quality: brackish.	▸ One bore (GW401369).

1. Groundwater quality relates to the condition of groundwater within a groundwater source and its suitability for different purposes.
2. Hydraulic conductivity measures the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of 1 m^2 under a unit hydraulic gradient at right angles to the direction of flow (m/ day).

19.4 Impact assessment—construction

Table 19-12 identifies the potential risks to the groundwater environment resulting from the proposal. The risks to the hydrogeological environment are the same for both the construction and operation of the proposal but would manifest through different construction or operation activities and for different durations.

The key issue identified for the proposal is the risk associated with excavations that could intersect aquifers (such as track lowering or bridge works). Dewatering of excavations (or cuts), whether temporary or permanent, have the potential to lower groundwater levels, reducing the availability of groundwater to nearby sensitive receptors such as GDEs or nearby users of groundwater. Where bridge piling or the construction of soil retaining walls are to occur, impedance to groundwater flow can also occur. This can result in changes to groundwater levels and quality.

The majority of the enhancement sites are assessed to have either no impacts or low-to-negligible impacts to groundwater. Three enhancements sites, the Riverina Highway bridge (Albury), the Pearson Street bridge (Wagga Wagga) and the Kemp Street bridge (Junee) have been assessed as having a greater than low risk rating and, therefore, impacts at these sites have been considered further in section 19.4.2.

TABLE 19-12 POTENTIAL RISK TO THE GROUNDWATER DURING CONSTRUCTION

Risk	Description of impact and cause	Potential construction activity resulting in impact type
Groundwater level decline due to dewatering	Dewatering resulting in groundwater level decline, potential impact to groundwater resources and sensitive receptors.	Earthworks for removal of existing infrastructure, foundation improvements, relocating service utilities, piling for bridges and track lowering. Groundwater take for construction water supply.
Changes to groundwater quality (salinity)	Changes to groundwater flow paths, including introduction of groundwater flow barriers or groundwater discharges which may change groundwater quality. Changes to groundwater levels and quality resulting from salinity can impact sensitive receptors such as registered bores and GDEs.	Drainage diversions associated with construction. Piling for bridge foundations. Construction of soil retaining walls.
Settlement	Changes to soil moisture content causing compression or settlement.	Cuts for the rail alignment that result in dewatering. While the risk could occur during construction, settlement impacts would typically manifest during the operational phase.
Contamination	Degradation of water quality through the introduction of new contaminants or the movement of potentially existing contamination plumes within the groundwater environment. Impact to existing groundwater contamination, resulting in potential spread to other areas.	Storage, spillage and leaks of hazardous substances used during construction. This potential impact is considered in section 20.3.2. Cuts for the rail alignment, piling for the bridge foundations and construction of soil retaining walls that alter groundwater flow paths, distributing existing contaminants. Importation and use of contaminated fill.
Changed recharge	Changes to groundwater recharge through altering surface infiltration, degree of evapotranspiration and groundwater seepage along the high wall of cuts leading to changes in groundwater availability for sensitive receptors, including GDEs.	Drainage diversions and general construction activities that result in changes to surface infiltration, such as the creation of construction accommodation, access paths and removal of vegetation.

19.4.1 Enhancement sites with negligible or low risk of impact

Enhancement sites have been assessed as having either no impacts or low-to-negligible impacts to groundwater based on the following constructability or landscape factors:

- limited depth of bulk excavations and/or extent of earthworks compared to predicted groundwater levels, which indicates that the water table would not be intersected, thus limiting the connection between construction and groundwater
- no-to-minimal change in the current landform that would significantly alter recharge such as changes to drainage, hardstand areas or landform use, also reducing the risk of mobilising contaminants or reducing water quality.
- potential minimal and localised groundwater intersection from piling (if required)
- distance to sensitive receivers, registered water supply bores and/or GDEs
- registered water supply bores are predicted to take groundwater from the deeper relevant groundwater system (i.e. a different groundwater source).

For further discussion on enhancement sites with negligible or low potential risk of impact refer to section 5.2.1 of Technical Paper 12: Groundwater.

19.4.2 Enhancement sites with increased risk of impact

The following enhancement sites were identified to contain potential risks greater than low, against one or more of the assessed risks outlined in Table 19-12.

Riverina Highway bridge enhancement site

The proposed works at the Riverina Highway bridge enhancement site involve the lowering of the track by up to one metre, installation of soil retaining walls and an underground storage tank. Groundwater is not anticipated to be intersected for the typical bulk excavation depths of up to 2.1 mBGL required for track lowering, foundation material improvement and installation of soil retention walls. However, the installation of the underground storage tank to a base excavation level approximately 8.9 mBGL is below the monitored maximum groundwater level (7.33–7.72 mBGL). This would result in approximately up to 1.8 m of dewatering during construction for its installation. The proposed construction impacts of the Riverina Highway bridge identified in Technical Paper 12: Groundwater include:

- 0.7 ML estimated to be dewatered with a radius of influence of up to 5.8 metres based on dewatering for 21 days
- localised groundwater flow paths and levels would be impacted from dewatering. Changes to groundwater flow paths and levels may disturb and migrate potential existing contamination or saline groundwater.

Given the radius of influence (5.8 m), the distance to GDEs (over 700 m) and registered bores (around 100 m), and the minimal time dewatering is required, the risk of groundwater take impacting these GDEs and registered bores is predicted to be negligible to low.

As dewatering is temporary (21 days) with a limited range of influence, no significant changes to soil moisture content are predicted and, therefore, the risk of settlement and deflection induced by dewatering on adjacent infrastructure is assessed as low. Likewise, due to the small surface area of (64 m^2) for the underground storage tank, it is not predicted to impact the recharge of the groundwater system through changes in infiltration or act as a barrier to groundwater flows.

Pearson Street bridge enhancement site

The proposed works at the Pearson Street bridge enhancement site have a potential moderate risk of intersecting the water table during construction. This is due to long-term historical groundwater monitoring undertaken by Wagga Wagga City Council, indicating that groundwater levels have a strong correlation to climatic conditions and groundwater level responses can vary significantly depending on location, with up to a 3.4 m fluctuation observed over 28 years at one nearby Wagga Wagga City Council monitoring bore. The works at this location include:

- track lowering by up to 1.5 m and installation of soil retaining walls
- the total depth of excavations is expected to be up to 2.8 mBGL
- piling works are also expected to extend to a maximum depth of 15 mBGL
- the work is proposed to take around 30 days to complete
- groundwater depth at the enhancement site is around 1.3–2.5 mBGL with groundwater of high quality suitable for raw drinking water.

The required depth for bulk excavations would be above the monitored groundwater levels. The hydrogeological conceptual model indicates that the groundwater level at the enhancement site likely has a strong correlation to climatic conditions and monitored groundwater levels could be influenced from nearby pumping. As such, there is a risk that groundwater levels could be elevated during construction if wetter climatic conditions occur or there are changes to pumping (if influenced). Under the above conditions there is an increased risk that potential elevated groundwater levels may be intersected during bulk excavations resulting in groundwater intersection and take.

Given the anticipated groundwater levels under current monitoring conditions, bulk excavations are not anticipated to intercept the water table. As no groundwater take is anticipated, and the existing land use would not significantly alter during construction to impact groundwater recharge from infiltration, the risk and resulting impacts from dewatering, settlement, contamination and recharge would be low, including any impacts to GDEs or registered users.

There is, however, a low-to-moderate risk that groundwater levels could be elevated at the time of construction due to future climatic conditions. This could result in potential groundwater take; however, the short timeframe required for the excavation works would limit potential impacts. GDEs located down-gradient from Pearson Street bridge are likely to supported by its local groundwater environment's hydraulic connection to surface water features, such as the Murrumbidgee River and its associated lagoons and oxbows.

Retaining walls, supported by piling methods such as secant piling, have the potential to act as groundwater flow barriers, altering groundwater flows and impacting local groundwater levels. Groundwater mounding, resulting in increased groundwater levels may occur up-gradient of the barrier (south to south-eastern section of the proposal) and shadowing, resulting in decreased groundwater levels down gradient. While the retaining walls would be perpendicular to the inferred groundwater flow path, they are limited in extent to the area underlying and proximal to Pearson Street bridge. This limited extent would result in a minor impediment to the regional groundwater flow and is unlikely to cause any perceivable impacts to GDEs or registered bores; therefore, the resulting risk and impact to changes in water quality from salinity would be low.

Kemp Street bridge enhancement site, Junee

The proposed works at Kemp Street bridge enhancement site involves a bridge replacement and installation of supporting walls. Earthworks would be required and excavations would predominately involve stripping of soil to allow for capping of the existing foundations, installation of supporting walls and treatment of foundation material. Total depth of bulk excavations is anticipated to be up to 5.0 mBGL. Piling would be required to support the new bridge and is anticipated to extend up to 30mBGL. Excavation earthworks are anticipated to take approximately 25 days.

Given the current design depths required for construction, it is anticipated up to approximately 1.8 m of groundwater in the shallow Lachlan fractured rock groundwater system would be intersected and require dewatering. Groundwater is predicted to be intersected during excavation required for the treatment of soil foundations and construction of the soil retaining wall. Piling is anticipated to also intersect the shallow Lachlan fractured rock groundwater system aquifer and potentially the deeper aquifer system if water bearing zones are present at depth; however, using appropriate piling techniques, no dewatering resulting from piling is predicted to occur.

The proposed construction impacts of the Kemp Street bridge identified in Technical Paper 12: Groundwater include:

- 11.4 ML estimated to be dewatered with a radius of influence of up to 5.1 m based on dewatering for 25 days
- localised groundwater flow paths and levels would be impacted. The changes to groundwater flow paths and levels may disturb and migrate potential existing contamination or saline groundwater
- there is a moderate risk of dewatering impacting a neighbouring water supply bore (GW064614) that is located approximately 7.5 m of the dewatering activity.

Given the calculated radius of influence (5.1 m) and the distance to GDEs (around 500 m), the risk of dewatering impacting GDEs is low. Additionally, these GDEs are situated within different localised topographic terrains from the point of dewatering, further reducing the risk of impact due to reduced groundwater connectivity within the proposal site. Given dewatering is temporary and for a relatively short duration, the groundwater is predicted to recover with no long-term impact. In the event that bore GW064614 was significantly impacted (unlikely), make-good provisions would apply.

As dewatering is temporary, no significant changes to soil moisture content are anticipated outside natural conditions and, therefore, the risk of settlement and deflection induced by construction dewatering on adjacent infrastructure is anticipated to be low. Likewise, given the proposal is not altering the existing land use (rail) during construction, the impact to groundwater recharge is assessed low. This is due to the site already being modified to accommodate rail, including altering drainage patterns, piling for bridge foundations and soil retaining walls.

19.4.3 Water supply

As outlined in Chapter 8: Construction of the proposal, water for various construction activities would be required, including, but not limited to: rail formation, road pavement, earthworks, concrete structures and dust control. Overall, the proposal would require around 56.9 ML of water and would be sourced from existing water suppliers.

Further investigation of options for the provision and storage of construction water would be undertaken during detailed design, in consultation with local councils and landowners. The preferred source of construction water and method of storage would be confirmed prior to the construction commencement date. If groundwater is used to supply a percentage of construction requirements, existing allocations would be purchased and would not result in additional groundwater taken outside of what has already been allocated through available water determination.

Groundwater take resulting from dewatering during construction was identified at Riverina Highway bridge and Kemp Street bridge enhancement sites, and includes:

- dewatering at Riverina Highway bridge enhancement site would result in an estimated take of 0.7 ML from the Upper Murray (alluvium) groundwater source which is negligible compared to regional data. As discussed in section 19.4.2, potential impacts of dewatering would be low at this site
- dewatering at Kemp Street bridge enhancement site would result in an estimated take of 11.4 ML from the Lachlan fractured rock groundwater system which is negligible compared to regional data. As discussed in section 19.4.2, potential impacts of dewatering would be low to moderate at this site.

ARTC or its contractor would obtain a relevant water access licence for the groundwater take at Kemp Street bridge enhancement site with sufficient volume to cover estimated groundwater take resulting from dewatering, subject to confirmation of this during detailed design. The volume of water take from Riverina Highway bridge would be exempt from requiring a water access licence (refer to section 4.3.3 of the EIS).

Potential groundwater take resulting from the proposal (including dewatering) would not impact on the current water balance of the Billabong Creek (alluvium), Wagga Wagga Alluvial or Lachlan Fold Belt Murray–Darling Basin groundwater systems as the estimated dewatering volume is negligible compared to regional water take. Depending on groundwater usage during the construction year at the Riverina Highway bridge enhancement site in Albury, there is potential that the required groundwater take would contribute additional impact above the sustainable limit of the Upper Murray groundwater source; however, any additional impact would be minor given the low predicted dewatering volumes (0.7 ML).

19.5 Impact assessment—operation

Operational risks and impacts are lower than during the construction phase for the proposal as the operation contains:

- a shallower permanent footprint—that is, the excavation depths during construction would be deeper than the final permanent footprint of the bridge foundations and rail design level
- return to pre-existing land use and operation procedures.

Most enhancement sites would result in minimal vertical change to the alignment except for the Riverina Highway bridge, Billy Hughes bridge and Pearson Street bridge enhancement sites as they require permanent track lowering. Therefore, to assess the operational risks and impacts, the sites with track lowering have been consider separately in this section.

Flooding mitigation and drainage design for the proposal would mimic existing discharge conditions at all enhancement sites and therefore the risk of impact to the groundwater environment resulting from flooding mitigation and drainage design is considered comparable and low. This is considered further in Chapter 18: Hydrology, flooding and water quality.

Accidental spillage as a result of leakage or rail accidents would also be minimised by implementing existing ARTC procedures to manage the potential leaks and spills. This is considered further in Chapter 24: Hazards of the EIS.

19.5.1 Enhancement sites with no track lowering

Groundwater is not anticipated to be impacted during operation of the proposal given its depth and the operational use would remain consistent with the current land-use activities (rail). The following enhancement sites contain no track lowering and minimal underground infrastructure that may impact or impede groundwater, either due to the depth of groundwater or limited extent of underground infrastructure. Further, there would be no material change to existing drainage or flow paths as a result of the proposal.

TABLE 19-13 LOW OPERATIONAL RISK AND IMPACT TO THE GROUND WATER ENVIRONMENT

Precinct	Enhancement site
Albury	- Murray River bridge - Albury Station pedestrian bridge - Albury Yard clearances - Table Top Yard clearances

Precinct	Enhancement site
Greater Hume, Lockhart	▸ Culcairn pedestrian bridge ▸ Culcairn Yard clearances ▸ Henty Yard clearances ▸ Yerong Creek Yard clearances ▸ The Rock Yard clearances
Wagga Wagga	▸ Uranquinty Yard clearances ▸ Edmondson Street bridge ▸ Wagga Wagga Station pedestrian bridge ▸ Wagga Wagga Yard clearances ▸ Bomen Yard clearances
Junee	▸ Harefield Yard clearances ▸ Kemp Street bridge ▸ Junee Station pedestrian bridge ▸ Junee Yard clearances ▸ Olympic Highway underbridge ▸ Junee to Illabo clearances

The operational impacts for these sites would be similar to, or lower than those described during construction. Likewise, the risks and impacts for these sites would be comparable to the existing operation of the rail corridor representing negligible change to the existing environment.

19.5.2 Enhancement sites with track lowering

The following enhancement sites contain an increased risk of groundwater impact due to their design requiring track lowering or underground infrastructure that may impact or impede groundwater flow due to its depth or extent.

- Riverina Highway bridge (Albury precinct)
- Billy Hughes bridge (Albury precinct)
- Pearsons Street bridge (Wagga Wagga precinct).

Riverina Highway bridge enhancement site

At Riverina Highway bridge enhancement site, track lowering was not anticipated to intersect groundwater (with excavation 5 m above the groundwater level) at the enhancement site. Due to this, track lowering would also have no impact on operation of the proposal.

However, the storage tank would be partially below the groundwater table. The storage tank would be constructed with near-impermeable material and given its small area (64 m^2), impacts to changes in groundwater levels, quality (contamination and salinity) and recharge are assessed to be low. This is also due to the structural integrity of the storage tank that would minimise the potential for leaks as well as the scale of the storage tank compared to the regional groundwater catchment and hence would not result in retardation or flow impacts on a regional scale.

For the same reasons outlined in the construction phase and, given that operation would be comparable to current operation activities and do not require dewatering, all risks and impacts are assessed to be low.

Billy Hughes bridge enhancement site

At the Billy Hughes bridge enhancement site, which contains track lowering, the groundwater environment was not anticipated to be impacted during construction although excavations were required. As the groundwater environment was not anticipated to be impacted in construction, groundwater is also not anticipated to be intersected during operation which requires no excavation. Any underground infrastructure, such as retaining walls, would be above the groundwater table and not impede its flow.

Pearson Street bridge enhancement site

The Pearson Street bridge enhancement site has the potential to cause continuous impact to the groundwater by alternating localised flow paths, and potential continued groundwater take if the new track elevation intersects the groundwater aquifer. The final design of the track lowering at the site is around 2.1–3.3 m above the monitored groundwater level.

There is a low-to-moderate risk groundwater above the track at intermittent periods given:

- groundwater levels can fluctuate over time and under different climatic conditions. Nearby monitoring bores have shown varying degrees of response to climate and local conditions
- current monitoring data indicates groundwater is influenced by local external forces, not just rainfall.

Should groundwater rise to the elevation of the track, this is predicted to be intermittent at most, and likely result in seepage through the base of the foundation drainage layer and into the installed surface water drainage network, this would result in potential groundwater take. It is not predicted to result in declining groundwater levels as it would only occur under wetter climatic conditions (i.e. when groundwater levels are rising). Therefore, the impact and risk to GDEs and registered water supply bores is assessed as low. The design has been designed to accommodate this potential seepage.

Changes in groundwater levels and flow paths may mobilise contaminants or salinity, potentially impacting nearby sensitive receivers. It is anticipated that under wetter climatic conditions where groundwater would be shallower, the quality (salinity) is anticipated to become fresher due to the increased recharge from rainfall infiltration. This would result in negligible risk to GDEs and registered water supply bores.

The presence of shallow, saline groundwater has been considered in the design. Sampling completed as part of the geotechnical investigation for the proposal included consideration of salinity and aggressivity (a measure of the potential for corrosion to occur on concrete or steel structures). Where aggressive soil and groundwater conditions have been recorded, these conditions would be considered during detailed design in the specification of material selection and thickness to allow for adequate durability.

As the operation of the proposal would not result in ongoing dewatering, soil moisture contents are not predicted to decrease outside their natural variation.

The operational use at Pearson Street bridge is comparable to existing land use activities (rail infrastructure). Therefore, there would be no changes to increase to existing impacts on recharging the groundwater system compared to current operations.

19.5.3 Water balance

Groundwater is not required for the operation of the proposal. Any water required during maintenance activities would be brought to site in accordance with ARTC's existing maintenance procedures; therefore, there would be no impact on water availability due to operation of the proposal. Maintenance activities are not predicted to require excavation to depths at which groundwater may be encountered.

As discussed in section 19.5.2, there is a low-to-moderate risk that groundwater may seep into the rail alignment at Pearson Street bridge enhancement site under different climatic conditions. However, this seepage would be intermittent and limited in extent therefore limiting any impact of the proposal on the existing relevant groundwater systems. The potential groundwater inflows would mix into designed drainage infrastructure with surface water flows and would likely form a small component of the total discharge water. Therefore, it is anticipated to have limited impact on the designed discharge quality and volumes.

19.6 Minimal impact consideration

The groundwater systems within the study area considered to be:

- less productive:
  - Lachlan fractured rock groundwater system—due to typically low yields and saline groundwater quality
  - Upper Murray (alluvium) groundwater system—due to low yields within the shallow aquifer
  - Billabong Creek (alluvium) groundwater system—due to low yields and saline groundwater quality
- highly productive:
  - Wagga Wagga Alluvial groundwater system —due to high yields and low TDS content.

An assessment of the proposals impacts from the potential changes in groundwater levels and quality on GDEs, beneficial use category, water supply works (i.e. registered bores), highly connected surface water source and culturally significant sites are provided in sections 19.4 and 19.5. The assessment of the proposal's impacts on aquifers and GDEs in regard to the minimal impact considerations of the *NSW Aquifer Interference Policy* indicates the proposal complies with Level 1 criteria, which considers the potential impacts acceptable.

Interference approvals under the *Water Management Act 2000* (NSW) have yet to commence; however, the aquifer interference policy is used to guide proponents and the Department of Planning and Environment (DPE) in assessing aquifer interference activities. Refer to section 4.3.3 for further information on approvals relaying to the *Water Management Act 2000* (NSW).

19.7 Mitigation and management

19.7.1 Approach to mitigation and management

Environmental management for the proposal would be carried out in accordance with the environmental management approach, as detailed in Chapter 27: Approach to mitigation and management and Appendix H: Construction environmental management plan outline of the EIS.

As construction activities have the potential to impact the groundwater environment, a groundwater management sub-plan (GWMP) would be prepared, and form part of the Construction Environment Management Plan (CEMP). The GWMP would comply with the proposal conditions and be implemented to monitor the effectiveness of mitigation and management measures applied during the construction of the proposal. The GWMP would include (but not be limited to):

- groundwater monitoring program, including the monitoring network, frequency of monitoring and test parameters
- a dewatering protocol, including the disposal, treatment or reuse of the extracted groundwater
- details for the disposal, treatment or reuse or extracted groundwater
- include requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.

The GWMP would be developed by a suitably qualified person and would determine the location and number of monitoring bores required to monitor the potential risk from construction.

Mitigation and management measures are outlined in the following sections to reduce the risk of the proposal's impact on the hydrogeological environment. The measures target key stages of the proposal: detailed design, pre-construction, construction and operation.

19.7.2 Mitigation measures

Measures that would be implemented to address potential impacts on groundwater are listed in Table 19-14.

TABLE 19-14 GROUNDWATER MITIGATION MEASURES

Stage	Ref	Impact/issue	Mitigation measure
Detailed design/ pre-construction	GW1	Groundwater interaction	Preliminary groundwater monitoring at all enhancement sites requiring excavations greater than 0.5 m below ground level will be completed to inform detailed design and confirm potential interaction with groundwater at these enhancement sites. This work may include design responses such as the installation of appropriate drainage measures and refinement of estimated groundwater take at Kemp Street bridge with an aim to minimise dewatering volumes.
Detailed design/ pre-construction/ construction	GW2	Groundwater monitoring	A groundwater monitoring program (level and quality), prepared by a suitably qualified person, will be implemented in accordance with the requirements outlined in this assessment prior to construction. This work will identify ongoing monitoring requirements following the completion of construction according to the risks to groundwater levels and quality. Ongoing groundwater monitoring (level and quality) will be carried out at the sites for the duration specified in the groundwater monitoring program.
Detailed design/ pre-construction	GW3	Groundwater interaction	Opportunities to use appropriate piling construction methodologies for bridge foundations that minimises groundwater take, such as the use of a tremie system, will be investigated during detailed design and implemented where practicable.
Detailed design	GW4	Groundwater	The quality of groundwater taken during excavation works at Riverina Highway bridge and Kemp Street bridge enhancement sites will be assessed for the suitability for re-use during construction (or by others), or disposed of accordingly.
Detailed design/ construction	GW5	Groundwater	Registered bore GW402492 at the Olympic Highway underbridge enhancement site will be avoided during construction. If this registered bore is accidently damaged during construction and cannot be used for its intended purpose (monitoring), make good arrangements will apply (such as replacement), subject to discussion with the registered owner.
Construction	GW6	Groundwater	Site inspection will be carried out to confirm the current viability of registered bore GW064614 (water supply) at Kemp Street bridge enhancement site. In the event that the bore is viable and the AIP minimal impact considerations are temporarily or permanently exceeded, make good provisions will apply.

Effectiveness of mitigation measures

The mitigation measures specified in Table 19-14 are anticipated to reduce the likelihood and/or consequence of the identified risks. The additional investigations would enable the mitigation to be tailored to the local conditions to ensure the effectiveness of the proposed mitigation measures. Further, the groundwater monitoring program for the proposal would confirm the effectiveness of the mitigation measures.

19.7.3 Interactions between mitigation measures

Mitigation measures to minimise the potential impacts to groundwater would also be implemented as part of those identified for Chapter 18: Hydrology, flooding and water quality and Chapter 20: Soils and contamination.

19.7.4 Residual risk

Residual impacts are impacts of the proposal that may remain after implementation of the management and mitigation measures detailed in sections 19.7.1 and 19.7.2. These are summarised in Table 19-15.

Further information on the approach to the environmental risk assessment, including descriptions of criteria and risk ratings, is in Appendix E: Environmental risk assessment.

TABLE 19-15 RESIDUAL RISK MANAGEMENT—GROUNDWATER

Stage	Potential impact	Pre-mitigated rating	Mitigation measures[1]	Residual risk rating	Residual risk management[2]
Construction	Contamination from construction activities, including accidental spills and leaks, impacting groundwater quality.	Low	CEMP	Low	N/A
Construction	Degradation of groundwater water quality through changes to groundwater flow paths.	Low	Groundwater monitoring program	Low	N/A
Construction	Construction work resulting an increased risk to nearby groundwater bores, GDEs and watercourse base flow due to groundwater drawdown and/or changes to quality and quantity.	Medium	GW3, GW5, GW6	Low	N/A
Construction	Changes to soil moisture content causing compression or settlement.	Low	N/A	Low	N/A
Operation	Changes to recharge due to drainage diversions or increased impervious surfaces.	Low	N/A	Low	N/A
Operation	Contamination of groundwater from maintenance procedures during the operational phase.	Low	Managed in accordance with ARTC procedures	Low	N/A

1. As described in Table 19-14.
2. For residual impacts with a risk rating of medium or above.