TECHNICAL REPORT 6

Groundwater Impact Assessment

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT

Technical and Approvals Consultancy Services: Illabo to Stockinbingal

Technical Paper 6 – Groundwater Impact Assessment

July 2022

2-0001-220-ESV-00-RP-0002

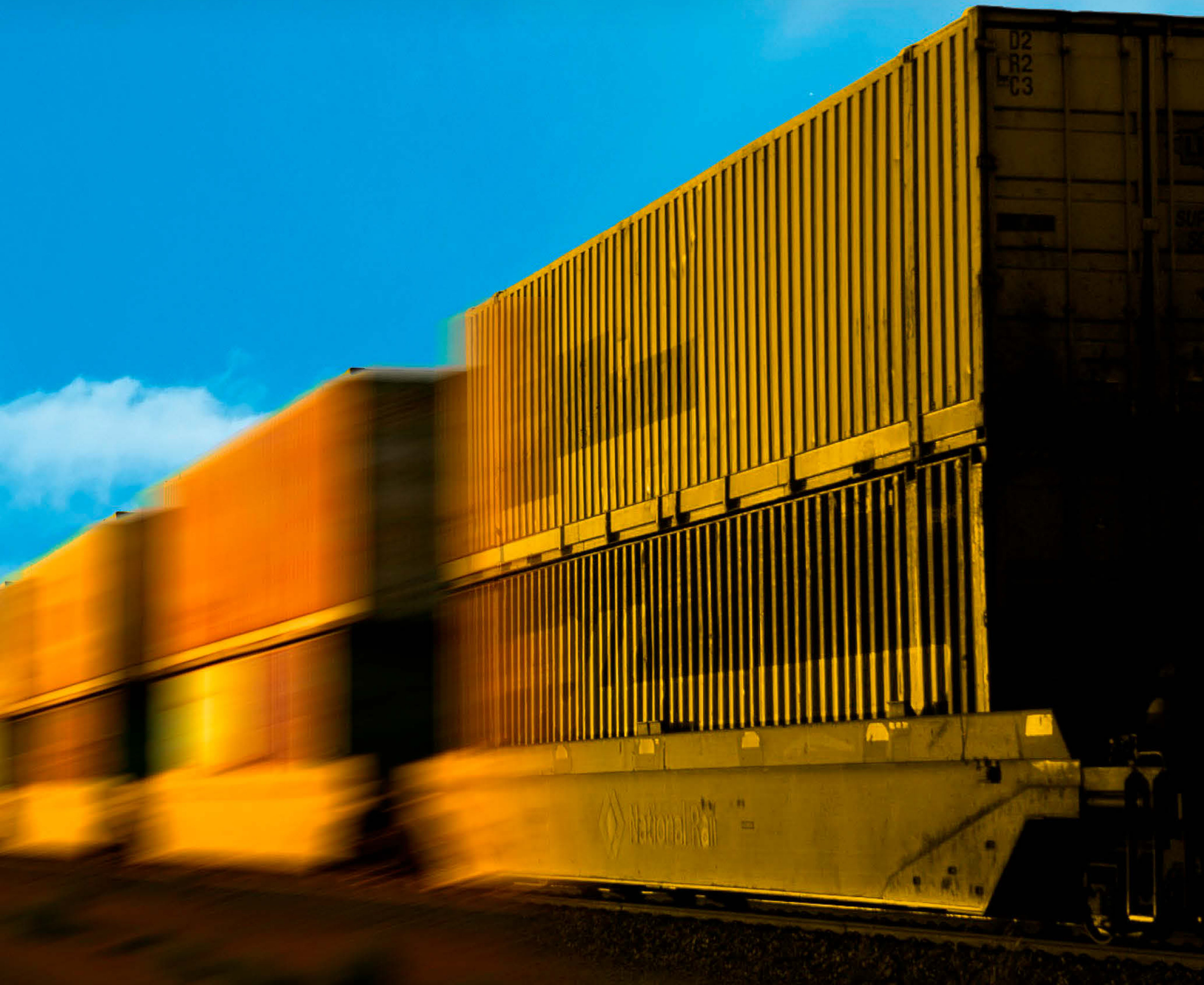


Table of contents

Table of contents (continued)

Table of contents (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Glossary

Alignment	The geometric layout (e.g. of a road or railway) in plan (horizontal) and elevation (vertical).
Alluvial	Sediments deposited by flowing water.
Alluvium	General term for unconsolidated deposits of inorganic materials (clay, silt, sand, gravel, boulders) deposited by flowing water.
Aquifer	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.
Bore	Artificially constructed or improved groundwater cavity used for the purpose of accessing or recharging water from an aquifer. Interchangeable with borehole, piezometer.
Borehole	Includes a well, excavation, or other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. Interchangeable with bores, wells, piezometers.
Catchment	The land area draining through the main watercourse, as well as tributary watercourses, to a site. It always relates to an area above a specific location.
Conceptual model	A simplified and idealised representation of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Confined aquifer	An aquifer 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.
Datalogger	A digital recording instrument that is inserted in monitoring and pumping bores to record pressure measurements and water level variations.
Detailed design	The stage of design where proposal elements are designed in detail, suitable for construction.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second. Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second).
DPE	NSW Department of Planning and Environment, formerly Department of Industry, Planning and Environment
Drawdown	The change in groundwater level in a bore, or the change in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.

Earthworks	All operations involved in loosening, excavating, placing, shaping and compacting soil or rock.
Fault/Fracture zone	Zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Formation	General term used to describe a sequence of rock layers.
Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.
Groundwater flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone.
Hydraulic conductivity	Measure of 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).
Hydraulic gradient	Change in the hydraulic head over a certain distance.
(Hydraulic) head	Elevation to which water will rise in a borehole connected to a point in an aquifer.
Impact	An event that disrupts ecosystem, community, or population structure and alters the physical environment, directly or indirectly.
Infiltration	The downward movement of water from the atmosphere into the ground; not to be confused with percolation.
Inland Rail	The Inland Rail programme encompasses the design and construction of a new inland rail connection between Melbourne and Brisbane, via Wagga, Parkes, Moree, and Toowoomba. The route for Inland Rail is about 1,700km in length. Inland Rail will involve a combination of upgrades of existing rail track and the provision of new track.
The proposal	The construction and operation of the Illabo to Stockinbingal section of Inland Rail.
Proposal site	The area that would be directly affected by construction and operation of the proposal. It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the storage areas/compounds sites etc., that would be used to construct that infrastructure.
Rail corridor	The corridor within which the rail tracks and associated infrastructure are located.
Recharge	Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).

Salinity classification	Fresh water quality – water with a salinity <800µS/cm. Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600µS/cm. Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800µS/cm. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000µS/cm. Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000µS/cm. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000µS/cm. Seawater quality – water that is generally around 55,000µS/cm.
Semi-confined aquifer	An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur, also referred to as a leaky aquifer.
Sensitive receivers	Land uses, landscape features and activities that are sensitive to changes in the environment such as water quality and quantity, noise, vibration, air and visual impacts. Sensitive receivers may include aquatic ecosystems, aquaculture areas, residential dwellings, schools and recreation areas.
Standing water level	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Study area	The wider area including and surrounding the proposal site, with the potential to be directly or indirectly affected by the proposal. The actual size and extend of the study area varies across each technical report, but for use within the groundwater assessment incorporates a 2km buffer surrounding the proposal site.
Trigger values	Trigger values are concentrations in waterways that, if exceeded, indicate a potential environmental problem. Exceedances of these values during monitoring ‘triggers’ an investigation and/or further management response, e.g. additional controls.
Water table	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric; it can be measured by installing shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.

Abbreviations

AHD	Australian height datum
ANZG	Australia and New Zealand Guidelines for Fresh and Marine Water Quality
ARTC	Australian Rail Track Corporation
CDFM	Cumulative deviation from mean
CEMP	Construction Environmental Management Plan
CHM	Conceptual hydrogeological model
DO	Dissolved oxygen
DPE	NSW Department of Planning and Environment, formerly Department of Planning, Industry and Environment (DPIE)
EC	Electrical conductivity
F_3/S_3	Primary structural deformation orientation (approximately NW-N/SE-S) within the Study area
GDE	Groundwater dependent ecosystem
GME	Groundwater monitoring event
GWMMP	Groundwater mitigation and management plan
HSU	Hydrostratigraphic unit
IRDJV	Inland Rail Design Joint Venture – WSP Australia Pty Ltd | Mott MacDonald Joint Venture legal entity
K	Hydraulic conductivity
km	Kilometres
LOR	Limit of reporting
mBGL	Metres below ground level
MDB	Murray-Darling Basin
NATA	National Association of Testing Authorities
SEAR	Secretary’s Environmental Assessment Requirements
SWL	Standing water level
TDS	Total dissolved solids
WBFZ	Water bearing fracture or fault zone
WBM	Water balance model

Executive summary

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate a high performance and direct interstate freight corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland, known as Inland Rail. Inland Rail represents a major national project that will enhance Australia's existing national rail network and serve the interstate freight market.

Approval for the Illabo to Stockinbingal section of the inland rail project is being sought as a critical state significant infrastructure under Division 5.2 of the NSW *Environmental Planning and Assessment Act 1979 (EP&A Act).* Therefore, an Environmental Impact Statement (EIS) is required.

This report has been prepared by Inland Rail Design Joint Venture (WSP/Mott Macdonald) as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to accompany the application for approval of the proposal and addresses the environmental assessment requirements of the Secretary (the SEARs) of the (then) NSW Department of Planning, Industry and Environment (now the Department of Planning and Environment), issued on 30 April 2021.

The key features of the proposal include:

- a total extent of about 42.5 kilometres (km), including about 39km of new, greenfield single track standard gauge railway between Illabo and Stockinbingal
- upgrades of about 3km of existing track for the tie-in works to the existing Main South rail line at Illabo, and the Stockinbingal to Parkes rail line at Stockinbingal
- construction of about 1.76km of new track to maintain the existing connection of the Lake Cargelligo rail line either side of the proposal
- realignment of a 1.4km section of the Burley Griffin Way to provide a road over rail bridge at Stockinbingal
- realignment of Ironbong Road to allow for safe sight lines at the new active level crossing.

A range of infrastructure associated with the operation of the rail corridor would also be installed, including permanent maintenance access roads, signalling and communications, signage, fencing and services and utilities.

Methodology

A desktop study was undertaken to describe the existing environment, characterise the hydrogeology and governing legislation and policies of the Study area. The desktop study was used to inform subsequent designs of the rail alignment and support combined staged hydrogeological and geotechnical field investigations. The combined investigations included the drilling of up to 70 test pits or bore holes, with 11 boreholes converted to monitoring bores to establish site specific aquifer characteristics including groundwater levels and water quality.

Four groundwater monitoring events (GME) of installed monitoring bores were undertaken to capture seasonal variation within the groundwater environment. The first GME was conducted in January 2019 to capture warmer seasonal data and included the installation of dataloggers to monitor changes in groundwater levels. In addition, water quality samples were obtained, and aquifer testing was completed to determine representative conductivity values of the groundwater resources. The second GME was undertaken in May 2019 to target cooler seasonal variation and included the data capture of monitored groundwater levels and groundwater and surface water samples. Following notable climatic changes in 2020, with increased rainfall recorded, a third and fourth GME was undertaken in February 2021 and April 2021, respectively.

Data obtained from the monitoring events and desktop study have been assessed and a conceptual hydrogeological model generated for the Study area.

The existing groundwater sources within the Study area includes the Lachlan fractured rock groundwater source governed by the Murray-Darling Basin Fractured Rock water sharing plan and the Lachlan alluvium governed by the Lachlan Unregulated and Alluvial water sources water sharing plan. These groundwater sources are referred to as the 'Fractured rock' and the 'Lachlan alluvial' within this report.

Groundwater quality results

Groundwater quality testing of the Lachlan alluvial identified the groundwater source as: marginally saline; slightly alkaline; containing a low abundance of dissolved metals; and consisting of Na-Cl-$HC0_3$ dominant water type.

Groundwater quality testing of the fractured rock identified the groundwater source as: marginal to slightly saline; slightly acidic to slightly alkaline; containing variable abundance of dissolved metals between location and across GMEs; and dominated by Na-Cl, Na-Mg-Cl-SO_4 dominant water types.

The identified groundwater quality characteristics were assessed against salinity targets listed in relevant water sharing resources and ANZG guideline values for Protection of Aquatic Ecosystems (fresh waters), 95 per cent level of protection. Groundwater quality was classified as beneficial use category A3 for the Lachlan alluvial and A3 to C1 for the fractured rock groundwater sources. Dissolved metals were generally below the adopted guidelines for the Lachlan alluvial, however quality and exceedances of dissolved metals varied in the fractured rock between location and across GMEs.

Groundwater levels

Only one bore encountered groundwater within the Lachlan alluvium, with the sediments of Billabong Creek, and recorded a groundwater level of around 249–250 metres Australian Height Datum (mAHD), approximately 7–8 metres below ground level (mBGL). Bores drilled within the Lachlan alluvial, proximal to Stockinbingal did not intercept groundwater to 284.65mAHD, approximately 19.15mBGL. A maximum groundwater level variation of 0.88m was recorded during the monitoring period.

Four bores recorded continuous groundwater level fluctuations within the fractured rock aquifer, with groundwater levels ranging from approximately 270mAHD to 365mAHD. Taking into consideration variations in surface ground level, this relates to approximately 2–16 mBGL. A maximum groundwater level variation of 1.84m was recorded during the monitoring period.

Seasonal groundwater level trends for the Lachlan alluvium indicated groundwater levels likely oscillate in response to climatic conditions. Groundwater level trends within the fractured rock varied with declining trends observed in BH213, BH215 and the majority of the monitoring period for BH217. BH054 was stable, whereas BH204 and BH217 (from March 2021) contained increasing groundwater level trends.

Hydraulic testing

Aquifer hydraulic testing was only assessed for the fractured rock aquifer. Three bores were tested and returned hydraulic conductivity values of 1.5×10^{-4}m/day and 10.10m/day. The wide range is attributed to the lower hydraulic conductivity of the bulk rock and the higher conductivity in areas where water bearing fractured zones are intersected.

Risk and impact assessment

Five primary risks were identified resulting from the construction and operation of the proposal. The main risk is associated with potential groundwater take (dewatering). The remaining four primary identified risks are:

- changes to groundwater flow paths or groundwater discharge impacting surface water and groundwater quality
- degradation of water quality through the movement of potentially existing contamination plumes within the groundwater environment
- contamination of groundwater from construction activities during the construction phase and maintenance procedures during the operational phase
- changes to groundwater recharge through altering surface infiltration.

The impact of the proposal on the underlying groundwater sources was assessed to contain a negligible to low risk to the groundwater environment during both construction and operation. This is principally due to the proposal's cut depths not anticipated to intersect the regional groundwater table for the Lachlan alluvial or Fracture rock groundwater sources. In addition, groundwater is currently not a preferred option to be used to support water supply for construction.

The potential groundwater impacts were assessed against the minimal impact considerations of the NSW Aquifer Interference Policy, with the predicted impacts anticipated to be less than level 1 impact considerations.

Any residual risk to the groundwater environment would be reduced by the implementation of appropriate groundwater mitigation and management measures.

1 Introduction

1.1 Overview

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane. Inland Rail involves the design and construction of a new inland rail connection, about 1,700 kilometres (km) long, between Melbourne and Brisbane. Inland Rail is a major national proposal that will enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Illabo to Stockinbingal section of Inland Rail ('the proposal'), which has a total extent of about 42.5km, and consists of about 39km of new, greenfield single track standard gauge railway and associated infrastructure between Illabo and Stockinbingal.

The proposal requires approval from the NSW Minister for Planning under Division 5.2 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Australian Government Minister for the Environment.

This report has been prepared by Inland Rail Design Joint Venture (WSP/Mott Macdonald) as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to accompany the application for approval of the proposal and addresses the Secretary's Environmental Assessment Requirements (SEARs) from the Secretary of the (then) Department of Planning, Industry and Environment (DPIE) (now the Department of Planning and Environment (DPE)), issued on 30 April 2021.

1.2 The proposal

The proposal is located between Illabo and Stockinbingal within the Riverina region of NSW. The location of the proposal is shown in Figure 1.1.

1.2.1 Key features

The key features of the proposal (which would be confirmed during detailed design) are shown in Figure 1.2 and includes:

- a total extent of about 42.5 kilometres, including about 39 kilometres of new, greenfield single track standard gauge railway between Illabo and Stockinbingal, including:
  - a combination of track vertical alignments on existing ground level, on embankments and in cuttings
  - 8 new bridges at watercourses, two road overbridges and one grade separated (road over rail) at Burley Griffin Way
  - one crossing loop and associated maintenance siding
  - construction of new level crossings and alterations of existing level crossings (at public roads and private accesses)
  - stock underpasses and other vehicular crossings on private land to allow for the movement of livestock and vehicles across the rail line
  - installation and upgrade of about 88 new and existing cross drainage culverts below the rail formation and 27 longitudinal drainage culverts below level crossings
  - removal of redundant sections of track along the existing Stockinbingal to Parkes line and Lake Cargelligo line at Stockinbingal

- upgrades of about three kilometres of existing track for the tie-in works to the existing Main South rail line at Illabo, and tie ins to the Stockinbingal to Parkes rail line at Stockinbingal
- construction of about 1.7 kilometres of new track to maintain the existing connection of the Lake Cargelligo rail line either side of the proposal
- realignment of a 1.4 kilometre section of the Burley Griffin Way to provide a road over rail bridge at Stockinbingal
- realignment of Ironbong Road to allow for safe sight lines at the new active level crossing.

Associated infrastructure would include signalling and communications, signage, fencing and services and utilities. The construction of the proposal would also require the following works:

- construction access roads and access tracks
- watercourse crossings
- temporary changes to the road network
- construction compounds.

1.2.2 Timing and operation

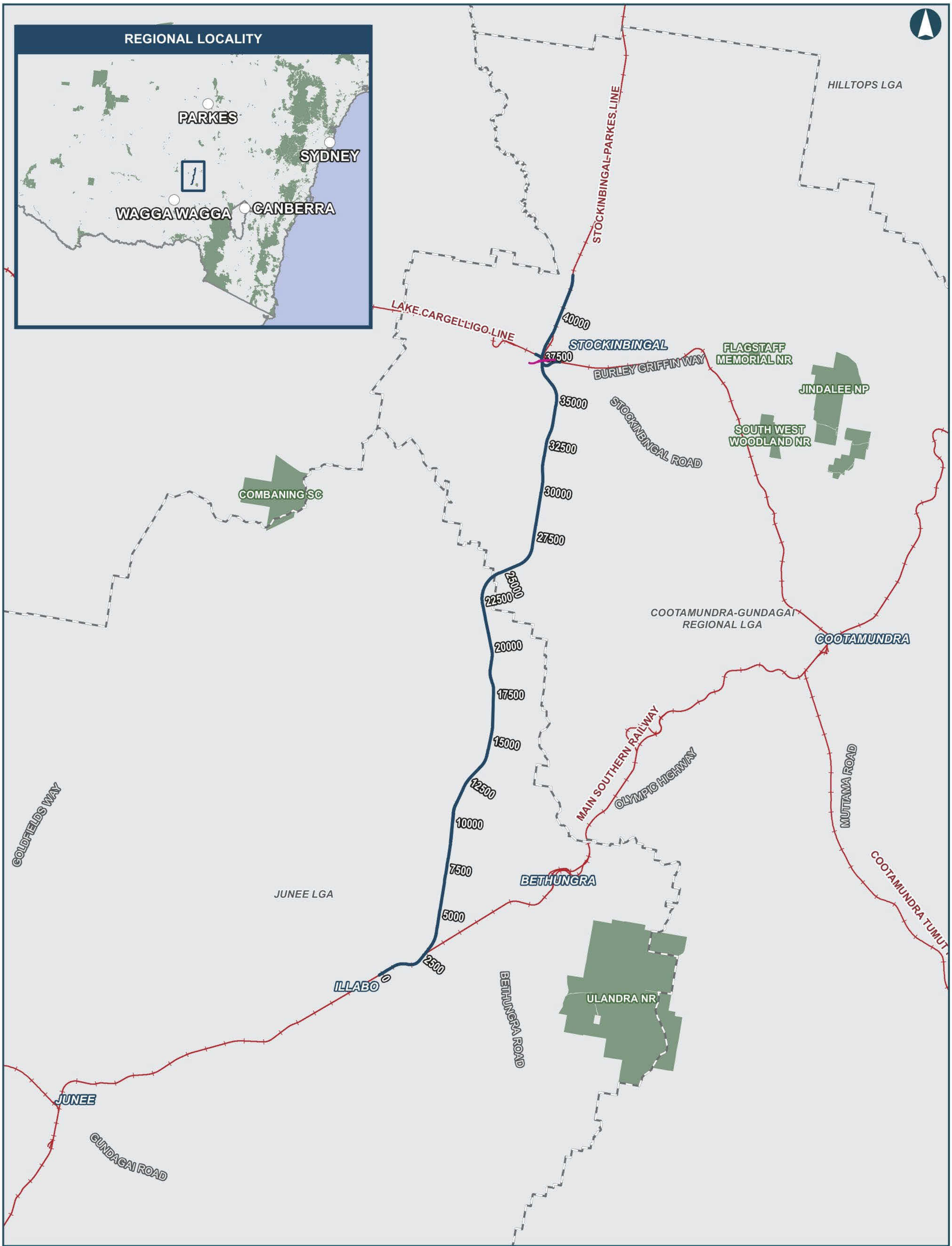
Subject to approval of the proposal, construction of the proposal is planned to start in mid-2024 and is expected to be completed mid-2026.

The proposal would form part of the rail network managed and maintained by ARTC. Train services would be provided by a variety of operators. It is estimated the Illabo to Stockinbingal section of Inland Rail would be trafficked by an average of 6 trains per day (both directions) from commencement of operations in late 2026, increasing to about 11 trains per day (both directions) in 2040.

The new rail line will be a faster, more efficient route that bypasses the Sydney rail network and will enable the use of double stacked trains (up to 6.5 metres high) along its entire length.

The trains would be diesel powered, and would be a mix of grain, intermodal (freight), and other general transport trains up to 1,800 metres in length.

The proposal is expected to be operational, as part of Inland Rail as a whole, once all 13 sections are complete, which is estimated to be in 2027. Prior to that, regional rail movements may occur on the Illabo to Stockinbingal section once complete.



ILLABO TO STOCKINBINGAL 1.1 Location of the proposal

0 2 4 6 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 7/23/2021 Paper: A3
Author: IRDJV Scale: 1:200,000
Data Sources: ARTC, NSWSS, ESRI

Key features of proposal
- Key features of proposal
- 40950 Chainage (distance in metres from southern limit of the proposal)
- Burley Griffin Way realignment

Existing features
- Local Government area boundary
- Existing rail
- Parks and reserves
- Sub-arterial road
- Arterial road

INLAND RAIL ARTC

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

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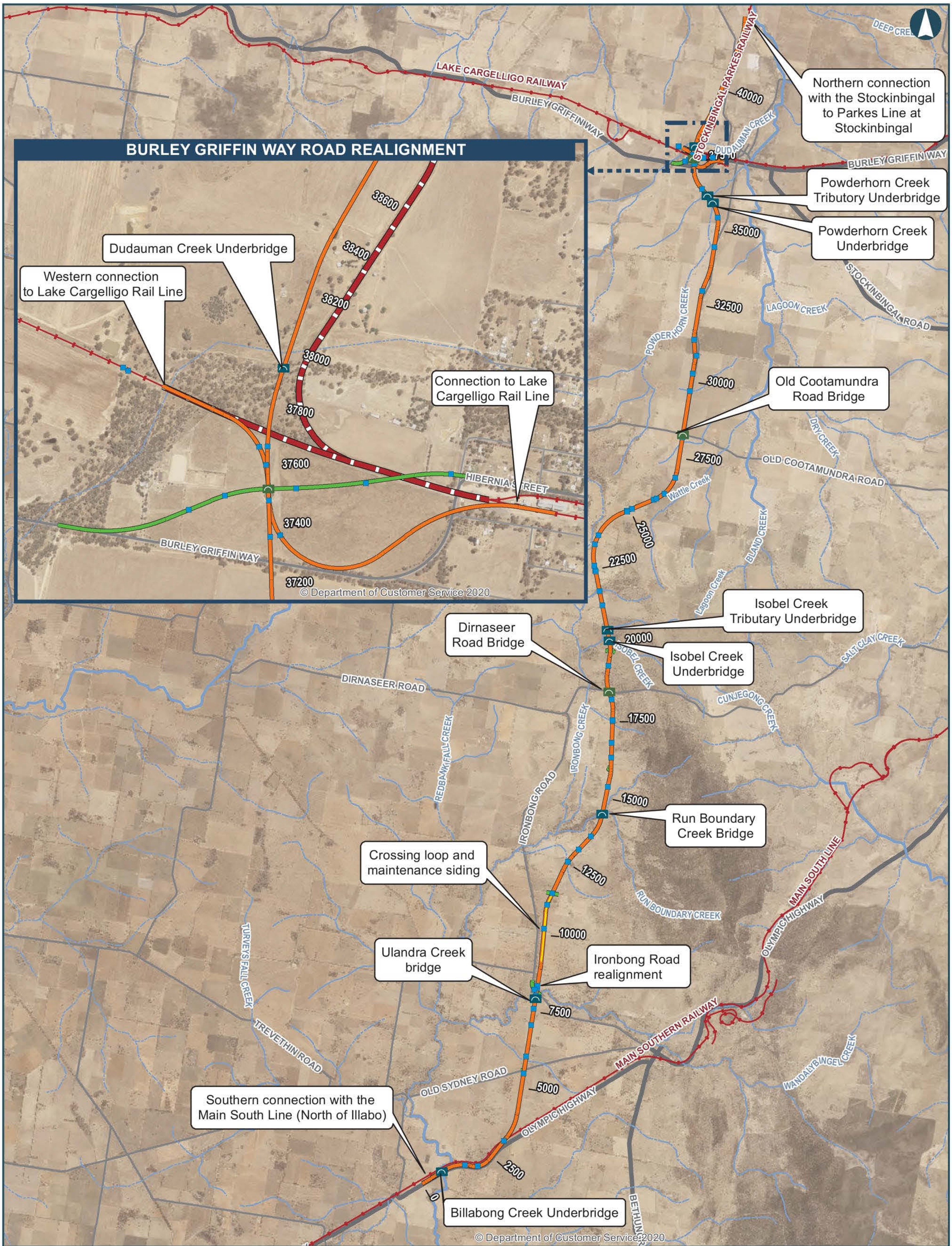

ILLABO TO STOCKINBINGAL 1.2 Key features of the proposal

0 1 2 3 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 7/23/2021 Paper: A3
Author: IRDJV Scale: 1:120,000
Data Sources: ARTC, NSWSS, ESRI

Key features of proposal
- New track/track upgrade
- 40950 Chainage (distance in metres from southern limit of the proposal)
- Crossing Loop & Maintenance Siding
- Burley Griffin Way Road realignment
- Culvert
- Bridge (road crossing)
- Bridge (water crossing)

Existing features
- Sub-arterial road
- Arterial road
- Existing Rail
- Major Watercourse
- Minor Watercourse
- Redundant sections of rail to be decommissioned

INLAND RAIL ARTC

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

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1.3 Scope and purpose of the report

This report has been prepared to specifically address the SEARs issued by (then) DPIE on 30 April 2021. The SEARs relevant to groundwater, and references to sections where they have been addressed in the report are presented below in Table 1.1.

This report describes the existing groundwater conditions and potential for impact of the proposal on the local and regional groundwater systems and aims to identify mitigation measures to minimise impact to these systems. Impacts including the existing and potential beneficial uses of groundwater (groundwater users and the areas environmental values, including those ecosystems sustained/dependent on groundwater). As such, this report has the following objectives:

- create a conceptual hydrogeological model (CHM) representative of the groundwater regime within the Study area
- characterise the existing environments groundwater levels, flows and quality
- assess the potential for change in groundwater levels and quality in response to the construction of bridge pilings and cuttings
- assess the change in groundwater flow due to the construction of bridge pilings and cuttings
- recommend mitigation measures, if required, which may minimise or avoid impacts to the groundwater regime.

Table 1.1 Proposal SEARs relevant to groundwater

Key issue	Requirements	Assessment
5. Water – Hydrology	1) The Proponent must describe (and map) the existing hydrological regime for any groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the BAM.	Chapter 4 Refer to Technical Paper 5 – Water quality impact assessment Technical Paper 1 – Biodiversity development assessment report
	2) Prepare a conceptual water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Section 3.6, section 5.5 and section 6.2.2.5
	3) Surface and groundwater hydrology impacts of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with current guidelines, including:	
	a) Natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Technical Paper 4 – Hydrology and flooding impact assessment
	b) Impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Sections 6.2.1 and 6.2.2
	c) Changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Sections 6.2.1 and 6.2.2 Technical Paper 4 – Hydrology and flooding impact assessment

Key issue	Requirements	Assessment
	d) Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Refer to Technical Paper 5 – Water quality impact assessment
	e) Minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems.	Technical Paper 4 – Hydrology and flooding impact assessment
	f) Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during both construction and operation, including an assessment of the availability of water where water entitlement is required to be purchased.	Chapter 6 Technical Paper 4 – Hydrology and flooding impact assessment
	4) The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Chapter 7 Refer to Technical Paper 5 – Water quality impact assessment
6. Water – Quality	1) The Proponent must:	
	a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	Refer to Technical Paper 5 – Water quality impact assessment Section 3.4.6
	b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Refer to Technical Paper 5 – Water quality impact assessment Refer to Technical Paper 15 – Contaminated land assessment
	c) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Refer to Technical Paper 5 – Water quality impact assessment
	d) identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments;	Refer to Technical Paper 5 – Water quality impact assessment
	e) identify proposed monitoring locations, monitoring frequency and indicators of groundwater quality.	Chapter 7

1.4 Structure of this report

This report has been separated into the following chapters:

- **Chapter 1 – Introduction** – provides a broad introduction to the proposal and identifies the key features for assessment.
- **Chapter 2 – Legislation and policy context** – this chapter includes background information for assessed legislation, policy and guidelines.
- **Chapter 3 – Methodology** – this chapter provides information on the processes for assessment. It includes background information for the desktop and site investigations.
- **Chapter 4 – Existing environment** – this chapter describes the existing environment within the Study area. The Study area characterisation includes the findings of the desktop assessment and field investigations.
- **Chapter 5 – Conceptual hydrogeological model** – this chapter incorporates the findings of Chapter 4 to generate a conceptual hydrogeological model for the Study area. This model forms the basis for Chapter 6.
- **Chapter 6 – Risk and impact assessment** – this chapter documents the identified risks and associated groundwater impacts that may be caused by the construction and operation of the proposal.
- **Chapter 7 – Mitigation and management measures** – this chapter lists the recommended mitigation and management measures to address the findings of the identified risk and impact assessment.
- **Chapter 8 – Conclusion** – provides a brief summary of key issues and their assessment, previously discussed within the report.
- **Chapter 9 – References** – list of references used within the report.

2 Legislation and policy context

The legislation, policies and guidelines listed within this Chapter have been incorporated into the assessment, findings and conclusions provided within the Groundwater Impact Assessment (this report).

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The objective of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is to protect and manage prescribed Matters of National Environmental Significance (MNES). Under the EPBC Act, proposed 'actions' that have the potential to significantly impact on MNES, the environment of Commonwealth land, or that are being carried out by a Federal Government agency, must be referred to the Federal Minister for the Environment for assessment.

As a result of the potential for impacts on protected matters, the proposal was referred to the (then) Australian Government Minister for the Environment in June 2018 (EPBC Referral No 2018/8233). On 6 August 2018, the (then) Australian Government Department of the Environment and Energy notified that the proposal is a controlled action, with the controlling provisions being 'listed threatened species and communities' (under section 18 & 18A of the EPBC Act).

No impacts to MNES relevant to potential groundwater impacts, have been identified in this assessment. This includes groundwater impacts to listed threatened species and communities that are classified as groundwater dependent ecosystems (GDEs) or RAMSAR wetlands (refer to section 4.4.2 and Chapter 6).

2.1.2 Water Act 2007

The *Water Act 2007* allows the Commonwealth in conjunction with the Basin States and Territory (South Australia (SA), Victoria (VIC), New South Wales (NSW), Queensland (QLD) and Australian Capital Territory (ACT)) to manage Australia's largest water resource, the Murray-Darling Basin, in the national interest. Notably it gives functions to the Bureau of Meteorology in reporting of water information and transferred the powers and functions of the Murray-Darling Basin Commission to the Murray-Darling Basin Authority (MDBA) through the Murray-Darling Basin Agreement. The purpose of the Agreement is to:

> *'promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water and other natural resources of the Murray-Darling Basin, including by implementing arrangements agreed between the Contracting Governments to give effect to the Basin Plan, the Water Act and state water entitlements'.*

Details of the Basin Plan and its key implementation tool, water resource plans (WRPs), are summarised below.

2.1.2.1 Murray-Darling Basin Plan 2012

The Murray–Darling Basin Plan (the Basin Plan 2012) aims to provide a coordinated approach to water use and management across the Murray–Darling Basin's four states and the ACT. It provides a framework to balance environmental, social and economic considerations for water use and water quality to an environmentally sustainable level. The Plan addresses both surface and groundwater use and water quality. Elements of the plan include:

- overall environmental water resource management objectives and outcomes
- defining separate water resource units within the Basin and sustainable diversion limits for these units, i.e. how much surface water and groundwater can be taken from the Basin, and a mechanism for adjustments to these limits
- an environmental watering plan – to protect and restore the Basin's rivers and wetlands

- a water quality and salinity management plan that sets objectives and targets
- identifying the risks to continued water availability in the Basin, and strategies to manage them
- a monitoring and evaluation program, including an annual report on the effectiveness of the Basin Plan
- preparation of Water Resource Plans (WRP) which implement the management objectives of the Basin Plan for specific areas containing one or several *sustainable diversions limits* (SDL)
- limits on the quantity of water that may be taken from the Basin water resources as a whole and from the water resources of each water resource plan area.

The plan excludes any groundwater that forms part of the Great Artesian Basin.

2.1.2.2 Water Resource Plans (WRP)

WRPs are an integral tool for implementing the objectives of the Basin Plan. They set rules on how much water can be taken from the Basin, ensuring that the SDL is not exceeded. The Murray-Darling Basin Authority (MDBA) works with the state governments to outline how each region aims to achieve community, environmental, economic and cultural outcomes and state water management rules to meet the Basin plan objectives. Importantly, state governments have had to revise current water management rules, including *water sharing plans* within NSW, to ensure they comply with the Basin Plan, including SDL rules on the delivery, protection and monitoring of water for the environment; licence conditions on water access rights; and critical human water needs in extreme circumstances (when triggered).

The WRPs are supported by supplementary studies including water quality management, monitoring plans, risk assessments, community engagement and descriptions of the SDL resource units contained within each WRP area.

There are 33 water resource plans (WRPs) within the Basin Plan, covering surface water, groundwater, or both across ACT, NSW, QLD and VIC. All required states and territories, except NSW, have had their WRPs accredited and are in operation. NSW submitted its 11 groundwater WRPs to the MDBA for assessment on 9 April 2020, with the remaining nine of its surface water WRPs submitted by 30 June 2020 (MDBA, 2020). The MDBA and NSW have agreed to a new bilateral agreement that will cover the 2020–21 water year as the NSW WRPs were not accredited before 1 July 2020. The NSW submitted WRPs are currently in the assess phase, and once accredited, groundwater within the proposal will likely be governed by the NSW Murray–Darling Basin Fractured Rock (GW11) and Lachlan Alluvial (GW10).

2.2 NSW legislation

2.2.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act) and Environmental Planning and Assessment Regulation 2021 (EP&A Regulation) establish a framework for the assessment and approval of developments in NSW. They also provide for the making of environmental planning instruments, including state environmental planning policies (SEPPs) and local environmental plans (LEPs), which determine the permissibility and approval pathway for development proposals and form a part of the environmental assessment process. In accordance with the provisions of the EP&A Act, the proposal is State Significant Infrastructure (SSI).

SSI may also be declared to be critical State significant infrastructure (CSSI) in accordance with section 5.13 of the EP&A Act, if it is of a category that, in the opinion of the Minister for Planning and Public Spaces, is essential for the State for economic, environmental or social reasons. The proposal was declared as CSSI in 2021.

Under section 5.14 of the EP&A Act, the approval of the NSW Minister for Planning is required for State significant infrastructure (including CSSI), and an EIS has been prepared under Division 5.2 of the EP&A Act.

2.2.2 Water Act 1912 and Water Management Act 2000

Water resources are administered under the *Water Act 1912* and the *Water Management Act 2000* by DPE. The *Water Act 1912* is being progressively phased out and replaced with the *Water Management Act 2000* with the implementation of water sharing plans. Within the proposal study area, groundwater resources are administered under the *Water Management Act 2000.* The object of the *Water Management Act 2000* is the sustainable and integrated management of the state's water sources for the benefit of present and future generations. The *Water Management Act 2000* governs the issue of water access licences (WALs) and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where water sharing plans have commenced. Water sharing plans establish rules for sharing water between water users and the environment, and areas rules for water trading. The *Water Act 1912* governs the issue of water licences for water sources that are not yet governed by the *Water Management Act* 2000.

Typically, if a project extracts (takes) groundwater directly, such as from groundwater pumping bores, or inadvertently, such as due to excavations intercepting groundwater, the following approvals or licences under the *Water Management Act 2000* would be required:

- water use approval under section 89
- water supply work approval under section 90 (falls under a water management work approval)
- WAL with sufficient entitlement volume in the relevant water source to cover groundwater take.

However, exemptions outlined in section 5.23 of the EP&A Act, allows for groundwater extraction activities that are assessed and approved as part of Critical State significant infrastructure (CSSI) projects to be exempt from water use approvals and water management work approvals. Therefore, if the proposal's groundwater extraction is assessed and approved as part of the Critical State significant infrastructure proposal, only a WAL would be required.

Groundwater supply for the proposal's construction is currently not considered as an option. However, ARTC and/or its contractor would finalise suitable water supply options prior to construction and obtain the necessary WALs, as relevant.

2.2.3 Water sharing plans

Water sharing plans establish rules for sharing water between water users and the environment, and rules for water trading. There are water sharing plans for regulated and unregulated river catchments and groundwater sources in water management areas. Water sharing plans describe the annual groundwater recharge volumes for each identified groundwater source and also the volumes of water that are available for sharing (the *Long Term Average Annual Extraction Limit* (LTAAEL)). Provisions are made for environmental water allocations, basic landholder rights, domestic and stock rights and native title rights. Water sharing plans are typically in place for 10 years, however they may be suspended in times of severe water shortages.

Two water sharing plans are relevant to the proposal site (refer to Figure 2.1):

- NSW Murray-Darling Basin Fractured Rock Groundwater Sources (2020)
- Lachlan Alluvial Groundwater Sources (2020).

Discussion of the water sharing plans relevant to the proposal is provided in the following sections.

2.2.3.1 Water Sharing Plan for the Murray-Darling Basin Fractured Rock Groundwater Sources 2020

The water sharing plan for the Murray-Darling Basin (MDB) Fractured Rock Groundwater sources commenced on 1 July 2020 and covers 11 groundwater sources located within the NSW portion of the MDB, approximately between Broken Hill to the west, Lithgow to the east and extending to the border of Queensland and Victoria. From the 11 groundwater sources within the water sharing plans, the proposal is situated within the Lachlan Fold Belt MDB groundwater source. Note, the Lachlan Fold Belt MDB groundwater source is divided into two management zones, the Lachlan Fold Belt MDB (Mudgee) and Lachlan Fold Belt MDB (other). The proposal only impacts the Lachlan Fold Belt MDB (other) management zone.

The Water Sharing Plan for the NSW MDB Fractured Rock Groundwater establishes a LTAAEL for each groundwater source that is the allowable limit of total extraction for that water source. The LTAAEL is the average annual recharge over a catchment that excludes identified high environmental value areas and considers aspects such as water for the environment. Each year a provision is made for basic rights to ensure the total extraction from the water source is within the LTAAEL. Groundwater extraction within the Lachlan Fold Belt MDB groundwater source has historically been below the LTAEEL.

The MDB contains a significant number GDEs, some of which are sensitive to water extraction. A list of the high priority GDEs is included in the plan, with specific provisions for protection of the listed GDEs. GDEs within the Study Area are detailed in section 4.9.2. Further discussion of GDEs within the proposal site is provided in Technical Paper 1 – Biodiversity Development Assessment Report.

2.2.3.2 Water Sharing Plan for the Lachlan Alluvial Groundwater Sources 2020

The water sharing plan for the Lachlan Alluvial Groundwater Sources, commenced on 1 July 2020.The Water Sharing Plan provides a legislative framework for water resources for the Lachlan Alluvial Groundwater Sources within the Lachlan Water Management Area and the Western Water Management Area. The water sharing plan was developed within the context of the MDB and is subject to agreements and statutes which cover water management within the MDB.

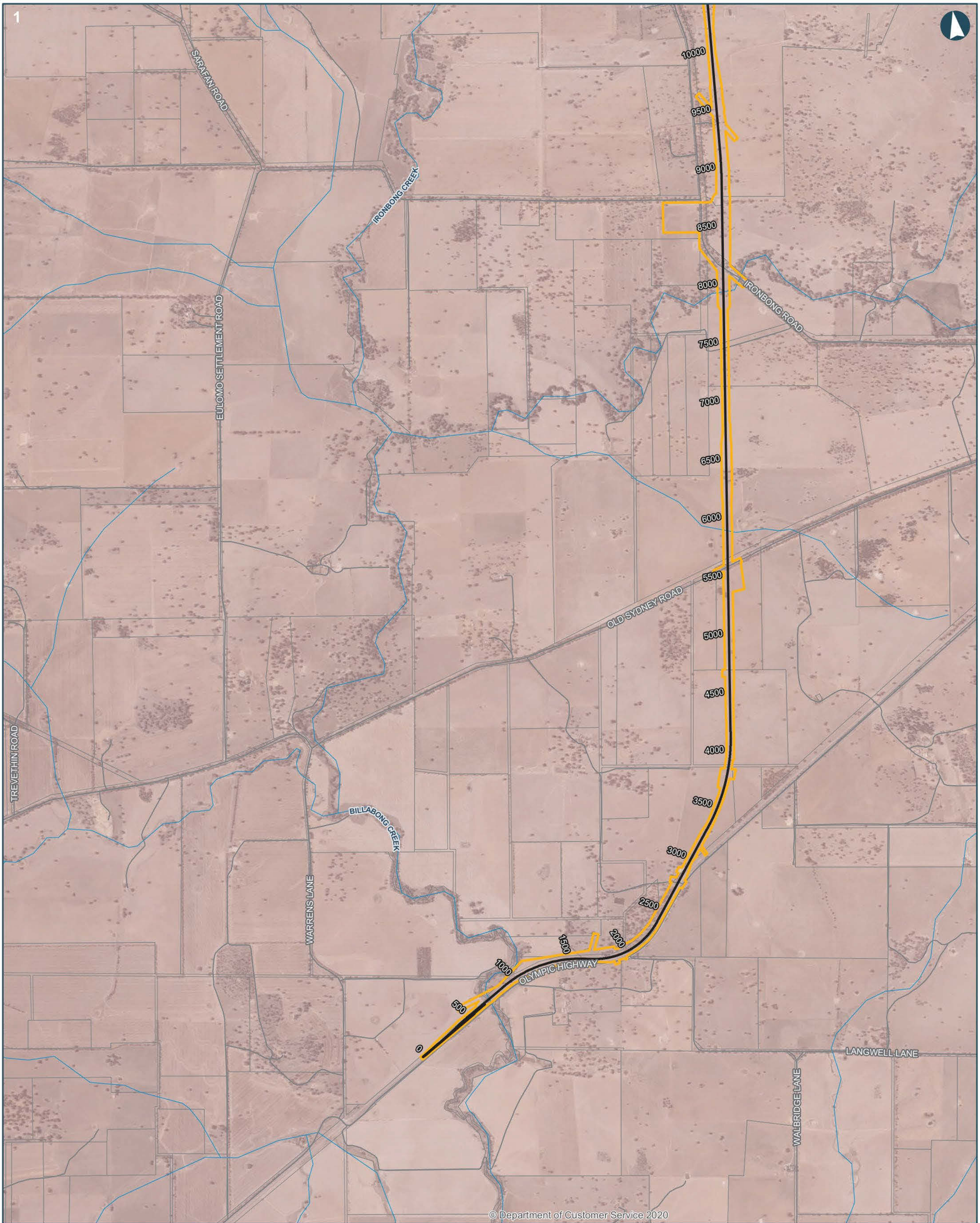
The water sharing plan covers three groundwater sources:

- Upper Lachlan Alluvial Groundwater Source
- Lower Lachlan Groundwater Source
- Belubula Valley Alluvial Groundwater Source.

The northern section of the proposal (proximal to Stockinbingal) falls within the Upper Lachlan Alluvial Groundwater Source, within Management Zone 7. Extraction of groundwater within the Upper Lachlan Alluvial Groundwater Source has historically been below the LTAAEL compliance trigger rating. If the compliance trigger in a groundwater source is reached, access to groundwater may need to be reduced. The DPE (2022) compliance trigger forecast has assigned the lowest risk rating (unlikely) for compliance actions to be triggered on the Upper Lachlan Alluvial Groundwater source for the 2022–2023 water calendar year.

The Upper Lachlan Alluvial Groundwater Source is considered to be ‘less highly connected’ to surface water, defined as, less than 70 per cent of groundwater extraction volume is derived from the streamflow over an irrigation season.

Two high priority GDEs have been identified in the Upper Lachlan Alluvial Groundwater Source. The GDEs are the Bogolong Springs (~70km north of the Study area) and Old Mans Springs (~100km north of the Study area), located in management zone 3. The GDEs, due to their significant distance from the Study area, are not expected to be impacted by the proposal.



ILLABO TO STOCKINBINGAL 2.1 Location of water sharing plans

MAP 1 OF 4

0 475 950 1,425 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 8/16/2021
Author: IRDJV
Paper: A3
Scale: 1:1,054,236
Data Sources: IRDJV, ARTC, LPI

Proposal site
Track alignment
Roads
Watercourse
Lot Boundary

Catchment Management Authority Boundary

Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater

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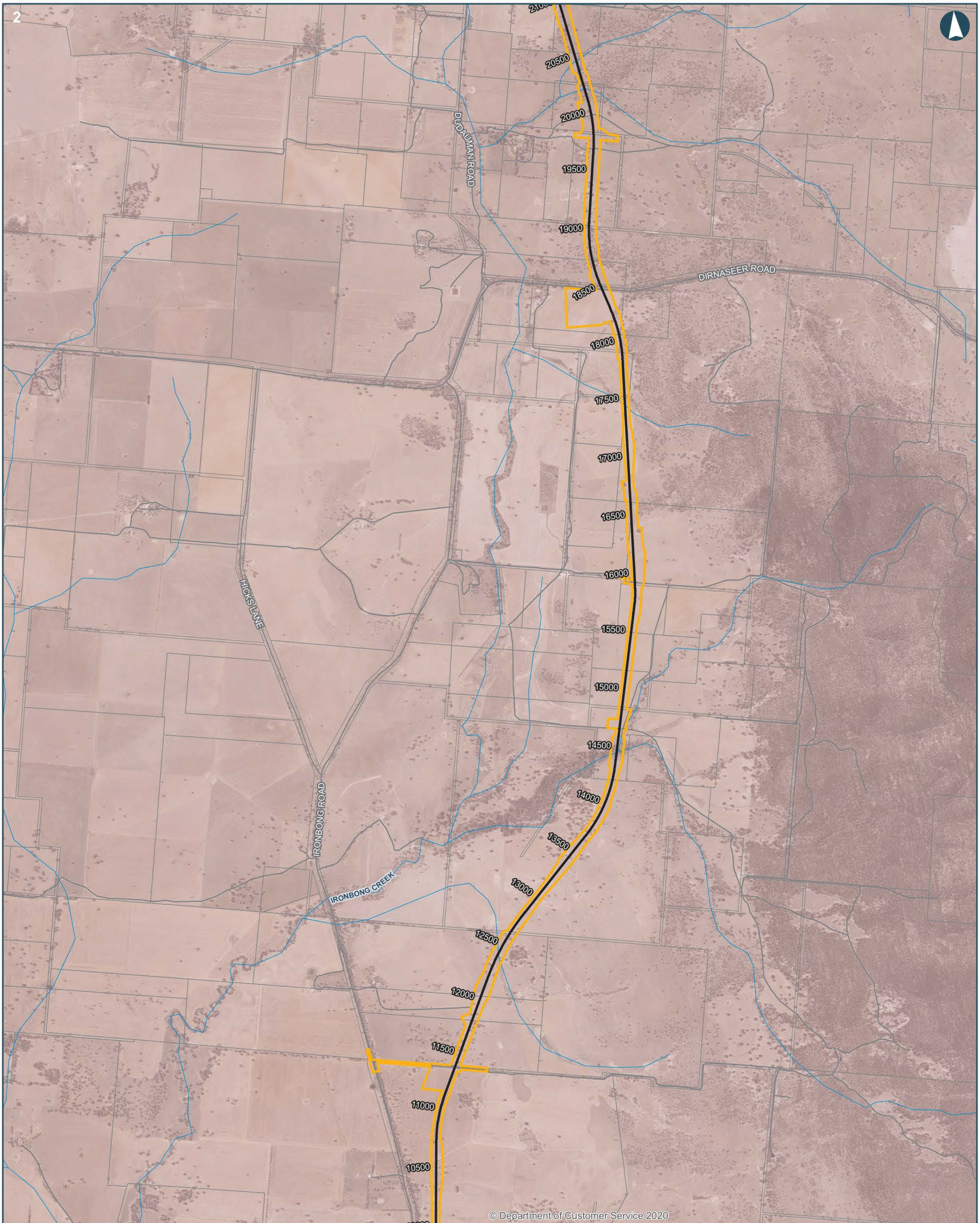

ILLABO TO STOCKINBINGAL 2.1 Location of water sharing plans

MAP 2 OF 4

0 475 950 1,425 m

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Proposal site
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Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater

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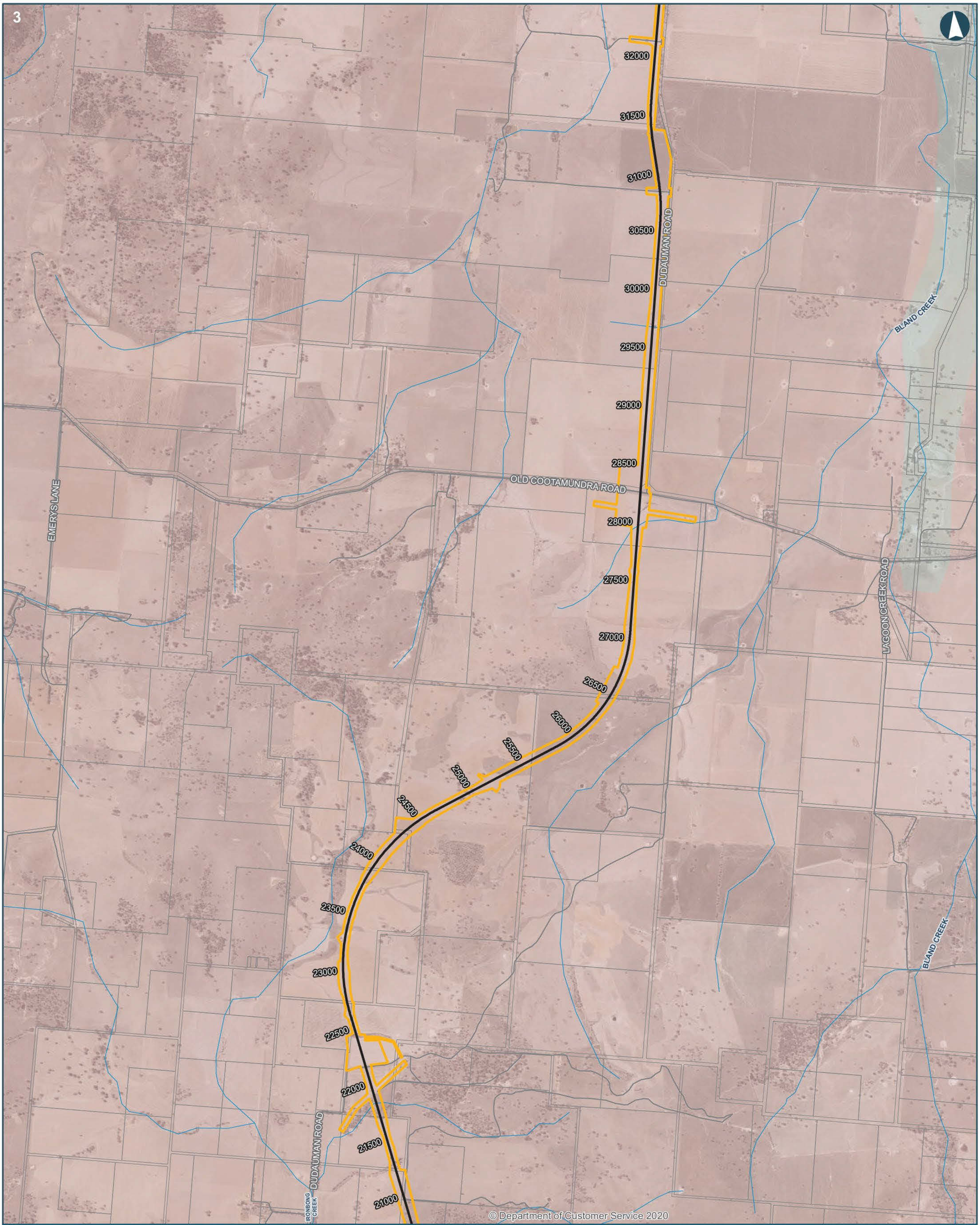

ILLABO TO STOCKINBINGAL 2.1 Location of water sharing plans

MAP 3 OF 4

0 475 950 1,425 m

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Date: 8/16/2021 Paper: A3
Author: IRDJV Scale: 1:1,054,236
Data Sources: IRDJV, ARTC, LPI

- Proposal site
- Track alignment
- Roads
- Watercourse
- Lot Boundary

Catchment Management Authority Boundary

- Water Sharing Plan for the Lachlan Unregulated And Alluvial Water Sources
- Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater

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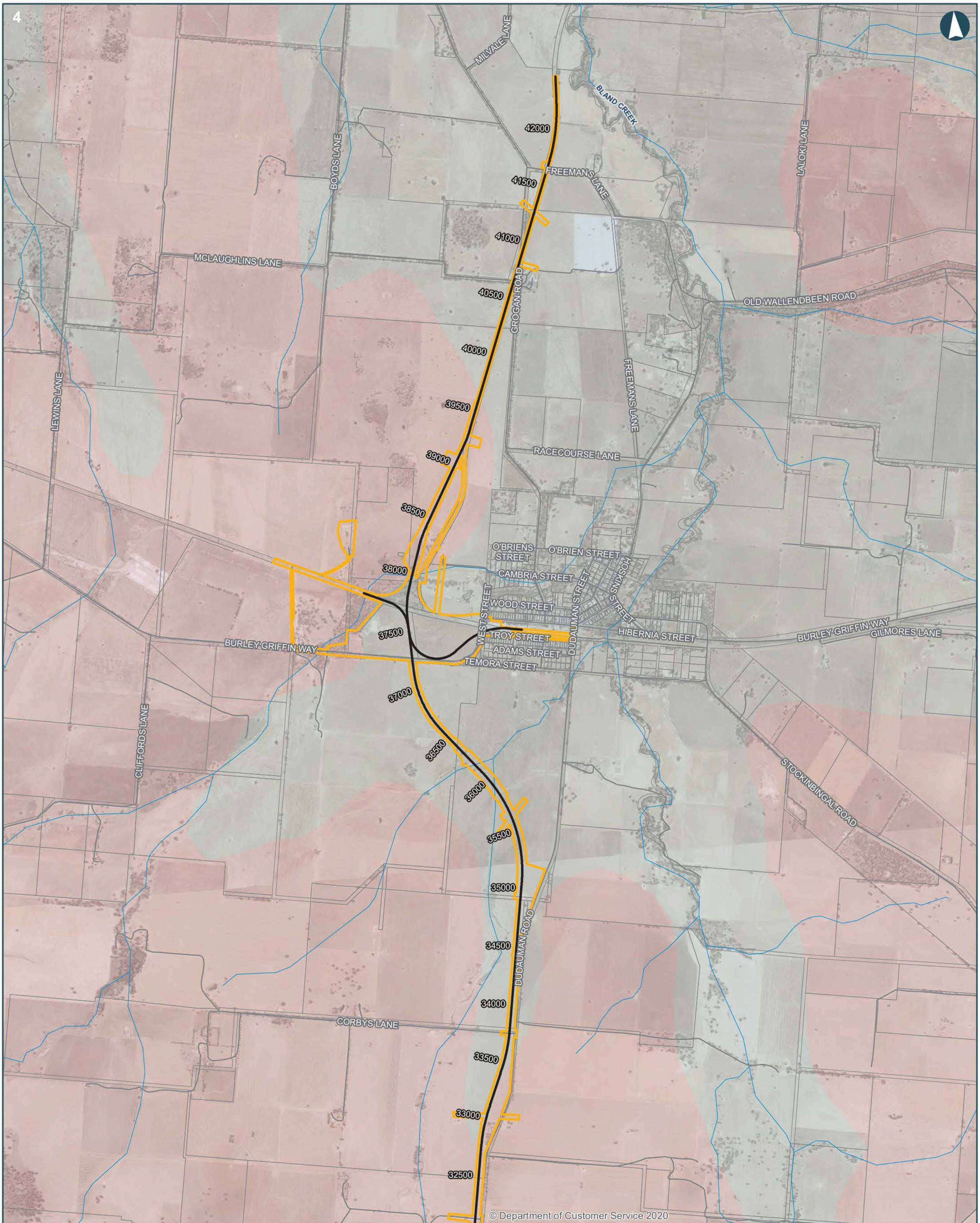

ILLABO TO STOCKINBINGAL 2.1 Location of water sharing plans

MAP 4 OF 4

0 475 950 1,425 m

Coordinate System: GDA 1994 MGA Zone 55

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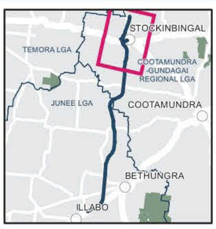

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2.3 Policies and guidelines

2.3.1 Commonwealth guidelines

Commonwealth guidelines relevant to the management of groundwater include:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 revision (ANZG, 2018).* The guidelines provide guidance on the management of water quality in Australia and New Zealand and incorporates setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources, including freshwater, groundwater and estuarine and marine waters.
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC, 2000)*. These guidelines provide for the sustainable use of Australia's water resources by protecting and enhancing quality, while maintaining economic and social development. This guideline has been superseded by ANZG. However, where default trigger values are currently being devised in ANZG, the guideline refers to ANZECC 2000 values.

2.3.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) was introduced in September 2012. The AIP clarifies the requirements for obtaining water licences and the assessment processes for aquifer interference activities under the *Water Management Act 2000* and other relevant legislative frameworks. The AIP also defines considerations in assessing whether more than minimal impacts might occur to a key water-dependent asset. However, not all approvals are currently in use. Nevertheless, the AIP remains relevant when considering activities that interfere with aquifers.

The AIP assists proponents of aquifer interference activities in preparing the necessary information and studies to be used in the assessment of project proposals that have a level of aquifer interference. The AIP forms the basis of assessment and subsequent advice provided by the NSW Government at the various stages of an assessment under the *Environmental Planning and Assessment Act 1979*.

An aquifer interference activity involves any of the following:

- the penetration of an aquifer
- the interference with water in an aquifer
- the obstruction of the flow of water in an aquifer
- the taking of water from an aquifer while mining or any other activity prescribed by the regulations
- the disposal of water taken from an aquifer while mining or any other activity prescribed by the regulations.

The *Water Management Act 2000* includes the concept of ensuring 'no more than minimal harm" for both the granting of water access licences and the granting of approvals. The AIP will be satisfied if adequate arrangements are in place to ensure that no more than minimal harm will be imposed on any water source or its dependent ecosystems.

For aquifer impact assessments, the AIP divides groundwater sources into "highly productive" and 'less productive' based on water quality and yield. Highly productive groundwater sources have total dissolved solids less than 1,500mg/L and can sustain yields greater than 5L/sec. Highly productive groundwater sources are further grouped into the following categories:

- alluvial
- coastal sands
- porous rock:
  - Great Artesian basin – Eastern Recharge and Southern Recharge
  - Great Artesian Basin – Surat, Warrego and Central
  - other porous rock.
- fractured rock.

Categories of less productive groundwater sources are alluvial, porous rock and fractured rock.

The groundwater sources within the Study area are considered less productive alluvial and fractured rock aquifers and are further detailed in section 4.6 to section 4.8.

Threshold for key minimal impact considerations have been developed for both the highly and less productive groundwater sources. For less productive groundwater sources, the minimal impact criteria, in relation to the proposal, are summarised as follows:

- Impacts to the water table are considered to be minimal where the water table change is less than or equal to 10 per cent of the cumulative variation in the water table and 40m from any high priority GDE or high priority culturally significant site. If the impact is greater, it must be demonstrated that the variation will not prevent the long-term viability of a GDE.
- Impacts to the water table are considered minimal if the cumulative decline in any water supply work is less than 2m. If the impact is greater, make good provisions apply.
- Impacts to water pressure are considered minimal if the cumulative decline in any water supply work is less than 2m. If the predicted impact is greater, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.
- Impacts to water quality are considered minimal if the change in groundwater quality remains within the current beneficial use category of the groundwater source beyond 40m from the activity. No increase of more an 1 per cent per activity in long term average salinity in a highly connected surface water source at the nearest point to the activity (alluvial water sources only). If this cannot be achieved, studies are required to demonstrate that the change will not prevent the long-term viability of the dependent ecosystem or affected water supply works.

2.3.3 NSW Government Groundwater Policy Framework Document

The NSW Government Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC), 1997) aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three component parts:

- The NSW Groundwater Quality Protection Policy (DLWC, 1998)
- The NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002)
- The NSW Groundwater Quantity Management Policy (DLWC, undated).

2.3.3.1 NSW Groundwater Quality Protection Policy

The NSW Groundwater Quality Protection Policy (DLWC, 1998) has been designed to protect groundwater resources against pollution. This policy provides a protective legislative framework for the sustainability of groundwater resources and their ecosystem support functions during resource management decision making. It will influence the type and selection of management activities and resource development opportunities that will be supported by the State's resource managers, land use planners and regulators. Key policy principles include:

- All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.
- Town water supplies should be afforded special protection against contamination.
- Groundwater pollution should be prevented so that future remediation is not required.
- For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.
- A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwater's that are incompatible with soil, vegetation or receiving waters.

- Groundwater dependent ecosystems will be afforded protection.
- Groundwater quality protection should be integrated with the management of groundwater quantity.
- The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.
- Where possible and practical, environmentally degraded areas should be rehabilitated, and their ecosystem support functions restored.

2.3.3.2 NSW Groundwater Dependent Ecosystems Policy

The NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002) has been designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored, for the benefit of present and future generations. The policy provides practical guidance on how to protect and manage these valuable natural systems through the following key principles:

- The scientific, ecological, aesthetic and economic values of groundwater-dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.
- Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of groundwater dependent ecosystems.
- Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed:
  - for protecting ecosystems which are known to be, or are most likely to be, groundwater dependent
  - for groundwater dependent ecosystems which are under an immediate or high degree of threat from groundwater-related activities.
- Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect groundwater dependent ecosystems. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.
- Planning, approval and management of developments and land use activities should aim to minimise adverse impacts on groundwater dependent ecosystems by:
  - maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems
  - not polluting or causing adverse changes in groundwater quality
  - rehabilitate degraded groundwater systems where practical.

2.3.3.3 NSW Groundwater Quantity Management Policy

The NSW Groundwater Quantity Management Policy (DLWC, undated) delivers advice for the management of groundwater quantities. This policy helps clarify legislation and management for groundwater users' rights in terms of their long-term access and in relation to the rights of others through the following key principles:

- Total use of groundwater in a water source or zone will be managed within the sustainable yield, so that the groundwater is available for future generations, and dependent ecological processes remain viable.
- Significant groundwater dependent ecosystems must be identified and protected.
- Total licensed entitlements will not exceed 125 per cent of the sustainable yield in currently over-allocated groundwater sources or zones.
- Groundwater access must be managed in such a way that it does not cause unacceptable local impacts.
- Artificial recharge of groundwater will be strictly controlled.

- Landholders overlying an aquifer will have a basic right to access groundwater for domestic and stock purposes.
- Access to groundwater will be managed according to an established priority of use.
- All rights (except basic rights) to access and extract groundwater must be licensed and metered.
- In systems that are not subject to a licence embargo or a Ministerial order, groundwater access licenses will be issues on the basis of demonstrated need, within the sustainable yield.
- Groundwater access licence holders have resource stewardship obligations and are required to abide by the conditions of their licence.
- Permanent and temporary transfer of groundwater access will be permitted within sustainable yield constraints, if the transfer does not cause unacceptable impacts on other users, water quality or dependent ecosystems. Inter-aquifer transfers will not be permitted.
- Within environmental and interference constraints, the management of groundwater access should provide business flexibility for existing users through carryover and borrowing provisions on annual entitlements.
- Approvals must be obtained before any groundwater access licence can be activated at a particular location.
- All activities or works that intersect an aquifer and are not for the primary purpose of extracting groundwater, need an aquifer interference approval.

3 Methodology

3.1 Overview

To achieve the objectives described in section 1.3, the following key activities were undertaken:

- a desktop review assessment of publicly available information on the known regional groundwater setting
- site investigations to establish the site-specific conditions considering the local and regional conditions identified in the desktop review. These intrusive investigations included installation a targeted groundwater monitoring network, gather groundwater level data from the key aquifers, collect and analyse groundwater quality parameters of the groundwater systems underlying the proposal alignment, and measure the permeability (hydraulic conductivity) of the aquifer units
- an assessment of the existing site baseline conditions and the physical mechanisms that might result in the inferred groundwater impacts potentially arising from the proposal
- quantification, where applicable, of the potential groundwater impacts.

Aspects pertaining to soil and groundwater contamination, are further assessed in Technical Paper 14 – Contaminated land assessment.

3.2 Study area

To adequately characterise the hydrogeological conditions relevant to the proposal site, a regional scale understanding is required. Groundwater regimes are complex and can be influenced by broad geographical scales and regional context typically refers to the catchment areas, often defined by geological domains.

The Study area for the assessment includes 2km wide investigation area around the proposal site that has allowed for the realignment of the proposal to mitigate potential impacts to the surrounding environment. The Study area was selected to incorporate the proposals potential area of influence on groundwater and potential impacts to sensitive receptors.

3.3 Desktop assessment

A desktop review of available data was undertaken to develop an understanding of the hydrogeological environment within the Study area and to identify sensitive receptors including watercourses, groundwater dependent ecosystems (GDEs) and registered groundwater bores. The findings of the desktop review aided the selection of locations for the installation of groundwater monitoring bores along the proposal site.

The following databases were used to provide background information for topography, climate, geology and sensitive receptors:

- Light Detection and Ranging (LiDAR) survey (completed in 2015), at 0.2m resolution topographic elevation contours with an accuracy of 0.15m vertical and <0.5m horizontal across a 10km wide strip along the proposal
- NSW Government's Department of Land Registry Services (NSW LRS) data – elevation grid data with 20m resolution – adopted to supplement topography contours outside of the LiDAR extent
- Cootamundra (1:250000) geological sheet (Warren et al, 1996) used for identification of regional lithology and geological structures
- GDE information from the Bureau of Meteorology (BOM) GDE Atlas
- registered groundwater bore data from the BOM National Groundwater Information System (NGIS) and WaterNSW
- climate data including rainfall and evapotranspiration from the Bureau of Meteorology (BOM)
- publicly available reports and databases further detailing the existing groundwater, soil, geological, topographical and hydrogeological environments.

Data and information obtained through the desktop assessment has been correlated with site investigation findings to determine the existing environmental conditions within the Study area (Chapter 4). Chapter 4 presents a description of the existing groundwater conditions within the Study area, including the hydrostratigraphic units, groundwater levels, hydraulic properties, groundwater quality, GDEs and groundwater users.

3.4 Site investigation

A groundwater monitoring network was installed collect baseline groundwater data. A description of the hydrogeological site investigations is summarised in the following sections.

The assessment also reviewed the findings from the geotechnical assessments completed for the proposal, including data collected from a total of 70 test pits and boreholes.

3.4.1 Groundwater monitoring network and events

The groundwater monitoring network consists of 11 groundwater monitoring bores. Locations of the groundwater monitoring bores were selected to:

- characterise groundwater resources along the full length of the alignment, targeting areas where groundwater data is not available or non-conclusive
- target locations where significant cuts are proposed, so the depth to the water table relative to the depth of the cut can be assessed
- provide for assessment and monitoring of potential impacts on sensitive receptors, including GDEs and landholder bores.

During the geotechnical drilling program in November to December 2018, 10 boreholes were converted to monitoring bores. An additional monitoring bore (BH054) was converted during a supplementary geotechnical drilling program in February 2021 in response to revisions in the proposals design. Refer to Figure 3.1 for the location of groundwater bores.

Groundwater bores were installed under the supervision of suitably qualified personal and constructed in accordance with the latest corresponding *Minimum Construction Requirements for Water Bores in Australia* 3rd or 4th edition (NUDLC 2012, NUDLC 2020) depending on the time of the bore installation. Immediately following installation, the groundwater monitoring bores were developed by the drillers using air injection to remove fine/silts from the screen area.

The groundwater monitoring bores were screened to test the Lachlan Unregulated Alluvial groundwater source and the Murray-Darling Basin Fractured Rock groundwater source that were identified underlying the proposal (refer to section 2.2.3 and section 4.6). The construction details for the groundwater monitoring bores is summarised in Table 3.1. Details on the geology of the region and the Study area are provided in section 4.5.

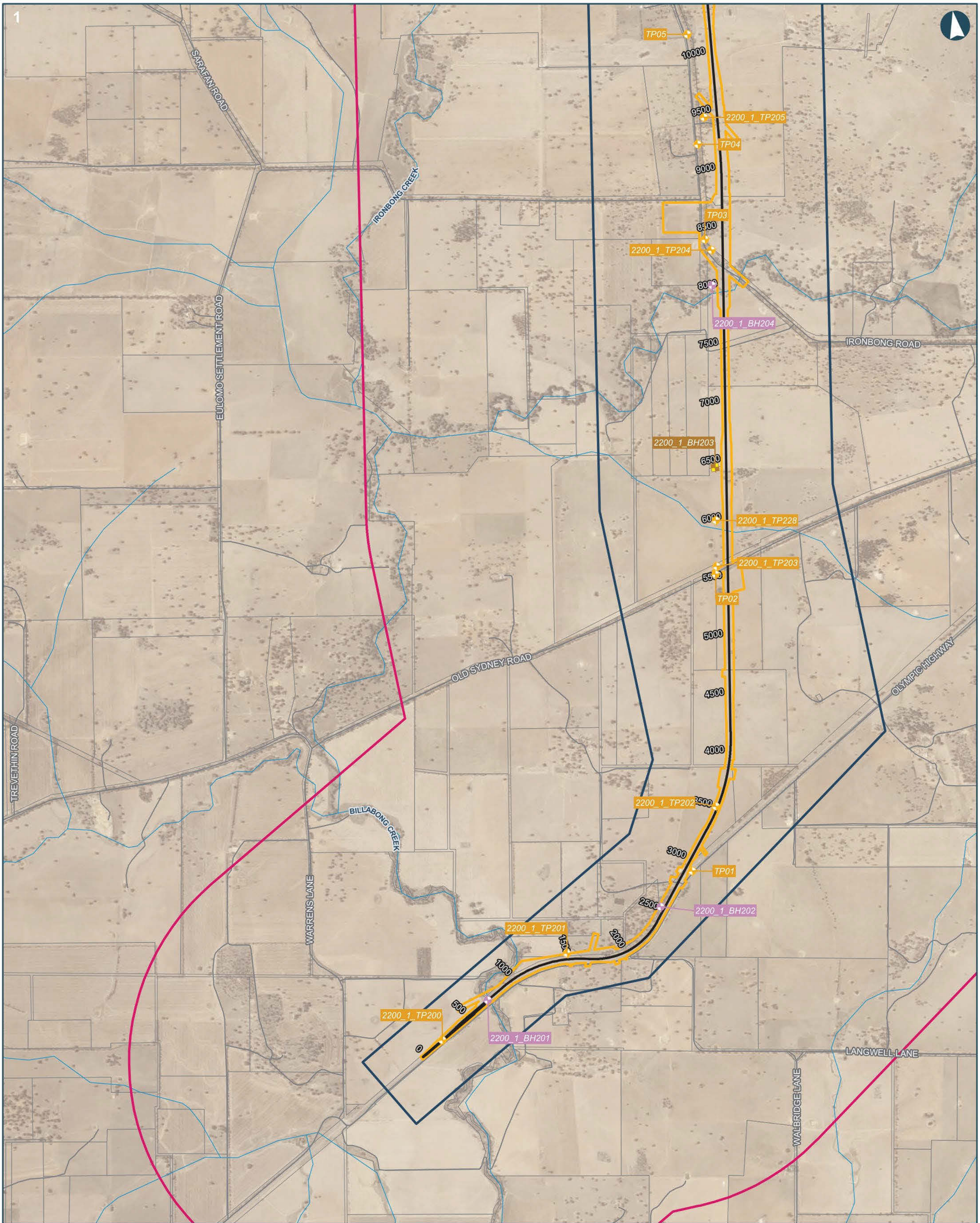
Table 3.1 Groundwater monitoring bore construction summary

Bore ID	Easting	Northing	Chainage	Bore depth (mBGL)[1]	Screen (mBGL)	Natural ground surface (mAHD)[1,2]	Screened lithology[4]
BH201	571382	6149302	750	20.14	8.0 – 20.0	257.30	QA
BH202	572979	6149825	2526	13.02[3]	6.6 – 12.2[3]	289.95	MDFR (CF)
BH204	574319	6155023	8007	20.80	14.0 – 20.0	284.53	MDFR (CF)
BH211	576936	6164824	18388	20.20	16.8 – 19.8	345.01	MDFR (FV)
BH212	576950	6165203	18804	25.22[3]	7.5 – 24.4[3]	379.63	MDFR (FV)
BH213	576994	6165779	19437	26.30	13.8 – 25.8	350.53	MDFR (FV)
BH215	576830	6167308	20915	18.70	9.0 – 18.0	377.25	MDFR (FV)
BH217	576142	6173054	28132	20.36	14.0 – 20.0	346.56	MDFR (FV)
BH219	579574	6182102	37524	20.97	11.0 – 20.0	303.73	QA
BH220	579548	6182537	37963	20.95	8.0 – 20.0	302.95	MDFR (CF)
BH054	576756	6164869	18501	30.00	12.0 – 30.0	341.82	MDFR (FV)

(1) mBGL: metres below ground level; mAHD: metres Australian Height Datum.
(2) Topographic elevation values obtained from ARTC supplied LiDAR (2015).
(3) Values adjusted for inclined (70°) boreholes. BH202 and BH212 total drilled meterage corresponds to 13.86m and 26.84m, respectively and screen depths of 7.0m – 13.0m and 8.0m – 26.0m, respectively.
(4) QA = Quaternary Alluvial; MDFR = Murray-Darling Basin Fractured Rock; CF = Combaning Formation; FV = Frampton Volcanics.

Four groundwater monitoring events (GME) were completed to assess seasonal variation in groundwater levels and quality. Information related to each GME is summarised below:

- GME 1 (21–25 January 2019) included groundwater gauging, groundwater quality sampling, installation of data loggers and aquifer characteristic testing (rising and falling head tests, commonly referred to as slug tests).
- GME 2 (20–23 May 2019) included groundwater gauging, groundwater and surface water quality sampling and datalogger information retrieval.
- GME 3 (8–11 February 2021) included groundwater gauging, water level datalogger download and replacement where recommended, from accessible pre-existing monitoring bores and groundwater quality sampling. The new monitoring bore (BH054) installed on 3 February 2021 was gauged, sampled and slug tested. A datalogger was also installed in BH054.
- GME 4 (7–9 April 2021) included groundwater gauging, groundwater and surface water quality sampling and datalogger download from all accessible monitoring bores.



ILLABO TO STOCKINBINGAL 3.1 Groundwater Study Area

MAP 1 OF 4

0 500 1,000 1,500 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 5/17/2021 Paper: A3
Author: IRDJV Scale: 1:30,000
Data Sources: IRDJV, ARTC, LPI

- Proposal site
- Track alignment
- I2S Investigation Corridor
- Groundwater Study
- Roads
- Watercourse
- Lot Boundary
- Boreholes
- Test Pit
- Groundwater Monitoring Bores

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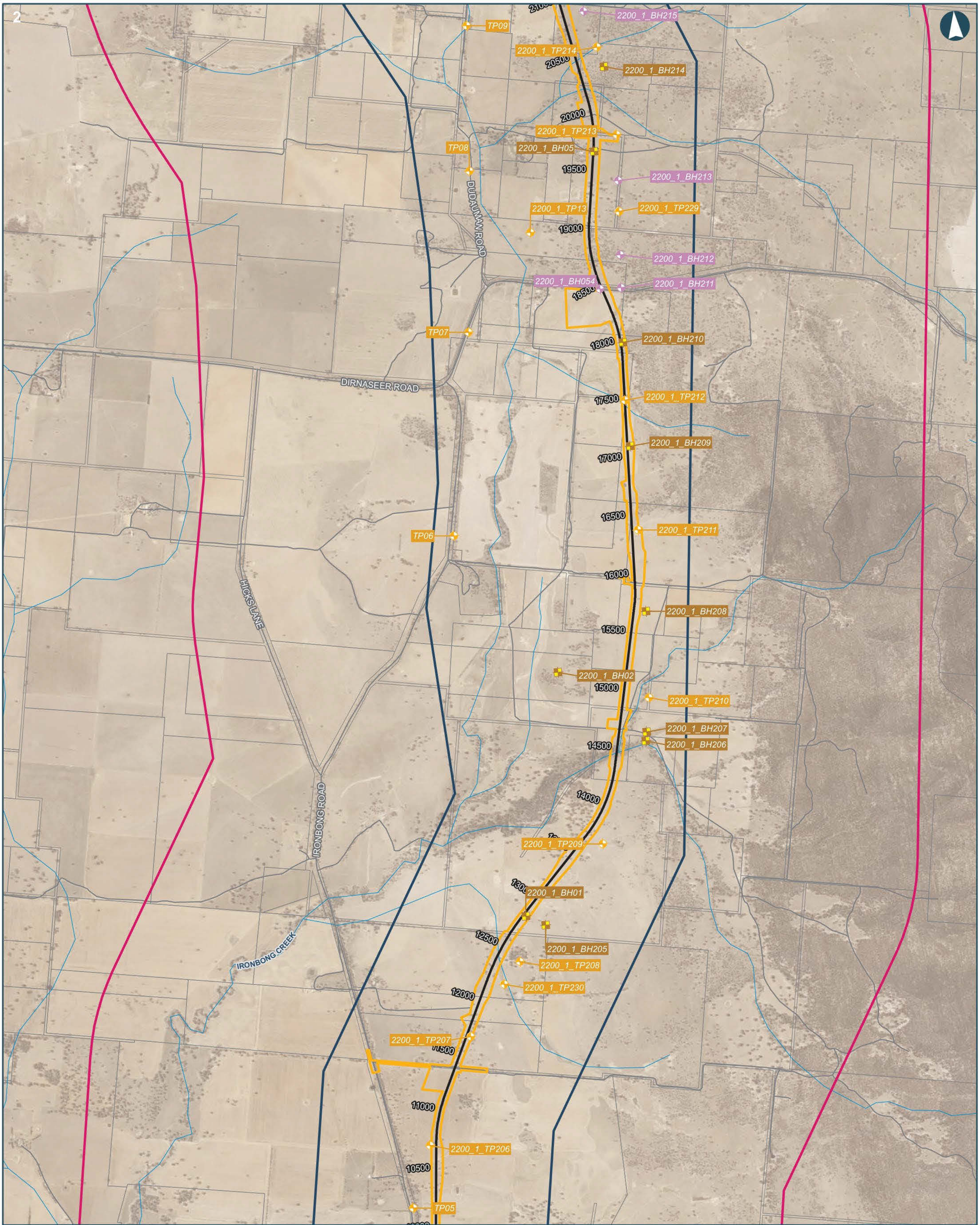

ILLABO TO STOCKINBINGAL 3.1 Groundwater Study Area

MAP 2 OF 4

0 500 1,000 1,500 m

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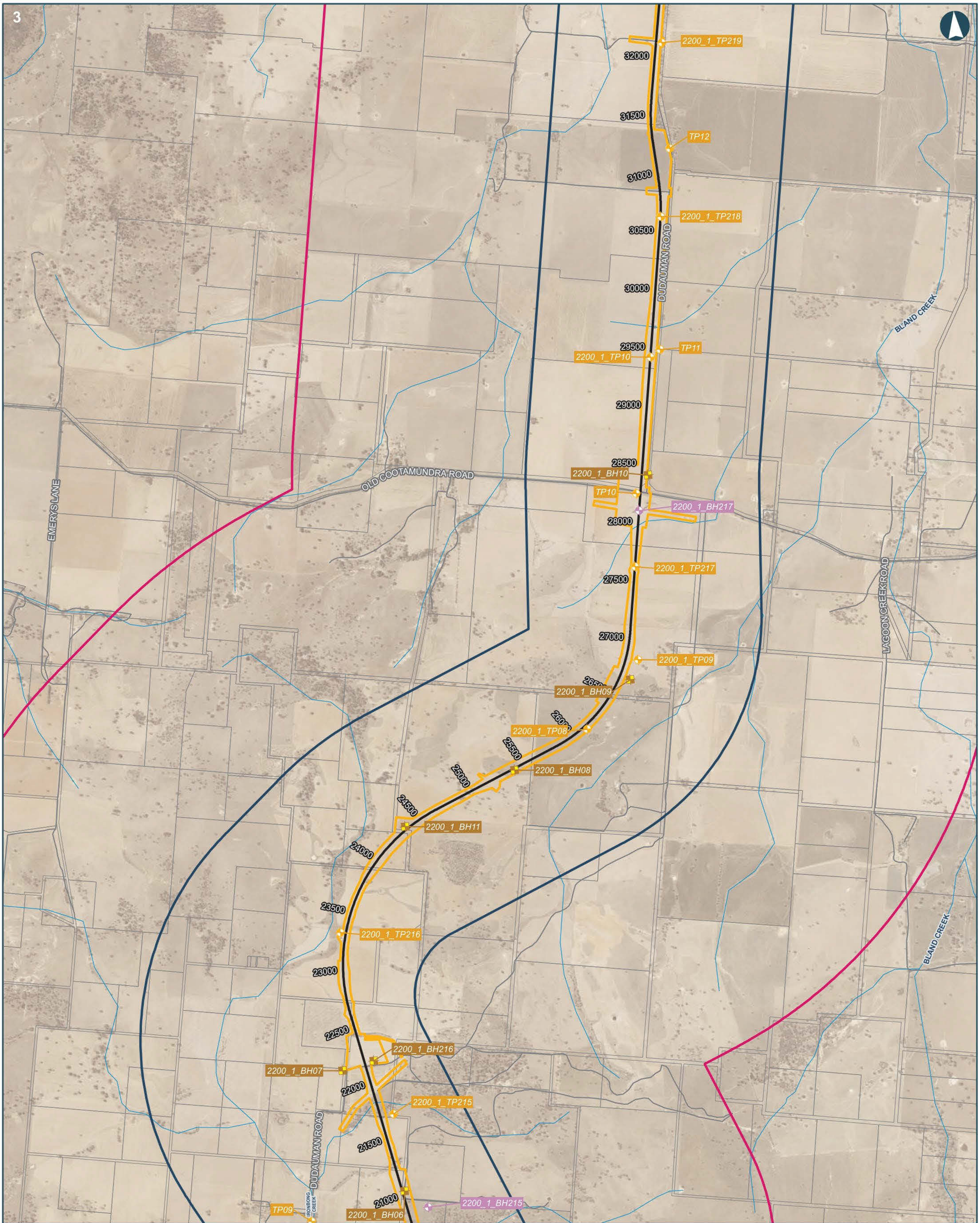

ILLABO TO STOCKINBINGAL 3.1 Groundwater Study Area

MAP 3 OF 4

0 500 1,000 1,500 m

Coordinate System: GDA 1994 MGA Zone 55

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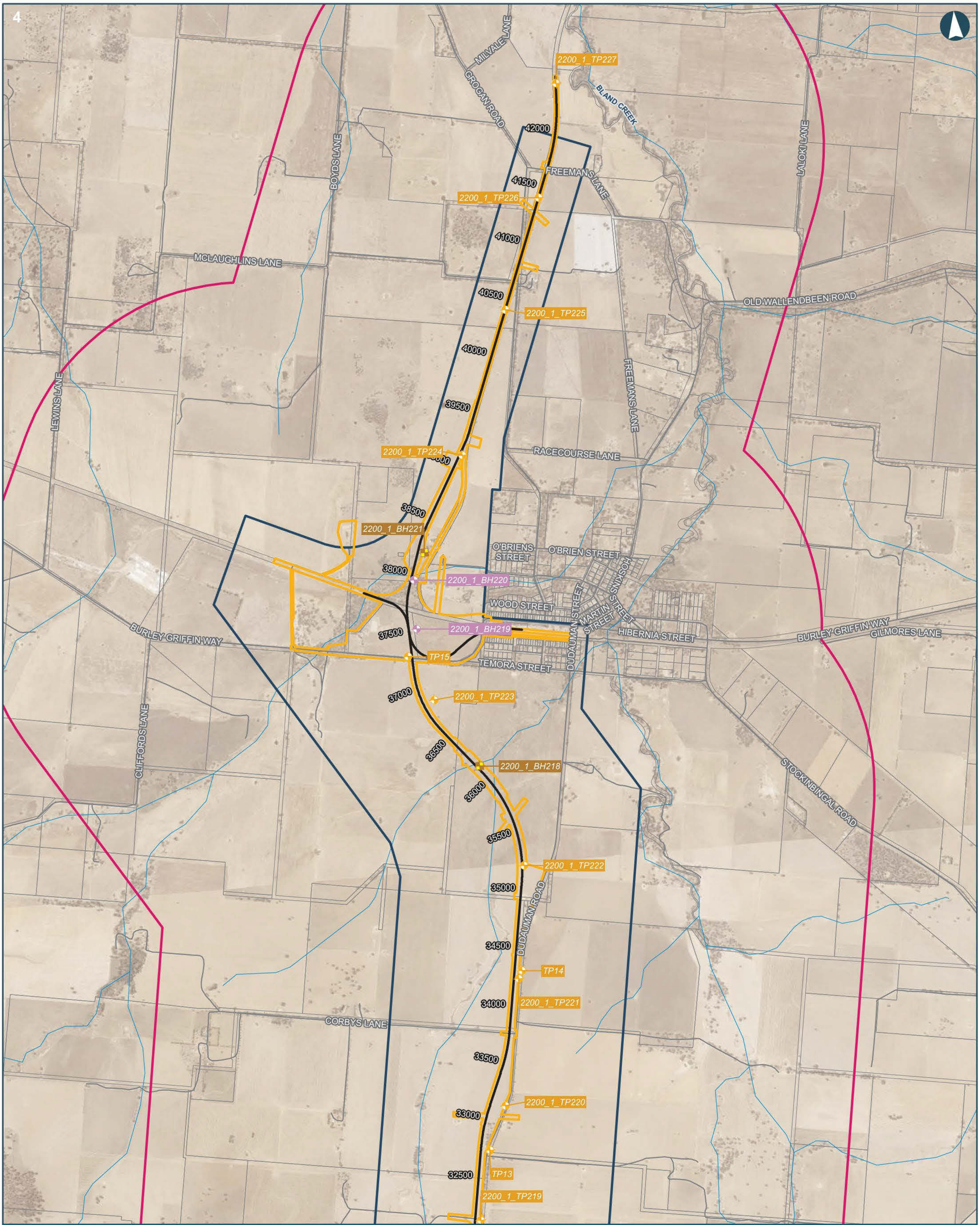

ILLABO TO STOCKINBINGAL 3.1 Groundwater Study Area

MAP 4 OF 4

0 500 1,000 1,500 m

Coordinate System: GDA 1994 MGA Zone 55

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3.4.2 Groundwater level monitoring

Automated groundwater level monitoring and data recording equipment (dataloggers) were installed in all groundwater monitoring bores during GME 1 (21–25 January 2019) except for BH054 where a datalogger was installed during GME 3 (8–11 February 2021) as the bore was drilled on 3 February 2021. Dataloggers were time synchronised and programmed to record groundwater levels at three hour intervals. During GME 3 the dataloggers in accessible monitoring bores were reset due to data memory restrictions and replaced, where recommended. Monitoring intervals were updated to record every six hours.

A barometric logger was also installed during GME 1 in BH213 to allow the data to be compensated for atmospheric influences. BH213 was selected for barometric monitoring as it is positioned approximately in the middle of the proposal site and half way between both Eurongilly and Cootamundra Airport BOM Stations. Both BOM stations received similar rainfall over the monitoring period. Cootamundra Airport data was used in the analysis of hydrographs. As BH213 was inaccessible during GME 3, a new barometric logger was installed in BH054. Additionally, manual groundwater levels were obtained during each GME using an electronic dip meter.

Hydrographs from automated groundwater level monitoring are provided in Appendix A.

3.4.3 Rising/falling head testing

Hydraulic conductivity results from bore rising or falling head tests, referred to as ‘slug’ tests and short term pumping-recovery tests are industry standard methods used to estimate aquifer property conditions in close proximity to the bore tested (volume of porous media with a limited radius of the test bore). These tests are advantageous as they can be conducted quickly and involve limited removal of water from the aquifer. However, due to the limited testing effect radius of these methods, the accuracy of these tests is at the “indicative” level (out by about one order of magnitude). In addition, slug testing can often over-estimate the hydraulic conductivity (‘K’). ‘K’ is the groundwater rate of flow through a porous medium in a unit of time under a unit hydraulic gradient through a cross sectional area commonly measured at a rate of metres per day (m/day). Further sustained hydraulic testing over extended periods of time, e.g. multi-day pumping tests, would be required to improve to robustness of ‘K’ values.

Slug testing or short term pumping-recovery tests were completed on all groundwater monitoring bores screened within the Murray Darling Fractured Rock that contained suitable groundwater levels to conduct the tests. Three groundwater monitoring bores (BH212, BH213 and BH215) contained sufficient volume of water during GME 1 and on BH054 during GME 3 to provide estimates of K values at proposed cut locations for seepage assessment. Slug tests were completed at locations selected to target areas of expected deep cutting. Data was unable to be obtained where there was insufficient column of water available to conduct a robust test. Where possible, several tests were completed at each groundwater monitoring bore to ensure representative results were obtained.

Slug tests conducted at BH213 and BH054 were performed with insertion and removal of a physical slug tube (made of solid acrylic) to create the water level displacement required (to apply an instantaneous head pressure differential from which equilibration is measured). Where groundwater recovery was limited (BH212 and BH215), the bores were pumped ‘dry’ using a 12-volt submersible pump and allowed to recover for up to 27 hours.

All bores hydraulically tested were screened within the fractured rock hydrostratigraphic unit, with slug test results analysed in AQTESOLV© software using the Bouwer and Rice (1976) solution, with Pandit and Miner (1986) translation method applied prior to analysis for short term pump recovery tests. Selected hydraulic conductivity values were used for the analytical assessment of inflow volumes (section 6.2.2). Results of the aquifer tests are presented in Appendix B.

3.4.4 Groundwater quality monitoring

To obtain baseline groundwater quality data, four GMEs were undertaken to capture seasonal variability within the groundwater regime. GME 1 and GME 3 were undertaken during summer and GME 2 and GME 4 were undertaken during autumn. GME 3 and 4 were undertaken after notable climatic shifts since the start of monitoring (GME 1) with increased rainfall occurring in the previous year (2020). NSW also experienced significant bushfires at the start of 2020 which may impact groundwater quality through seepage during recharge.

During the GME events, groundwater was sampled with a decontaminated 12-volt submersible pump that was positioned adjacent to the screen sections of the groundwater monitoring bore. Where limited groundwater was encountered, a decontaminated plastic bailer was used to obtain a grab sample. Each of the groundwater monitoring bores that were accessible and contained retrievable groundwater quantities were sampled.

Groundwater samples collected in the field were analysed for a broad chemical suite designed specifically to assess the regional characteristics of the groundwater sources. Table 3.2 details the groundwater analytical suite.

Table 3.2 Groundwater analytical suite

Category	Parameters	
Physiochemical parameters (measured in the field)	• Electrical conductivity (EC) Temperature • Dissolved oxygen (DO)	• pH • Oxidation-reduction potential (ORP) • Total dissolved solids (TDS)
Major anions	• Chloride • Bicarbonate	• Sulphate
Major cations	• Calcium • Sodium	• Magnesium • Potassium
Dissolved metals	• Aluminium • Arsenic • Cadmium • Chromium • Copper	• Iron • Mercury • Nickel • Lead • Zinc
Absorption ratio	• Sodium	

The groundwater analytical suite parameters comprising dissolved oxygen (DO), temperature, pH, oxidation-reduction potential (redox), electrical conductivity (EC), and total dissolved solids (TDS) were recorded in the field periodically during purging and groundwater samples were obtained following stabilisation of parameters to within 10 per cent (or 0.2°C for temperature), in accordance with *Groundwater Sampling and Analysis – a field guide* (GA, 2009).

Groundwater samples were collected in laboratory supplied bottles with appropriate preservation where required in accordance with AS/NZS 5667 (1998), *Water Quality – Sampling Guidance on Sampling of Groundwaters*. Samples collected for dissolved metal analysis were field filtered through a 0.45 micrometre (µm) filter. All groundwater samples were transported under appropriate chain-of-custody protocols in an ice-filled esky to a NATA accredited laboratory within holding times. Field duplicates were collected at a ratio of 1 in 10 for quality control during GME 1, 2 and 4.

Laboratory results are included in Appendix C.

3.4.5 Surface water quality sampling

Surface water features (such as farm dams) and watercourses adjacent to groundwater monitoring bores were inspected at the time of the January 2019 GME with the aim to obtain water quality samples. However, the ephemeral nature of these watercourses and preceding dry weather conditions resulted in generally dry conditions in all inspected watercourses, thus no samples could be collected. One grab sample was collected from Ironbong Creek, (at a location near BH204) was collected during the GME 2 from stagnant water adjacent to a box culvert crossing. Following a period of increased rainfall in March 2021, the April 2021 GME included the collection of surface water samples from Ironbong Creek, Powder Horn Creek and Dudauman Creek.

Details of surface water quality sampling is available within Technical Paper 5 – Water quality impact assessment.

3.4.6 Groundwater quality assessment criteria

3.4.6.1 Salinity

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; typically based on salinity. 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:

- was adopted in the NSW Groundwater Quality Protection Policy (DLWC 1998)
- has been adopted in the NSW Aquifer Interference Policy
- are used in the relevant WRPs.

Given the above, beneficial use categories have been adopted for this assessment. Beneficial use categories based on salinity are listed in Table 3.3.

Table 3.3 Beneficial use categories adopted for assessment (DPI, 2018)

Beneficial use	Salinity (TDS mg/L)[1]						
	A1	A2	A3	B	C1	C2	D
	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 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.

Salinity targets for vegetation GDEs associated with aquatic ecosystems that rely on the surface expression of groundwater, as identified in the WRPs, are listed below:

- 900mg/L (1,343 microSeimens per centimetre (µs/cm)) for GDEs identified in section 4.9.2 that are within the riparian zone of 100m
- 3,000mg/L (4,478µs/cm) for remaining GDEs that access fresh water.

3.4.6.2 Other water quality parameters

The default trigger values of the 95 per cent level of protection has been adopted for the proposal, as the system is considered to be a moderately disturbed, upland river, ecosystem, due to the dominant agricultural land use practices. Groundwater that may be intersected is likely to be discharged to the local environment, subject to approval processes, and therefore the proposed nominated guideline criteria for reference is based on ANZG and corresponds to the Protection of Aquatic Ecosystems (fresh waters).

Table 3.4 provides guideline values for the proposal based on the ANZG guidelines, which currently defers to the ANZECC Water Quality Guidelines for Fresh and Marine Waters (ANZECC 2000) as the updated toxicant default guidelines have yet to be finalised.

Table 3.4 Groundwater quality guidelines

Analyte	Unit[1]	Guideline (trigger value)	Source	Adopted level of protection (%)
Aluminium (pH>6.5)	mg/L	0.055	Toxicants – Fresh Waters	95
Arsenic (III)	mg/L	0.024	Toxicants – Fresh Waters	95
Cadmium	mg/L	0.0002	Toxicants – Fresh Waters	95
Chromium (Cr^{VI})	mg/L	0.001	Toxicants – Fresh Waters	95
Copper	mg/L	0.0014	Toxicants – Fresh Waters	95
Lead	mg/L	0.0034	Toxicants – Fresh Waters	95
Mercury	mg/L	0.0006	Toxicants – Fresh Waters	95
Nickle	mg/L	0.011	Toxicants – Fresh Waters	95
Zinc	mg/L	0.008	Toxicants – Fresh Waters	95
Ammonia	mg/L	0.9	Toxicants – Fresh Waters	95
Nitrate	mg/L	0.7	Toxicants – Fresh Waters	95
pH	pH units	6.5–8.0	Environmental Stressors – Upland river	–
DO	% sat	90–110	Environmental Stressors – Upland river	–

(1) mg/L = milligram per litre; % sat = per cent saturated.

Water quality criteria for surface water quality parameters are discussed in Technical Paper 5 – Water quality impact assessment. For an assessment regarding potential groundwater contamination, refer to Technical Paper 14 – Contaminated land assessment.

3.5 Impact and risk assessment

The following impact and risk assessment methodology was used to determine the groundwater impact due construction and operation of the proposal:

1. determine how the proposal may impact groundwater
2. identify the groundwater associated risks due to the proposal
3. quantify the impact at the identified groundwater impact locations, where practical, based on the proposal's conceptual hydrogeological model.

The identification and assessment of groundwater impacts relies on the conceptual hydrogeological understanding of the Study area. Where data is limited, assumptions have been made, and have been stated within the report.

3.6 Water balance model

3.6.1 Selecting the relevant domains

The regional catchments for both the Lachlan alluvial and fractured rock aquifers are extensive, covering up 16,722km^2 and 90,000km^2, respectively (refer section 2.2). The proposal is located at, and crosses, the boundary of two regional catchment management zones; the Murrumbidgee and the Lachlan catchment management zones. The location of the proposal at the boundary of these catchments reduces the contribution from primary factors that dominate the regional water balance of the systems, such as the Lachlan and Murrumbidgee River. This is particularly the case for alluvial sediments within the proposal, where regionally the Lachlan and Murrumbidgee Rivers typically provide significant contribution to the groundwater resources. However, as the proposal is located outside these rivers regional floodplains, they have limited impact on the water balance model (WBM) within the Study area. In addition, within the Murrumbidgee catchment associated fractured rock aquifers, the local topographic highs and outcropping Lachlan formation encountered within the proposal play a more prominent role within the WBM, due to localised recharged. It is therefore more appropriate that the key components for the proposal's water balance be calculated at the Study areas sub-catchment domain level.

Three sub-catchment domains exist within the proposal (refer section 4.2). Two belong within the Lachlan catchment and contribute recharge to the Lachlan alluvial aquifer. The remaining sub-catchment provides contribution to the fractured rock aquifer. For definition of the aquifers refer to section 4.6.1.

3.6.2 Water balance model equation

A WBM can be calculated as the 'components that effect input, minus, the components that effect output, is equal to the change in storage (of a groundwater system)'. It provides a first pass conceptual idea, both qualitatively and quantitatively, of the controls and their approximate governing contributions within the nominated hydrological system. The following water balance equation has been generated for the Study area, with abbreviations and definitions of the key contributing components listed in Table 3.5 and Table 3.6. References for values used in calculations for the WBM are presented in Table 3.7. Simply put the water balance model equation is the sum of inputs (contributing factors) minus the sum of outputs (losses from the system).

$$\mathbf{dv/dt = [R_{(inf)} + S_{(c)} + I_{(inf)} + GWBF_{(in)}] - [Q_{(pump)} + GWBF_{(out)}]}$$

Table 3.5 Definition of positive groundwater contribution parameters

Parameter (positive contribution)	Definition
dv/dt	Change in storage (can also be a negative).
R(inf)	Infiltration from rainfall across the sub-catchments. This value includes loss from other climatic and topographic factors such as evapotranspiration.
S(c)	Stream (and flooding) contribution. Includes contribution from surface water runoff.
I(inf)	Infiltration contribution from irrigation.
GWBF(in)	Groundwater baseflow into the groundwater domain from regional systems.

Table 3.6 Definition of negative groundwater contribution parameters

Parameter (negative contribution)	Definition
Q(pump)	Groundwater removed from pumping of stock and domestic bores and basic landholder rights.
GWBF(out)	Groundwater baseflow out of the groundwater domain into regional systems.

Table 3.7 Description of values applied to the water balance model

Parameter	HSU[1]	Comment
Catchment area (km^2)	Lachlan alluvial and fractured rock	Approximate catchment area defined from topographic highs using LiDAR data.
$R_{(inf)}$ (m^3/yr)	Lachlan alluvial	2.5% infiltration factor from rainfall data obtained from Eurongilly (BOM Station 73124) (DPI-W 2016).
	Fractured rock	1.0% infiltration factor from rainfall data obtained from Eurongilly (BOM Station 73124).
$S_{(c)}$ (m^3/yr)	Lachlan alluvial	The watercourses within the catchment are ephemeral and dry (no flow) throughout most of the year. The Flood Study Report (IRDJV, 2019e) identified a baseflow contribution from Wattle Creek (gauge 412134), located within the Study area, during flood events. The calculated baseflow contribution for the December 2010 flood event has been extrapolated catchment wide and has a 2.5% annual exceedance probability of a similar event occurring.
	Fractured rock	Negligible contribution assumed from watercourses due to low connectivity to the primary aquifer (fractured rock). Infiltration from stream to shallow, perched aquifer is subject to evapotranspiration, further reducing contribution to the deeper aquifer (refer section 4.6).
$I_{(inf)}$ (m^3/yr)	Lachlan alluvial and fractured rock	Irrigation recharge rate of 30mm/ha per year of non-rice crop farmlands applied (Bilge, 2012). Value includes losses from evapotranspiration. 25% of defined catchment area assumed for irrigation (dryland crops).
$GWBF_{(in)}$ (m^3/yr)	Lachlan alluvial	The location of the proposal is within the upper bounds of the regional catchment and baseflow contribution would be linked primarily to streamflow and flooding contributions and leakage from dams within the defined catchment domain. Leakages from dams are considered minimal compared to the streamflow and flooding contribution that occurs during significant rainfall events. Groundwater baseflow and streamflow contribution are therefore considered to be the same source and thus groundwater base flow has been excluded (assumed 0) for the WBM.
	Fractured rock	Negligible due to the localised controls on groundwater flow within the aquifer (BOM 2012). Refer section 4.6.

Parameter	HSU[1]	Comment
$Q_{(pump)}$ (m^3/yr)	Lachlan alluvial	Negligible volume assumed from pumping occurring within the catchment boundaries. This is due to the Study area containing only one registered bore user, listed for household and domestic, that has been assessed as potentially extracting groundwater from the Lachlan alluvial (refer section 4.9.1).
	Fractured rock	Average distribution assumed for the total groundwater usage of stock and domestic bores for within the Lachlan fractured rock (DPI-W 2017). Stock and domestic bore usage volumes selected for the WBM as they contain priority water access rights and comprise the primary registered bore category within the Study area.
$GWBF_{(out)}$ (m^3/yr)	Lachlan alluvial	Values taken from Stockinbingal, Zone 7 within the Upper Lachlan Groundwater Flow Model (Bilge, 2012).
	Fractured rock	Negligible due to the localised controls on groundwater flow within the aquifer (BOM 2012). Refer section 4.6.
dv/dt (m^3/yr)	Lachlan alluvial and fractured rock	To be determined from the sum of all contributions (the water balance).

(1) HSU: Hydrostratigraphic Unit.

3.6.3 Water balance model uncertainty

Quantitative WBMs are designed to generate a conceptual understanding between the critical influencing factors on the groundwater cycle for a given domain. Therefore, any determined value represents a first pass approximation of the influence of the critical factors within the groundwater cycle. These generated numbers may be used for a qualitative approach to the proposals groundwater impact assessment (refer Chapter 6). Where a factor has been excluded from the WBM, it has been accounted for in the comments of Table 3.7 or assessed to be a non-critical component (negligible factor) of the groundwater cycle within the Study area. The following general comments, in addition the comments provided in Table 3.7, provide insight into the generation of the quantitative WBM equation presented in section 5.5:

- Evapotranspiration was not considered for preliminary WBM calculations as the depth of the groundwater table (refer section 4.6) was considered to be below or near (within 3m) of the evapotranspiration extinction depth of 10mBGL.
- Evapotranspiration contribution during infiltration has been applied in the selection of appropriate infiltration rates.
- Where groundwater may exist above the evapotranspiration extinction depth (perched above fractured rock), evapotranspiration is the dominant factor and vastly exceeds the contribution from all recharge factors (refer section 4.3).
- When no significant flooding event occurs during a year, the stream and flooding contribution is considered to be negligible. Outside of significant rainfall events that generate streamflow conditions and possibly flooding, localised leakage from dams would be the primary contributing attribute to the streamflow contribution. Leakage from dams would be dependent on the dam construction.
- The quantitative groundwater loss due to pumping value is likely exaggerated as it assumes all registered bores (production and basic landholder right) are functioning and that there is an equal distribution of bores across the relevant water sharing plan. However, realistically bores across the relevant water sharing plan are not evenly distributed but grouped around localised suitable groundwater resources. Higher densities of registered bores are typically encountered within the eastern portion of the water sharing plan (refer to section 2.2.3) and the Study area contains comparatively less bores than the eastern portion of the water sharing plan. In addition, approximately half of the registered bores have been assessed as possibly functional (refer to section 4.9.1), further indicating the exaggerated nature of the groundwater loss component due to pumping within the selected WBM domain.
- The WBM presented for the fractured rock is for the deeper groundwater aquifer. The shallow aquifer is expected to be non-permanent, due to the dominant negative process of evapotranspiration for perched groundwater above.
- All values listed are approximate and are intended as a guide to identify the contribution from the critical components within the groundwater cycle.

4 Existing environment

4.1 Existing environment overview

The combined desktop assessment and site investigations (detailed in Chapter 3) have been completed to develop a description of the existing hydrological regime and conceptual understanding of the proposal.

The following sections within this chapter describe the environmental conditions of the Study area.

4.2 Topography and catchments

The proposal crosses two major catchments, that of the Lachlan and the Murrumbidgee, which have further been subdivided into the following three sub-catchments within the Study area:

- **Lachlan Lower Slopes (Lachlan Major Catchment):**

  A minor sub-catchment located within the northern section of the proposal between Stockinbingal and Old Cootamundra Road that is associated with alluvial soils. The sub-catchment includes gently sloping to level farming land located east of the Dudauman Range. Elevation is typically between 300mAHD to 310mAHD, however, rare outcrops of volcanics exist within the sub-catchment that form part of the Lachlan upper slopes, where elevation proximal to Stockinbingal, can reach up to approximately 330mAHD.
- **Lachlan Upper Slopes (Lachlan Major Catchment):**

  The dominant sub-catchment and topography within the upper part of the proposal that starts south of Old Cootamundra Road and extends to the north to Stockinbingal. Topography is characterised by moderately undulating terrain west of Lighthouse Hill, the Twins Range and east of the Bethungra Range, where it is cut by numerous watercourses associated with Ironbong Creek and its associated tributaries. Elevation typically ranges between 320mAHD to 370mAHD.
- **Murray-Darling Basin Fractured Rock (Murrumbidgee Major Catchment):**

  The primary sub-catchment within the central to southern part of the proposal, between Illabo and south of Old Cootamundra Road, where it becomes part of the Lachlan upper slopes sub-catchment to the north. The sub-catchment generally passes through moderately to steep undulating land controlled by outcropping volcanics. The southern portion of the sub-catchment proximal to Illabo, transitions into gently to moderately undulating land where it is intersected by Billabong Creek. Elevation levels within the sub-catchment portion of the proposal, closely resembles the Lachlan upper slopes and extends to approximately 390mAHD. However, within a few kilometres east of the proposal (between 1.5km to 10km), where the western hills of the southern Tablelands are located, elevation can extend up to approximately 700mAHD. There is no direct interaction within this sub-catchment with the Murrumbidgee River regional floodplain.

The proposal typically traverses undeveloped rural areas used primarily for grazing and agriculture. The major industries in the area include livestock, wool and wheat. Most of the land within the Study area has been cleared and disturbed for agricultural activities, however some patches of remnant vegetation remain. For further details on surface water features within the primary catchments, refer to section 4.4.

4.3 Climate

Meteorological data was obtained from weather observation stations including Cootamundra Airport (BOM Station 73142), Eurongilly (BOM Station 73124) and Wagga Wagga AMO (BOM Station 71250). Eurongilly station provides long-term rainfall data to provide a more accurate historical summary, May 1884 to January 2021. Cootamundra Airport provides short-term rainfall data to encompass recent rainfall events in the provided hydrographs (Appendix A), November 1995 to April 2021. The Wagga Wagga station provides long-term evapotranspiration data, recorded from 1966 to 2021. A summary of historic climate data is provided in Table 4.1.

Historic monthly average rainfall and evapotranspiration data is shown in Figure 4.1 (BOM, 2021).

Table 4.1 Summary of historic climate data obtained from BoM stations 73142, 73124 and 71250 (BoM 2021)

Climate data	Values[1]	Comment
Mean monthly rainfall (Eurongilly: 1884–2021)	36.9mm – 51.0mm	Minimum rainfall typically occurs in February and March. Maximum rainfall typically occurs in June, July and October. Mean rainfall is generally consistent across all months.
Historic annual rainfall range (Eurongilly: 1884–2021)	194.8mm – 995.5mm	Historic minimum occurred in 1944. Historic maximum occurred in 1974.
Combined yearly rainfall mean (Eurongilly: 1884–2021)	532.0mm	Excludes months containing significant data gaps.
Mean monthly evaporation range (Wagga Wagga: 1966–2021)	39mm – 313.1mm	Minimum evaporation occurs in June and July. Maximum evaporation occurs from December to February.
Combined yearly evaporation mean (Wagga Wagga: 1966–2021)	1850.75mm	Rainfall marginally exceeds evapotranspiration in June and July. Evapotranspiration greatly exceeds rainfall from September to April.

(1) mm = millimetre.

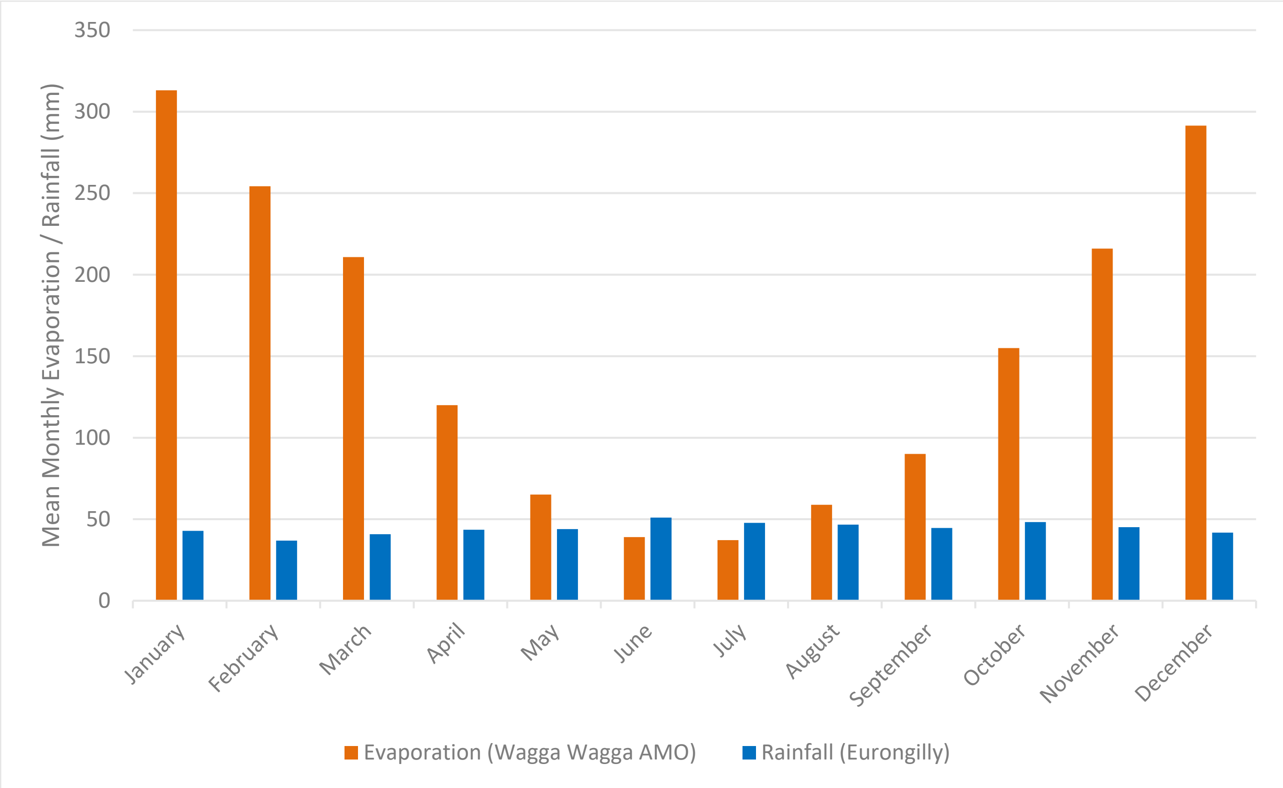


Figure 4.1 Mean monthly rainfall from available data between 1884 and 2021 at Eurongilly (BOM ID: 73124) plotted against mean monthly evaporation data between 1966 and 2021 at Wagga Wagga (BOM ID: 72150)

4.3.1 Long term rainfall trend

The long-term, annual cumulative deviation from mean (CDFM) rainfall for the 1884 to 2021 period at the Eurongilly station is plotted in Figure 4.2. The long-term cumulative residual rainfall plots provide an indication of the broad scale trends in rainfall pattern and are formulated by subtracting the average annual rainfall for the recorded period from the actual annual rainfall and then accumulating these residuals over the assessment period. Periods of below average rainfall are represented as downward trending slopes while periods of above average rainfall are represented as upward trending slopes. Rainfall can act as a primary recharge component for groundwater sources and downward trending slopes identified in climate graphs may be considered as ‘drying’ trends with associated potentially lower groundwater levels. In comparison, upward trending slopes can be considered as ‘wetting’ trends with potentially associated higher groundwater levels. The degree of association and response to groundwater levels to climatic trends will be dependent on the groundwater’s connectivity to local climatic recharge factors. For further information relating to groundwater sources located within the Study area and their connectivity to climate factors, refer to section 4.6.3.

The cumulative deviation plot shows a general upward sloping trend from 1950 to 1992, followed by a downward sloping (drying) trend until 2010, corresponding to the nationwide millennial drought and dry heatwave that impacted the Murray-Darling Basin. The record over the next 10 years shows a generally neutral trend, indicating average rainfall conditions.

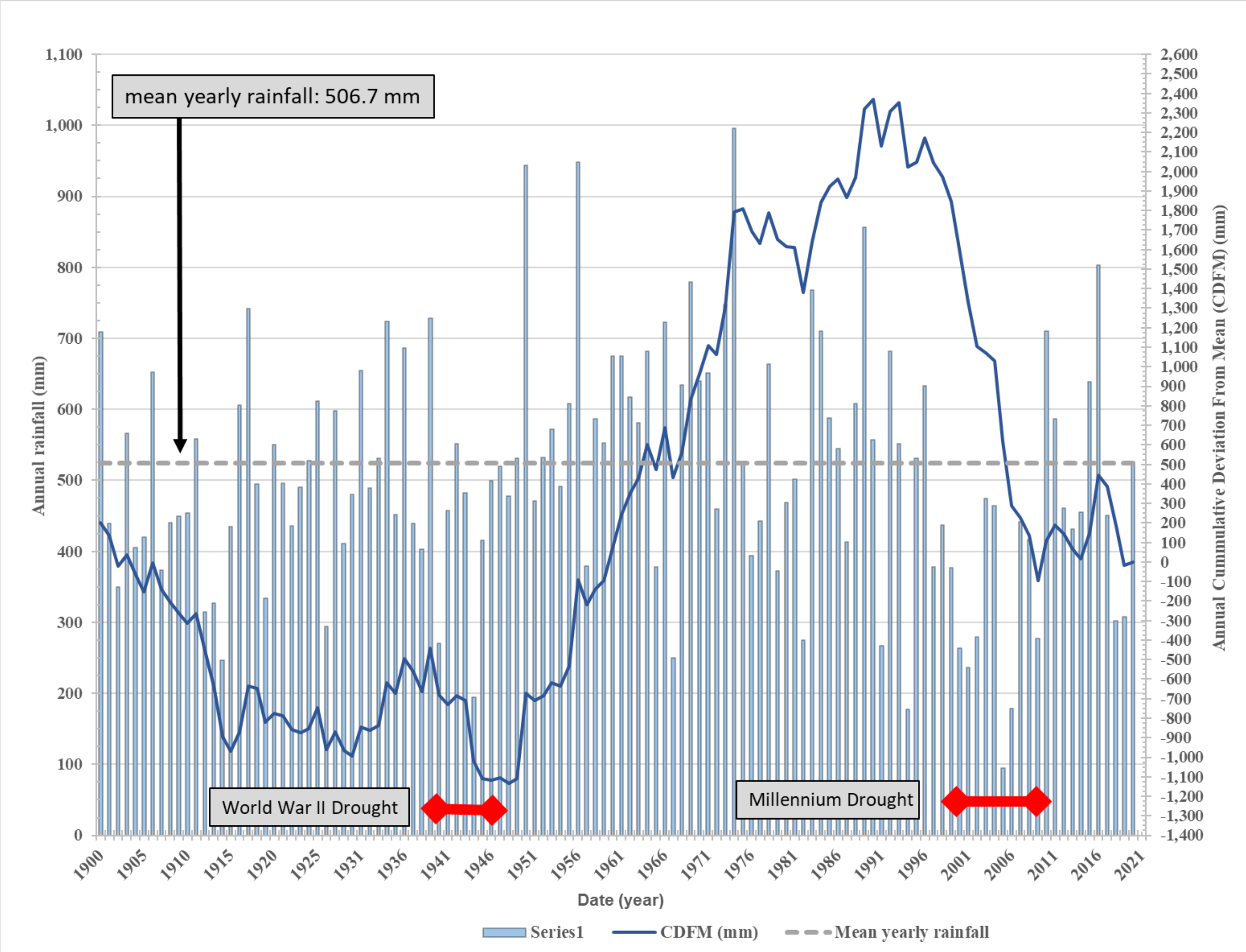


Figure 4.2 Long-term annual rainfall and CDFM curve (Eurongilly, 73124)

The above figures and table (Figure 4.1, Figure 4.2 and Table 4.1) illustrate that the climate is characterised by low annual precipitation, that for most the year, is exceeded by evaporation. The recent climatic trend (i.e. within the last decade) indicates the Study area is generally receiving rainfall approximate to its historic annual mean.

4.4 Surface water features

The proposal lies within two catchments (refer section 4.2) but is predominantly subject to local catchment flooding processes of minor (and predominantly ephemeral) watercourses and their tributaries that feed into the larger regional scale rivers. The named watercourses relevant to each catchment include:

- Lachlan Catchment:
  - Dudauman Creek
  - Powder Horn Creek
  - Wattle Creek
  - Bland Creek
  - Lagoon Creek
  - Dry Creek
  - Skeleton Hut Creek.

- Murrumbidgee Catchment:
  - Isobel Creek
  - Run Boundary Creek
  - Ironbong Creek
  - Redbank Fall Creek
  - Wandalybengle Creek
  - Merrybundinah Creek
  - Billabong Creek.

4.4.1.1 Murrumbidgee Local Catchments

At the southern end of the proposal there is no direct interaction with the Murrumbidgee River regional floodplain and the proposal is not impacted by regional scale flooding. Approximately 22km of the proposal lies within the Murrumbidgee catchment which slopes in a southerly direction and the proposal generally runs in a north-south alignment from Illabo. The proposal in this section is a greenfield site after the existing Main Southern line crossing of Billabong Creek.

The flood behaviour in this area is dominated by three watercourses, Billabong, Ironbong and Ulandra Creeks and the remaining watercourses are tributaries of these three or tend to be local overland flow, upstream catchments taken up by farmland. Ulandra Creek is a tributary of Ironbong which then becomes Billabong Creek at the rail and Olympic Highway crossing. Billabong Creek then flows south for a further 35km before joining the Murrumbidgee River upstream of Wagga Wagga.

4.4.1.2 Lachlan River Local Catchments

The proposal is located within the upper portions of the Lachlan River catchment and crosses the tributaries of the Lachlan River for approximately 16km of the alignment. Dudauman Creek and Powder Horn Creek are the main watercourse intersections in the rail alignment and these are both tributaries of Bland Creek which is located to the east of the proposal. Bland Creek heads in a northerly direction and discharges into Lake Cowal which overflows into the Lachlan River floodplain during high flows.

The flood behaviour in this area is dominated by Powder Horn Creek across the farming areas to the south of Stockinbingal. Dudauman Creek flows through the developed areas of Stockinbingal and is controlled by flood levees running west to east before joining Bland Creek to the east of town. Further to the south in the upper most reaches of the catchment is Wattle Creek which forms the headwaters of Bland Creek and all other areas of the project are subject to local overland flows.

Details on flooding and hydrology are presented in Technical Paper 4 – Hydrology and flooding assessment.

4.4.2 Wetlands

No wetlands of International Importance (RAMSAR listed wetlands) are located near the proposal. The closest listed wetlands are located more than 400km north of Stockinbingal and therefore will not be impacted by the proposal.

4.5 Geology and soils

4.5.1 Regional geology

Mapped surface geology from the Cootamundra 1:250 000 Geological Sheet (Warren et al, 1996) within the Study area comprises the Ordovician Junawarra Volcanics, Silurian igneous sediments of the Frampton Volcanics, Combaning Formation, as well as Quaternary-aged alluvial and colluvial sediments (Figure 4.3). Geological units underlying the proposal are described in Table 4.2.

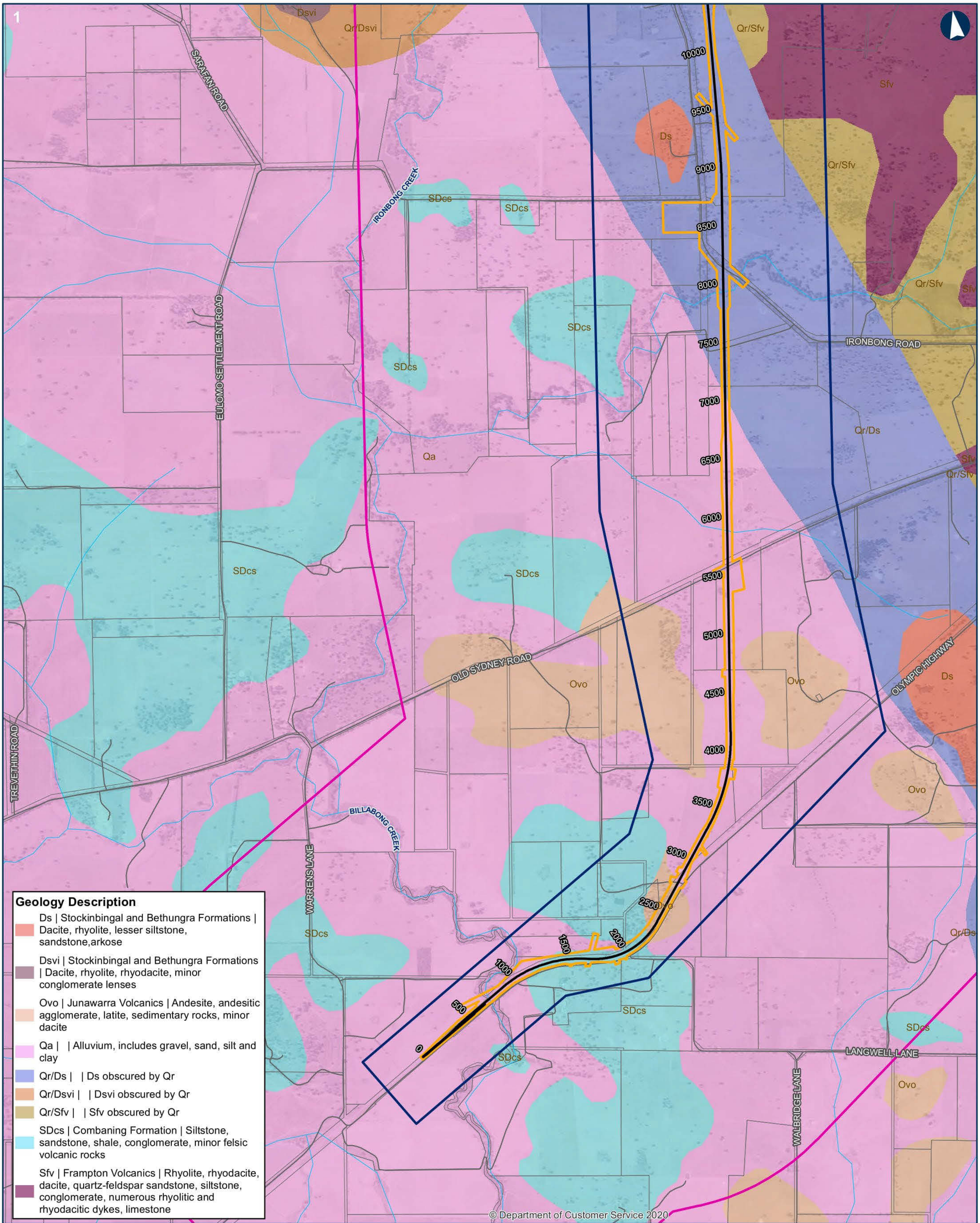
Table 4.2 Regional geological units

Age	Formation	Lithology
Quaternary	Unnamed, map symbol: Czs	Sand or gravel plains; may include some residual alluvium; quartz sand sheets commonly with ferruginous pisoliths or pebbles; local clay, calcrete, laterite, silcrete, silt and colluvium.
	Unnamed, map symbol: Qc	Colluvium and/or residual deposits, sheetwash, talus, scree; boulder, gravel, sand; may include minor alluvial or sand plain deposits, local calcrete and reworked laterite.
Devonian	Combaning Formation	Siltstone, sandstone, shale, conglomerate, and minor felsic volcanic rocks.
Silurian	Frampton Volcanics	Rhyolite, rhyodacite, dacite, quartz-feldspar sandstone, siltstone, volcaniclastic and polymictic conglomerate, numerous rhyolitic and rhyodacitic dykes, limestone.
Ordovician	Junawarra Volcanics	Andesite, andesitic agglomerate, latite, sedimentary rocks and minor dacite.

4.5.1.1 Geological controls and structure

Regional deformation can act as critical controls for groundwater flow within fractured rock hydrostratigraphic units (refer section 4.6.1), and this is particularly important in understanding groundwater setting along the proposal alignment.

The proposal is situated within the western limb of the eastern zone of the Lachlan Fold Belt, that is bounded by a major regional structure, called the Gilmore Fault Zone (Stuart-Smith, 1991). The Gilmore Fault Zone is a stratigraphic control, known as a thrust-fault (structural movement that has caused the eastern geological units to be thrusted over the western geological units), that extends for several hundreds of kilometres from mid-NSW to southern Victoria (Stuart-Smith, 1991). It is located approximately 13km to the west of the Study area. In addition to the Gilmore Fault Zone, the Juigong Shear Zone is located approximately 13km to the east of the Study area.



ILLABO TO STOCKINBINGAL 4.3 Regional Geology

MAP 1 OF 4

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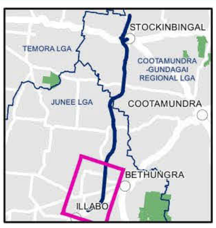
Track alignment
Groundwater Study Area
Roads
Watercourse
Lot Boundary



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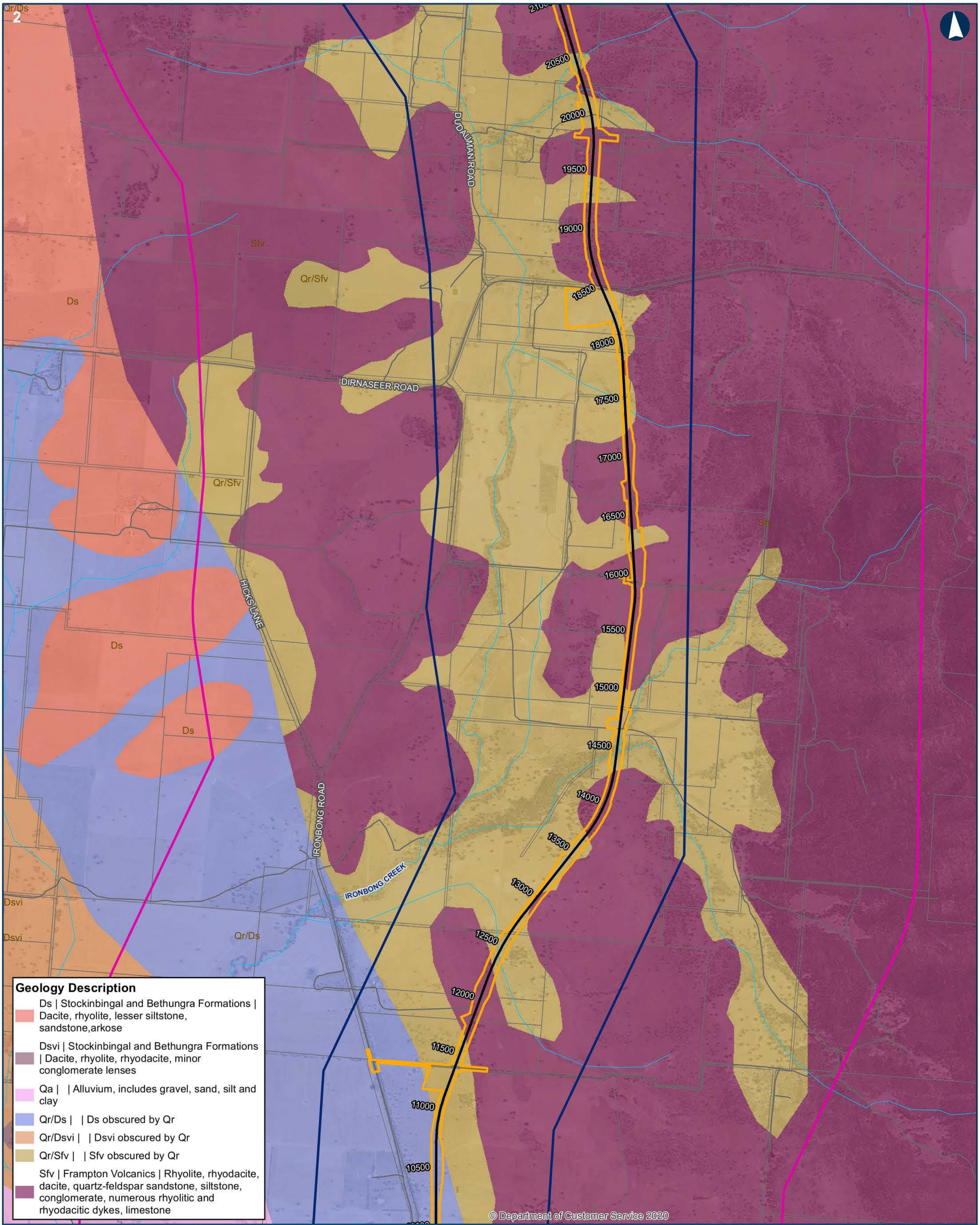

ILLABO TO STOCKINBINGAL 4.3 Regional Geology

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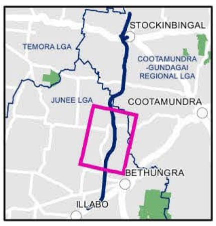

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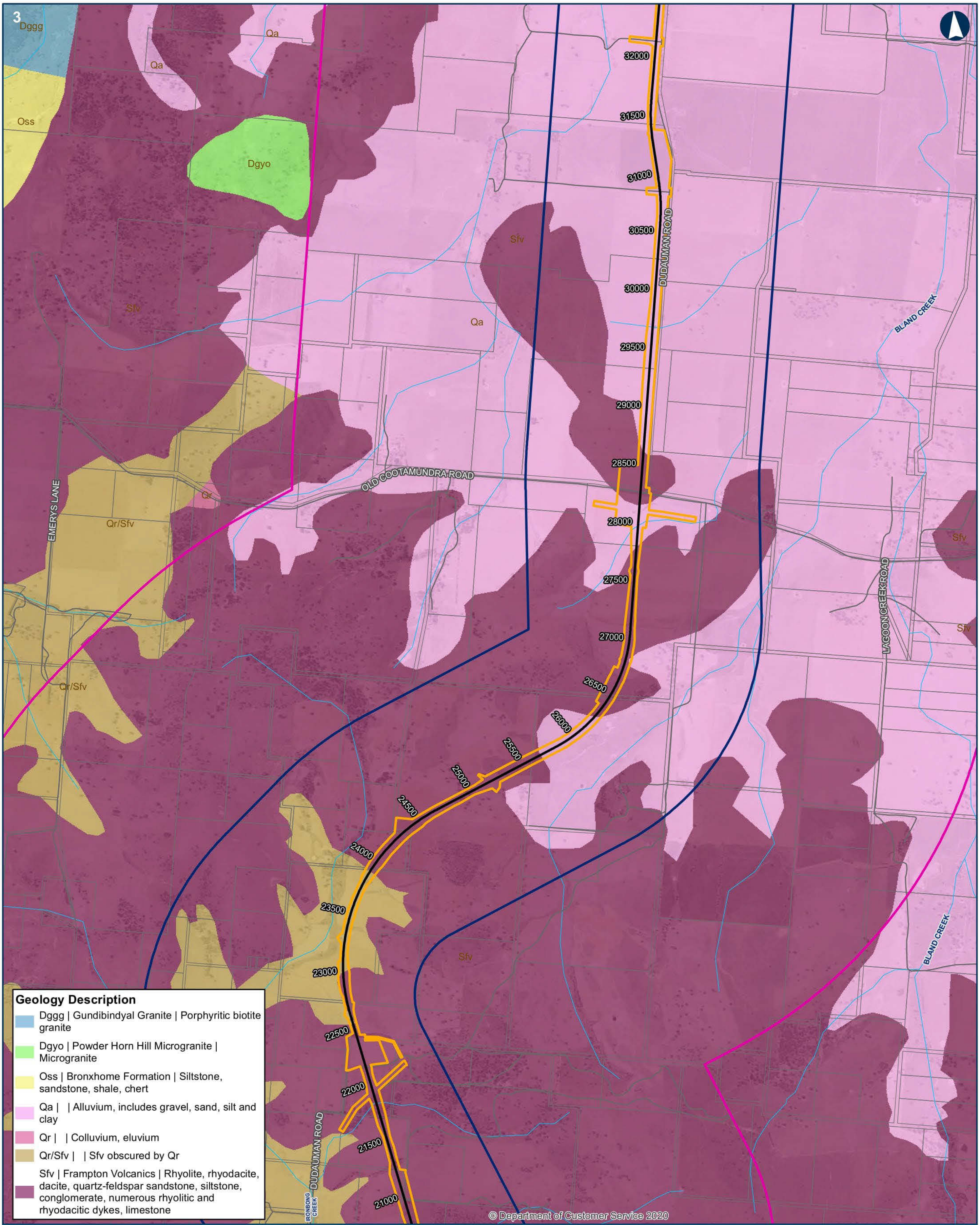

ILLABO TO STOCKINBINGAL 4.3 Regional Geology

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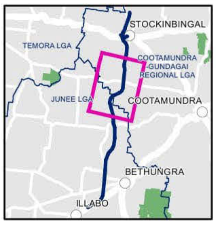

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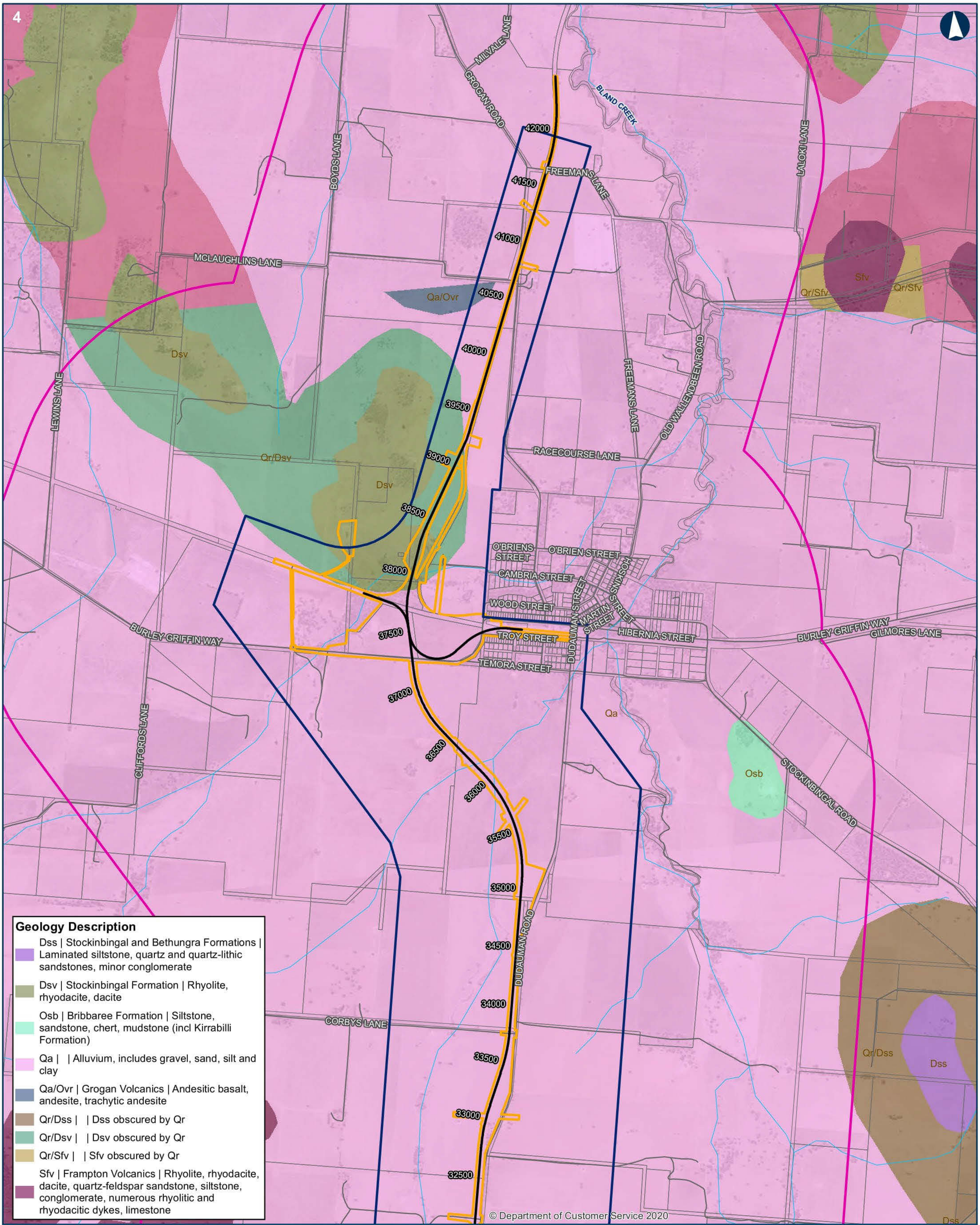

ILLABO TO STOCKINBINGAL 4.3 Regional Geology

MAP 4 OF 4

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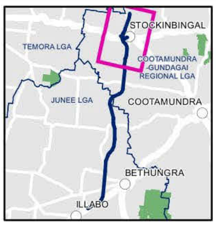

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The regional geological setting is defined as part of orogenic processes (plate collision and mountain building), however the structural evolution and deformation has been under significant scholarly debate within the past decade (Collins & Hobbs, 2001; Aitchison & Buckman, 2012; Musgrave, 2015). The following generally accepted, key regional structural facts have been summarised and further defined by Venkatraman (2017):

- Peak deformation occurred during the late Ordovician to Silurian, that divided the region into three distinct structural zones (the western, central and eastern).
- The eastern zone of the Lachlan Fold Belt is dominated by north-south structural grain.
- The central zone of the Lachlan Fold Belt is characterised by northwest trending structures.
- There is evidence of multiple, cyclic, compression and extension deformation phases. This has resulted in a series of basement highs and troughs, that can create localised lithological thickening and thinning. The study area is located within and at the margin of the Tumut Trough.
- Structural deformation (and control) within the region proximate to the study area is dominated by foliation and folding that occurred during the 3rd deformation event (defined as F_3/S_3). This event has overprinted previous mineralogical structural alignment.
- Controlling structural deformation (F_3/S_3) of alignment, faults and folding are classified as tight to isoclinal, steeply plunging (to the north and south) and near vertical. Stuart-Smith (1991) during a study of the Gilmore Fault Zone measured the geological dip and strike measurements of F_3/S_3 as 86/344 to 87/356 (dip/strike); north-northwest to north.

The structural alignment of the rock fabric and defects act as a critical control to groundwater resources (availability, location, flow and volume) and partly to their water quality, for any groundwater source located within fractured rock underlying the proposal.

4.5.2 Geology within the study area

Intrusive investigations along the proposal alignment were undertaken to define site geology and aid the geotechnical and hydrogeological assessment. Generally, site soils matched mapped regional geology, although the distinction between alluvial and colluvial sediments was often difficult to discern during field investigations. This could be due to the stratigraphy having formed as a combination, to varying degrees, of both processes. Table 4.3 summarises the information collected from the geotechnical boreholes that were converted into groundwater monitoring bores and portrays a suitable representation of the proposals underlying geology.

Typically, encountered rock within the proposal was moderately to highly defected with sub-vertical joints. Where significant structural defect zones were intersected, core was often unable to be retrieved during drilling (core loss). This occurred within all the boreholes listed in Table 4.3 that were converted to monitoring bores and intersected rock. Core loss intervals varied between 0.1m (BH204 and BH212) to 1.55m (BH213), with bores often containing multiple zones of core loss.

Table 4.3 Groundwater monitoring boreholes within the Study area

Boreholes	Total depth (m)[1]	Lithology	Formations Intersected[2]
BH201	20.14	Alluvial deposits mostly composed of gravelly clay and sandy clay with fine to coarse sub-angular gravel and medium to coarse grained sand to termination depth.	Quaternary alluvium
BH202	13.22	Possible deep profile of residual clays to 11.0mBGL, overlying extremely weathered to highly weathered meta-siltstone and meta-sandstone to termination depth.	Combaning Formation
BH204	20.80	Possible gravelly clay to clay alluvium/residual soils to 13.1mBGL, derived from underlying deeply weathered interbedded meta-siltstone and meta-sandstone.	Quaternary alluvium[3] Frampton Volcanics
BH211	20.20	Residual clay and sandy gravelly clay to 14.5mBGL, overlying coarse grained tuff to termination depth.	Frampton Volcanics
BH212	26.85	Shallow residual silty clay soils to 0.8mBGL, overlying highly fractured, fine to medium grained rhyolite.	Frampton Volcanics
BH213	25.22	Possible colluvial or alluvial gravelly clay soils to 1.7mBGL, overlying a deep profile of residual clays to 8.6mBGL, above highly fractured fine to medium grained rhyodacite to termination depth.	Quaternary colluvial/ alluvial Frampton Volcanics
BH215	18.70	Shallow gravelly clay residual soil to 1.6mBGL, overlying fine grained rhyolite to termination depth.	Quaternary alluvium Frampton Volcanics
BH217	20.36	Possible clay colluvial/alluvial deposits to 9.0mBGL, overlying highly fractured fine to medium grained meta-sediments to termination depth.	Quaternary colluvium/ alluvium Frampton Volcanics
BH219	20.97	Alluvial deposits containing beds of sandy clay, Silty clay and clay, with lenses of gravel to termination depth.	Quaternary alluvium
BH220	20.95	Alluvial deposits containing beds of gravelly clay, sandy clay and clay to 7.4mBGL, overlying possible cemented alluvial sand or extremely weathered sandstone to 17.3mBGL, situated above meta-siltstone and meta-sandstone to termination depth.	Quaternary alluvium Combaning Formation
BH054	30.00	Residual soil containing sandy clay and interbedded claystone and clay to 2.5mBGL. Weathered tuff underlies the residual soil to 12.1mBGL and is underlain by rhyolite, rhyodacite and dacite to termination depth.	Frampton Volcanics

(1) Adjusted vertical depth for BH202 and BH212 (refer to section 3.4.2)

(2) Where quaternary alluvial or colluvial sediments are not listed, encountered sediments are likely residual and have been combined with the hard-rock geological formation.

(3) Possibly present.

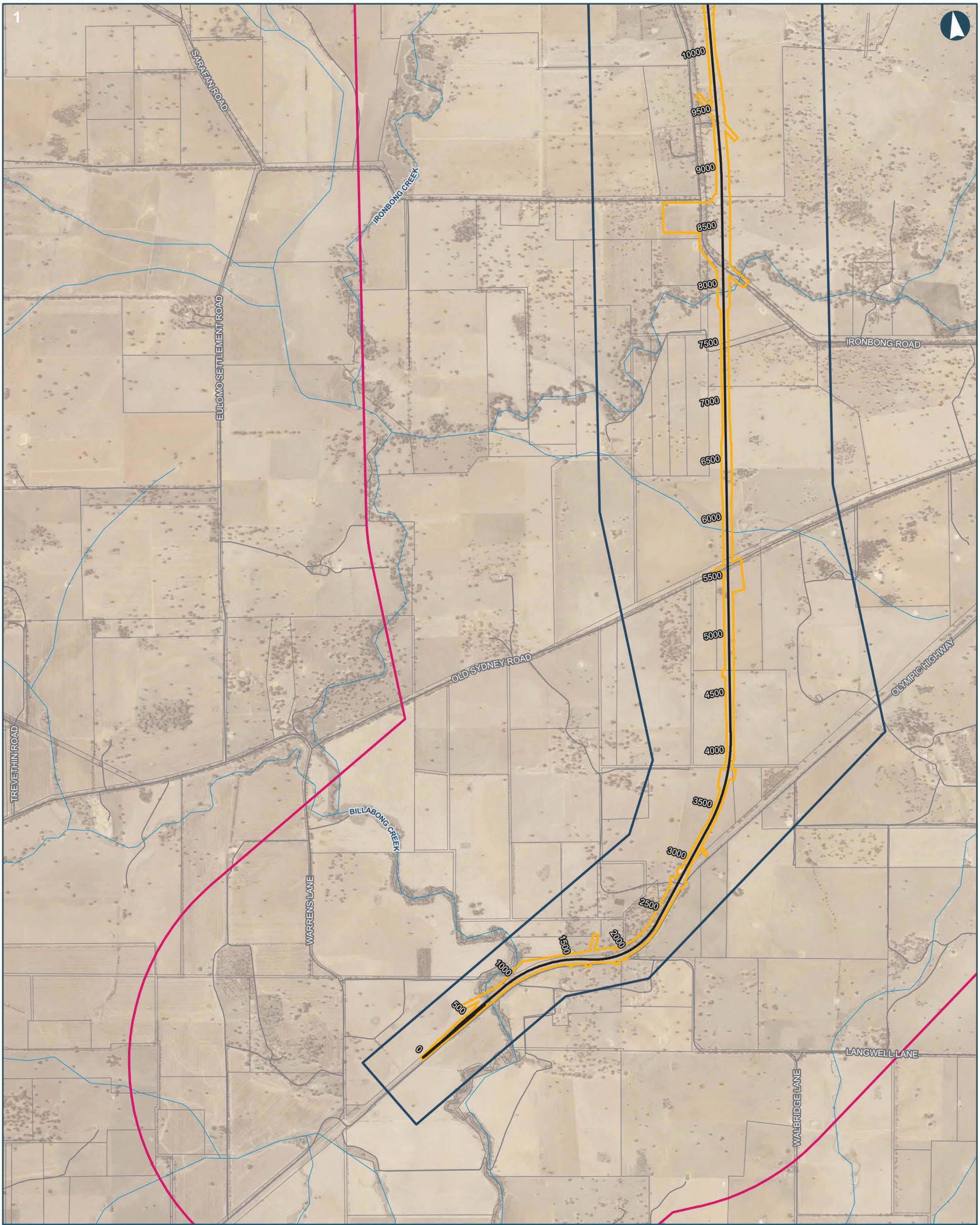
4.5.3 Salinity

Soil types within the study area are known to have localised salinity hazards. Salinity hazard is complex and relates to the soil type, the landscape features, local hydrology and also the development on the land.

Landscapes known to contain saline soils exists within the proposal (Junee Local Environmental Plan (LEP) 2012) at the following locations:

- west of the proposal between chainage 11,800 and 17,100. The saline identified land is associated with the topographic low and sediments of Ironbong Creek and its tributaries
- east of the proposal between chainage 14,600 to 14,700. Within the proposal, extending west, between chainage 17,450 to 17,550
- west of the proposal between chainage 18,000 to 18,400
- east and west of the proposal within the alluvial sediments associated with Isobel Creek at the proposed bridge crossing (chainage 19,700 to 20,200)
- west of the proposal proximal at chainage 21,300 and within the proposal between chainage 21,725 and 21,825. The identified saline land exists within the saddle of two topographic ridges
- a large (approximately 35ha) area of land associated with the alluvial sediments of Ironbong Creek and its tributaries. The saline land is predominately west of the proposal between chainage 22,800 and 23,900. However, underlies and crosses to the east of the proposal site between chainage 23,150 to 23,550 and proximal to 23,700.

The NSW Office of Environment and Heritage, Soil and Land Information System contains data points in the local area identifying evidence of soil salinity where soils have been sampled previously. In addition, the Environmental Planning Instrument – Salinity (DPE, 2021) has mapped saline soil within the Study area and is presented in Figure 4.4, with GIS data obtained from DPE (2021). Refer to Technical Paper 14 – Contaminated land assessment for further details regarding soils and salinity.



ILLABO TO STOCKINBINGAL 4.4 Saline land within the Groundwater Study Area

MAP 1 OF 4

0 500 1,000 1,500 m

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- Lot Boundary

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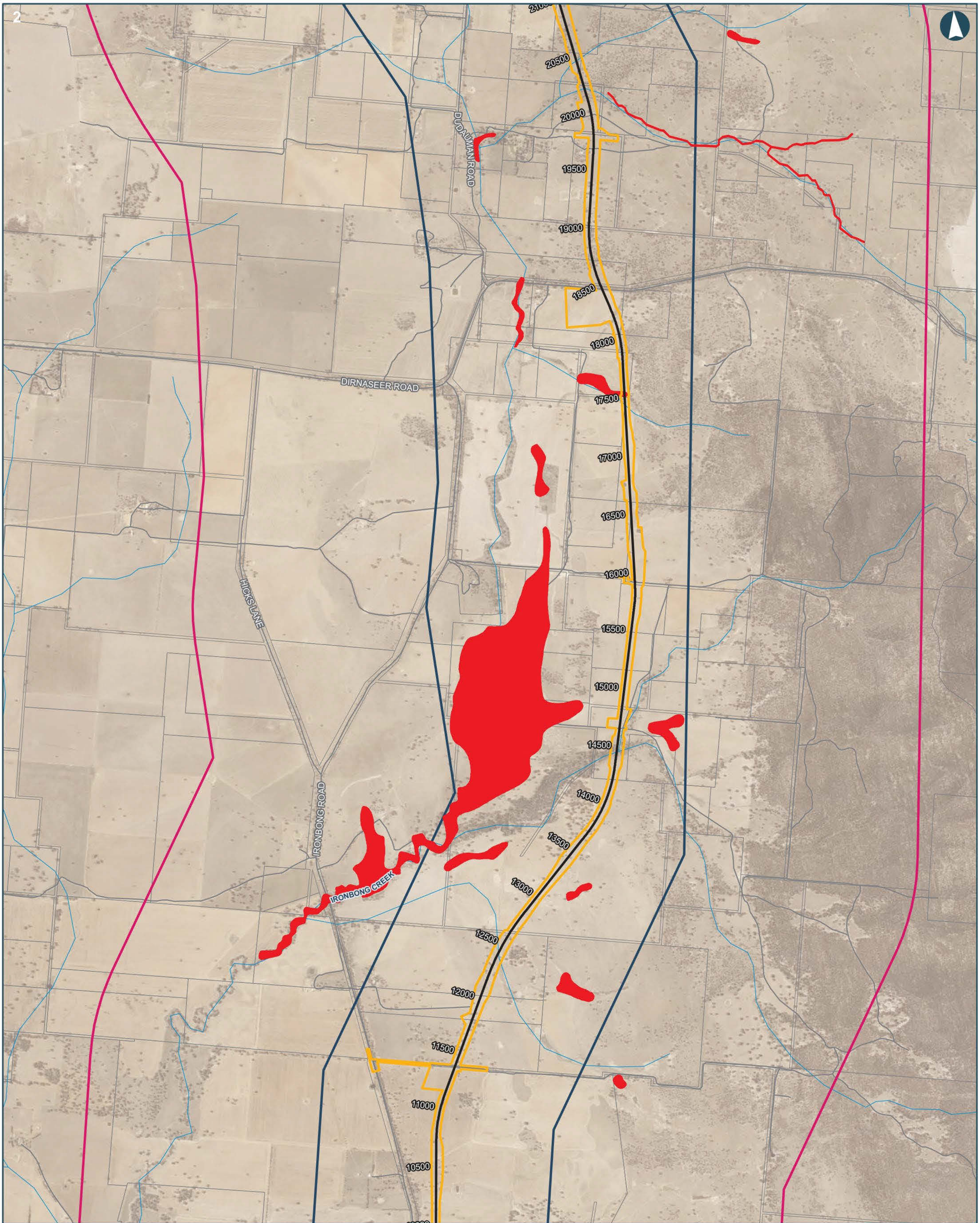

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MAP 2 OF 4

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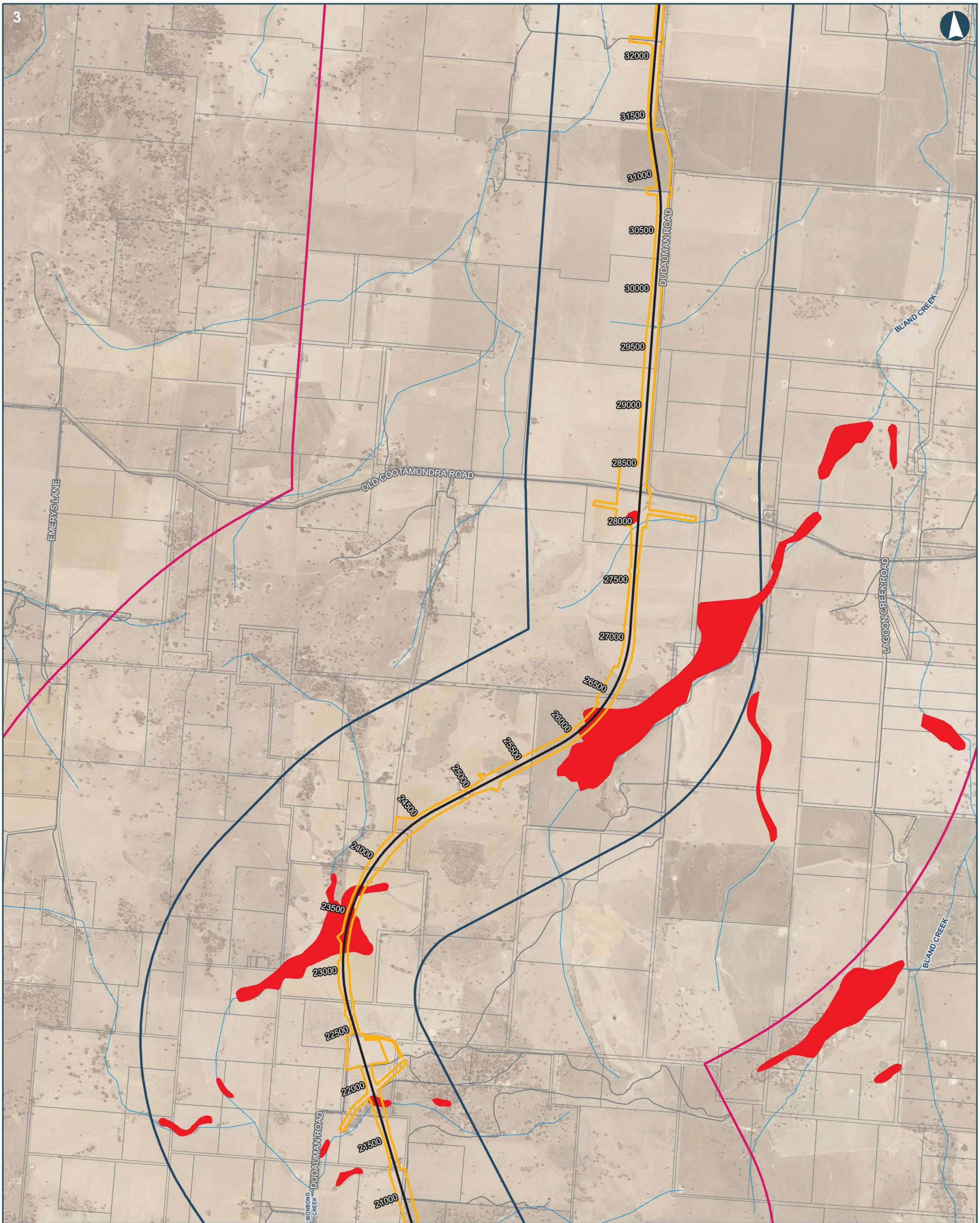

ILLABO TO STOCKINBINGAL 4.4 Saline land within the Groundwater Study Area

MAP 3 OF 4

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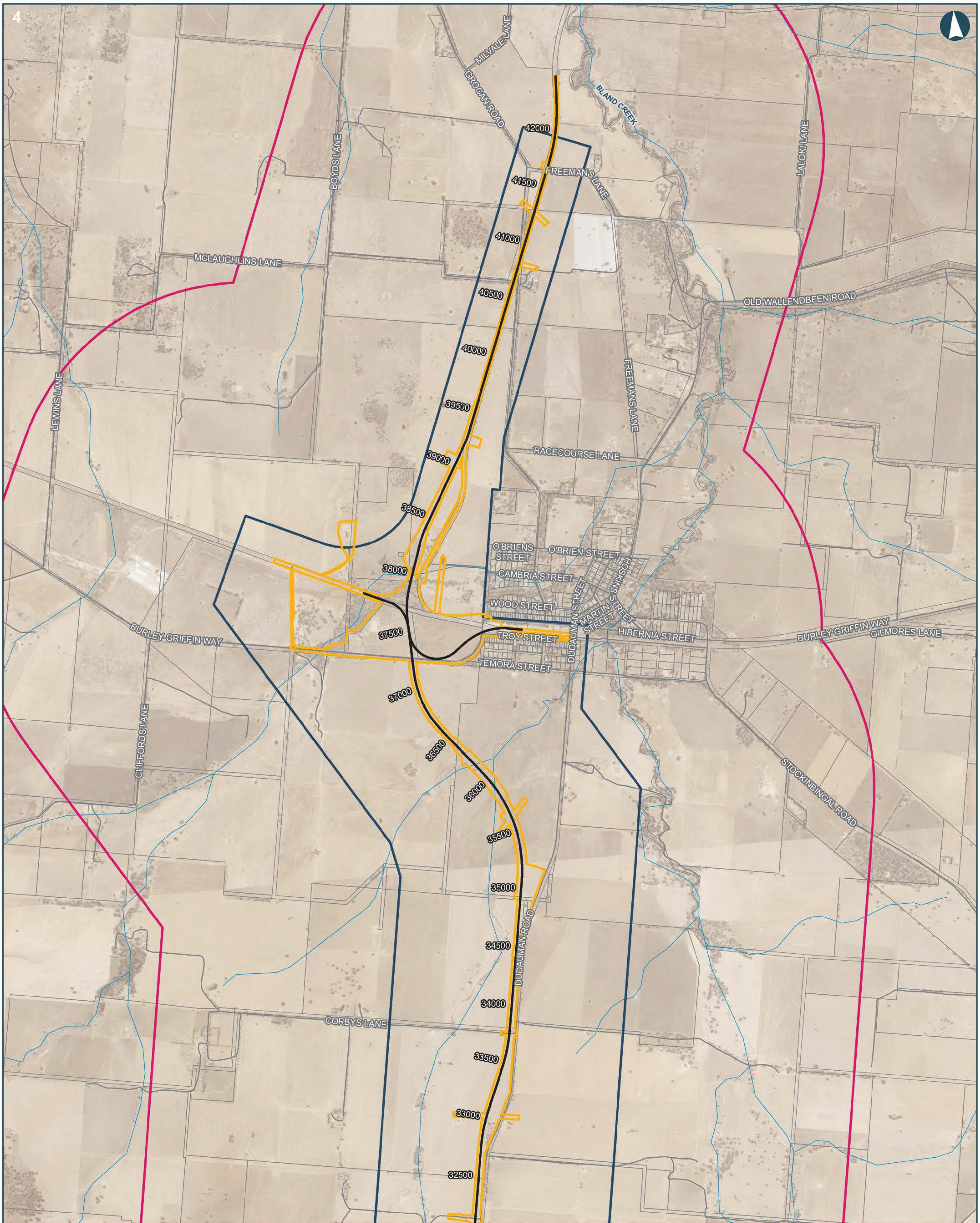

ILLABO TO STOCKINBINGAL 4.4 Saline land within the Groundwater Study Area

MAP 4 OF 4

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- I2S Investigation Corridor
- Groundwater Study Area
- Salinity (EPI 2021)
- Roads
- Watercourse
- Lot Boundary

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4.6 Hydrogeology

4.6.1 Hydrostratigraphy

Hydrostratigraphic units (HSUs) are defined as geological materials of similar hydrogeological properties. HSUs are generally based on stratigraphic units, although units of similar groundwater storage and transfer properties are often classified together as a single HSU.

HSUs within the Study area are generally delineated as per the water sharing plans, described in section 2.2.3. However, alluvial sediments associated with Billabong Creek governed under the NSW MDB Fracture Rock Groundwater Sources 2020, share similar hydrogeological properties to the Lachlan Alluvial Groundwater Sources 2020 (i.e. contains a permanent unconfined to semi-confined groundwater resource). These alluvial sediments associated with Billabong Creek have therefore been grouped together with the Lachlan Alluvial Groundwater Sources 2020, for assessment purposes.

Table 4.4 provides a summary of the encountered characteristics of the HSUs within the Study area. Borehole details are provided in Appendix B.

Table 4.4 HSU within Study Area

Hydrostratigraphic unit	Groundwater resource unit (geology unit)	Estimated thickness where encountered (m)	Characteristics
Lachlan alluvial [1]	Quaternary alluvial and colluvium – sand, gravels, clay, silt	5 – 20+	Unconfined to semi-confined water bearing zones. Overlying basement fractured rocks mostly situated within drainage lines and low-lying plains. Limited connectivity to underlying fractured rock HSU.
Fractured rock (shallow)	Quaternary and Tertiary colluvial or residual and – sand, gravels, clay, silt Weathered Ordovician – Devonian volcanics (Combaning Formation, Frampton Volcanics, Junawarra Volcanics)	0 – 15 (unconsolidated sediments and weathered rock of the shallow fractured rock aquifer)	Perched/unconfined to semi-confined water within unconsolidated sediments and weathered rock that overlie the fractured rock basement. This water is anticipated to contribute locally to regional groundwater, however the amount of recharge will be controlled by dominant climate factors such as evapotranspiration. Potentially confined by overlying alluvial/ colluvial clays. Outcropping through regional hills.
Fractured rock (deep)	Ordovician – Devonian volcanics (Combaning Formation, Frampton Volcanics, Junawarra Volcanics)	100+ (basement fractured rock of the deep fractured rock aquifer)	Semi-confined to confined system within a fractured rock basement. Low primary porosity, highly localised groundwater flow controls due to the varying degree of structural deformation. Higher groundwater yield rates would be related to thickness and width of water bearing structural deformation zones that are present.

(1) Includes alluvium sediments associated with Billabong Creek that is governed within the NSW MDB Fractured Rock Groundwater Sources 2020. Inclusion is due to the permanent nature of the groundwater resource within the watercourse's sediments.

4.6.1.1 Lachlan unregulated and alluvial (Lachlan alluvial)

The Lachlan alluvial is largely associated with the Cainozoic undifferentiated sediments and the Quaternary colluvium deposits within the northern portion of the proposal study area. The Lachlan alluvial is attributed with thicker sequences of alluvial deposits, which represents the key factor in discerning between the Lachlan alluvial and the similar sediments that have been identified to form the shallower aquifer within the fractured rock HSU. Regionally, the Lachlan alluvial is described as consisting of sand or gravel plains that may include some residual alluvium, quartz sand sheets, local clay, calcrete, laterite, silcrete, and silt. Several geotechnical boreholes intersected the Lachlan alluvial which was observed to consist of a silty clays and sandy clays with gravel lenses, indicating the HSU within the proposal could be classified as a less productive aquifer (refer section 2.2.3). Encountered sand and gravel lenses were typically discrete and less than 1m thick. The presence of these preferential flow thin bands will help restrict discharge rates if groundwater within the Lachlan alluvial is intersected due to their limited thickness (reduced aquifer transmissivity).

Regionally, the Lachlan alluvial is divided into two main aquifer systems, a shallow aquifer is between 35–60mBGL deep and a deeper aquifer that reaches up to a maximum of 150mBGL deep. The shallow aquifer is unconfined/semi-confined and the deeper aquifer is semi-confined. Within the Lachlan alluvial groundwater levels are monitored at a regional scale by WaterNSW from 295 monitoring bores (152 sites). A long-term regional decline has been as groundwater extraction from the resource has steadily increased.

Within the Study area, the Lachlan alluvial consists of a semi-confined to unconfined HSU forming the water table. Due to the location of the Study area at the boundary of the regional catchments, the alluvial aquifers are likely to be shallower in extent. Site investigations have indicated the Lachlan alluvial was on average 8m thick although regions of greater thickness were intersected, with a thickness of greater than 20m encountered in two boreholes (BH201 and BH219), which terminated within the Lachlan alluvial at 20.14mBGL (236.9mAHD) and 20.97mBGL (282.83mAHD), respectively. BH201 was drilled adjacent to Billabong Creek watercourse in the south of the Study area and BH219 in the low lying alluvial proximal to Stockinbingal in the north.

The Lachlan alluvial unconformably overlies the fractured rock within the Study area and is expected to have limited connectivity with the deeper fractured rock HSU. Connectivity may be present between the shallow fractured rock aquifer and the Lachlan alluvial, particularly during periods of significant rainfall or flooding, where the shallow fractured rock aquifer may contribute groundwater into the Lachlan alluvial.

4.6.1.2 Murray-Darling Basin fractured rock (fractured rock)

The fractured rock HSU consists of two aquifers that underlie the Lachlan alluvial, and outcrop locally across most of the central and southern portions of the Study area.

The first aquifer is the shallow fractured rock aquifer, a shallow perched/unconfined to semi-confined system consisting of unconsolidated sediments and weathered rock. The shallow aquifer is expressed within the Study area at topographic highs and along the slopes of hills. It is inferred to extend up to approximately 15mBGL. The system is anticipated to be strongly controlled by localised topographic influences and climatic conditions. The shallow aquifer is expected to be limited in depth, cover and potential volume of groundwater. Rainfall infiltration is expected to be the primary recharge process, while evapotranspiration is considered the primary extraction process.

The second aquifer is the deep fractured rock aquifer, a semi-confined to confined system comprising of fractured rocks from the Lachlan Fold Belt, including the Combaning Formation, Frampton Volcanics, and the Junawarra Volcanics. The deeper aquifer is considered the primary ‘fractured rock’ aquifer as the system is considered permanent and representative of the regional groundwater system. Groundwater flow is structurally controlled, with fractures and faulting being the dominate conduits for groundwater movement in the region. Fractured rock aquifers have low primary porosity and higher secondary porosity (controlled by fractures, faults and foliation). The deeper fractured rock aquifers within the Lachlan Fold Belt tend to have low storage capacity with regional yields reported as up to 5l/s, but more commonly <1l/s (Hassall & Associates, 2003). Both regional and local faults are found within the Study area.

Intersected deeper fractured rock lithology during sub-intrusive investigations displayed a strong structural alignment, inferred to match the dominant northwest to north regional orientation. Intersected structure defects indicated that the fractured rock was brittle and occasionally clay coated. Staining was observed on defects and interpreted to be goethite and/or limonite, indicating the preferential flow conduits of groundwater along these defects.

These observations made during desktop studies and site investigations of hydraulic conductivity and groundwater levels, indicates the deep fractured rock HSU is highly variable as hydraulic conductivity is strongly dependent on the degree of fracturing or faulting intersected by the groundwater bore.

4.6.2 Groundwater level measurements

Groundwater levels recorded in the Lachlan Alluvial ranged from 7.36mBGL to 19.09mBGL. Monitoring bore BH201, which is situated adjacent to a drainage channel, consistently recorded the shallowest groundwater levels, ranging from at 7.36mBGL to 7.75mBGL. During GME1, in BH219 where 19.09mBGL was recorded, the bore only contained a shallow water column of 0.3m. Following purging for sampling, the bore failed to recover and was dry during subsequent monitoring events, indicating that the minor water intersected in the bore was likely artificial and was not representative of the groundwater level within the region.

Groundwater levels, where observed, within the fractured rock ranged from 1.72mBGL to 20.47mBGL. Groundwater monitoring bore BH217 recorded the shallowest value of 1.72mBGL. The bore was screened in the underlying fractured rock and the recorded groundwater level is likely indicative of the potentiometric surface of the confined fractured rock aquifer (refer section 5.2). Key observations include:

- during drilling (using solid flight auger) of BH217 groundwater was not observed up to 9mBGL. However, groundwater measurements during subsequent GMEs indicated shallow groundwater levels
- groundwater measurements recorded for BH204, BH213, BH215 and BH054 are likely representative of the fractured rock aquifer
- groundwater measurements recorded in BH211, BH212 and BH219 during GME1 are likely residual drilling fluids from borehole construction and are considered not representative of actual groundwater
- groundwater monitoring bores BH202 and BH220 were dry throughout all GMEs.

Manual groundwater levels recorded during the GMEs within the Lachlan alluvial and fractured rock obtained are summarised in Table 4.5.

Table 4.5 Groundwater levels

Bore ID	HSU	GME 1 (January 2019)		GME 2 (May 2019)		GME 3 (February 2021)		GME 4 (April 2021)	
		SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]
BH201	Lachlan alluvial [1]	7.72	249.58	7.75	249.55	7.62	249.64	7.36	249.94
BH202 [2]	Fractured rock	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH204	Fractured rock	13.37	271.16	13.43	271.10	12.93	271.60	12.91	271.62
BH211 [6]	Fractured rock	19.48 [4]	325.53 [4]	Dry	Dry	Dry	Dry	Dry	Dry
BH212 [2]	Fractured rock	20.47 [4]	359.16 [4]	Dry	Dry	N/A [7]	N/A [7]	N/A [7]	N/A [7]
BH213 [5]	Fractured rock	8.29	342.24	8.70	341.83	N/A [7]	N/A [7]	N/A [7]	N/A [7]

Bore ID	HSU	GME 1 (January 2019)		GME 2 (May 2019)		GME 3 (February 2021)		GME 4 (April 2021)	
		SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]	SWL (mBGL)	SWL (mAHD) [3]
BH215	Fractured rock	14.52	362.73	16.24	361.01	N/A [7]	N/A [7]	N/A [7]	N/A [7]
BH217 [5]	Fractured rock	1.72	344.84	1.90	344.66	2.51	344.05.	1.76	344.80
BH219	Lachlan alluvial	19.09 [4]	284.64 [4]	Dry	Dry	Dry	Dry	Dry	Dry
BH220	Fractured rock	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
BH054	Fractured rock	N/A[6]				16.97	324.85	16.95	324.87

(1) BH201 located within alluvial sediments of Billabong Creek.

(2) Inclined (70°) borehole. SWL measurement has been compensated for inclined angle to represent SWL as measured from vertical.

(3) Topographic elevation values obtained from ARTC supplied LiDAR survey, 2015.

(4) SWL measurement likely artificial due to residual drilling fluids, levels are not considered to be representative of groundwater level.

(5) Measured groundwater levels are anticipated to be representative of the potentiometric groundwater level, not intersected groundwater depth.

(6) BH054 installed on 3 February 2021.

(7) BH212, BH213 and BH215 were unable to be monitored during GME3 and GME4 due to land access restrictions.

4.6.3 Hydrographs

Hydrographs, including daily rainfall from Cootamundra Airport (BOM Station 73142), for monitoring bores listed in Table 4.3 are presented in Appendix A. A summary of hydrograph behaviour from bores that contained measurable groundwater levels during the monitoring period is provided in Table 4.6. Bores that were ‘dry’ or that were not considered to reflect groundwater conditions (BH202, BH211, BH212, BH219 and BH220) are excluded from the summary.

Table 4.6 Summary of hydrograph behaviour during the monitoring period

Attribute	BH201	BH204	BH213 [1]	BH215 [1]	BH217	BH054
Hydrostratigraphic unit	Lachlan alluvial	Fractured rock	Fractured rock	Fractured rock	Fractured rock	Fractured rock
Monitoring period	January 2019 – April 2021	January 2019 – April 2021	January 2019 – May 2019	January 2019 – May 2019	January 2019 – April 2021	February 2021 – April 2021
Standing water level range (mAHD)	249.12–250.00	269.93–271.77	341.52–342.06	360.39–361.50	343.63–344.99	324.82–324.97
Groundwater level range (m)	0.88	1.84	0.55	1.11	1.36	0.14
Response to rainfall events [1]	Yes, but supressed	No observable trend	No observable trend	No observable trend	No observable trend	No observable trend
Groundwater level trend	Oscillating in response to climatic conditions.	Increasing	Declining	Declining	Generally, declining except for period of significant recharge in March 2021.	Stable

(1) Bores were unable to be monitored during GME 3 and 4 due to land access restrictions.

4.7 Hydraulic properties

An overview of conducted hydraulic aquifer testing, with an assessment of the retrieved data's quality is presented in Table 4.7. A summary of results of the slug tests and short-term recovery hydraulic testing that were considered fit for use are presented as estimates of hydraulic conductivity (m/day) in Table 4.8. Reports are included in Appendix B.

Table 4.7 Summary of hydraulically tested bores with an assessment of their suitability for use.

Bore ID	Methodology	Number of tests	Displacement obtained during testing (m)	Approximate duration of test	Obtained data 'Fit for Use'
BH212	Short term pump recovery test	1	0.79	27 hours	No
BH213	Slug tests (falling and rising)	8	0.25–0.67	<5 seconds	Yes
BH215	Short term pump recovery test	1	0.97	20.5 hours	Yes
BH054	Short term pump recovery test	1	0.55	1 hour	Yes

The results obtained from BH212 have been discounted due to the second GME (May) determining the fluid within the bore was likely introduced drilling fluids and not actual groundwater. This potentially resulted in the surrounding rock not being saturated during testing, resulting in a non-representative 'K' value.

Table 4.8 Hydraulic conductivity results from 'fit for use' slug tests

Bore ID	Number of tests	Approximate test length	Minimum K (M/day)	Maximum K (M/day)	Geometric mean (M/day)
BH213	8	< 5 seconds	4.53	10.10	7.22
BH215	1	20.5 hours	1.5×10^{-4}		
BH054	1	1 hour	10.1×10^{-3}		

All hydraulic aquifer testing was conducted within the fractured rock aquifer. Bores screened in the fractured rock returned K values ranging between $1.5\text{x}10^{-4}$m/day and 10.1m/day, which is within the representative values provided by Domeninco and Schwarts (1990) for fractured igneous and metamorphic rock ($6.91\text{x}10^{-4}$m/day to 25.92m/day) and unfractured igneous and metamorphic rock ($2.59\text{x}10^{-9}$m/day to $1.72\text{x}10^{-5}$m/day).

Analysed K values for the deeper fractured rock aquifer differed by up to 6 orders of magnitude. The lower range of the K values ($10.1\text{x}10^{-3}$m/day to $1.5\text{x}10^{-4}$m/day) is considered to represent bulk rock within the Study area that does not intersect major water bearing zones associated from faults or folding. The higher K value obtained at BH213 is likely to relate to a water bearing zone associated with inferred structural deformation as the bore is positioned in a localised trough (refer section 5.1.3). These structure zones containing water are referred to as water bearing fracture or fault zones (WBFZs).

4.8 Groundwater quality

Water quality results obtained from the existing environment within the proposal for both HSUs indicate most analytes are within the adopted guideline values. Table 4.9 provides a summary of the groundwater quality results compared to the adopted guideline values.

Table 4.9 Summary of groundwater quality results from GMEs compared to the adopted guideline values

Parameter	Lachlan alluvial (BH201)	Fractured rock (BH204, BH213, BH215, BH217 & BH054)
Field electrical conductivity (EC)	Field values are above adopted guideline values, with marginal water quality; EC values ranged from 1,351µS/cm to 1,764µS/cm.	Field values are above adopted guideline values, with marginal to slightly saline water quality; EC values ranging from 1,369µS/cm (BH204) to 7,354µS/cm (BH213).
Field pH	Within adopted guideline values. pH ranged from 7.04 to 7.43.	Within adopted guideline values. pH ranged from 6.53 (BH054) to 7.47 (BH204).
DO	Below adopted guideline values, with DO ranging from 34.6% to 60.6%.	Predominantly below adopted guideline values, with DO ranging from 6.2% (BH213) to 98.4% (BH054)[1].
Dissolved metals	Adopted guideline values surpassed for Cu during GME1 and GME4. All other analytes were below adopted guideline values throughout the GMEs.	The following analytes exceeded adopted guideline values: • Al in BH054 during GME3 & GME4 • Cd in BH213 (GME2) & BH054 (GME3) • Cu in BH204 (GME1 & 4), BH213 (GME2), BH215 (GME2), BH217 (GME1 & 4) and BH054 (GME3 & 4) • Ni in BH215 (GME1) and BH054 (GME4) • Zn in BH204 (GME1), BH215 (GME1 & 2), BH217 (GME1) and BH054 (GME3 & 4).

(1) A DO content of 530.3% was recorded in BH215 during GME 1. High DO values are likely due to the aeration of the water during extraction for testing and are not considered representative of the HSUs baseline DO water quality.

4.8.1 Field parameters

Time series of field EC and pH for the proposal monitoring bores are presented in Figure 4.5 and Figure 4.6.

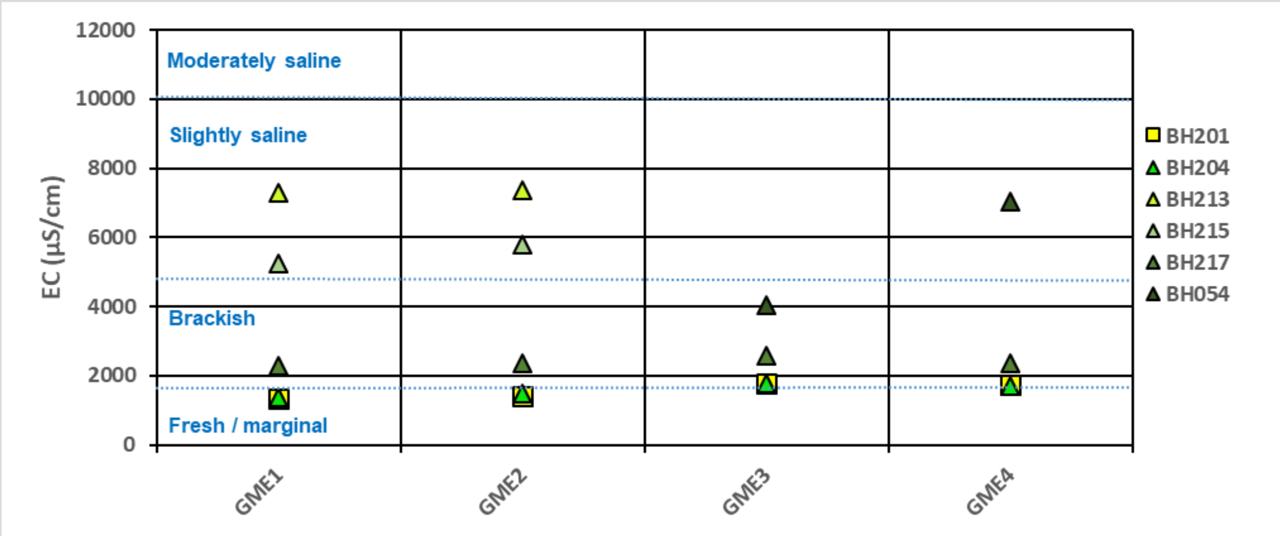


Figure 4.5 EC time series for the proposals monitoring bores that contained recoverable water

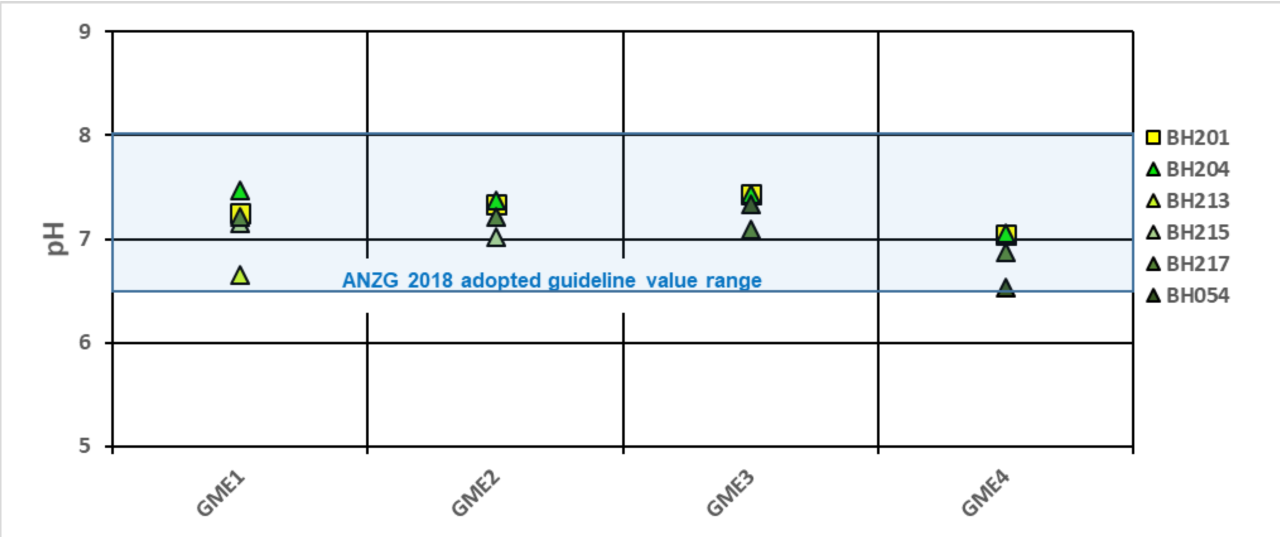


Figure 4.6 pH time series for the proposals monitoring bores that contained recoverable water

Groundwater sampled from the Lachlan alluvium (BH201) is classified as marginally saline and is slightly alkaline with pH recorded between 7.25 to 7.43. Groundwater sampled from within the fractured rock was typically more saline and is classified as marginal (BH204) to slightly saline (BH054). The groundwater was also slightly acidic to slightly alkaline with pH ranging between 6.53 (BH054) to 7.47 (BH204).

4.8.2 Dissolved metals

Concentrations above the laboratory limit of reporting (LOR) of dissolved metals in groundwater are presented in Figure 4.7. The major findings for dissolved metals are as follows:

- **Lachlan alluvial** (BH201): Elevated Cu levels were detected during GME 1 and 4. arsenic, cadmium, chromium, mercury, lead and zinc were below laboratory LOR for all GMEs.
- **Fractured rock** (BH204, BH213, BH215, BH217 & BH054)**:**
  - Water quality varied at each bore location and between GMEs. However, mercury was below LOR for all bores sampled across the GMEs.
  - BH054 contained comparatively elevated dissolved metal concentrations compared to other fractured rock monitoring bores.

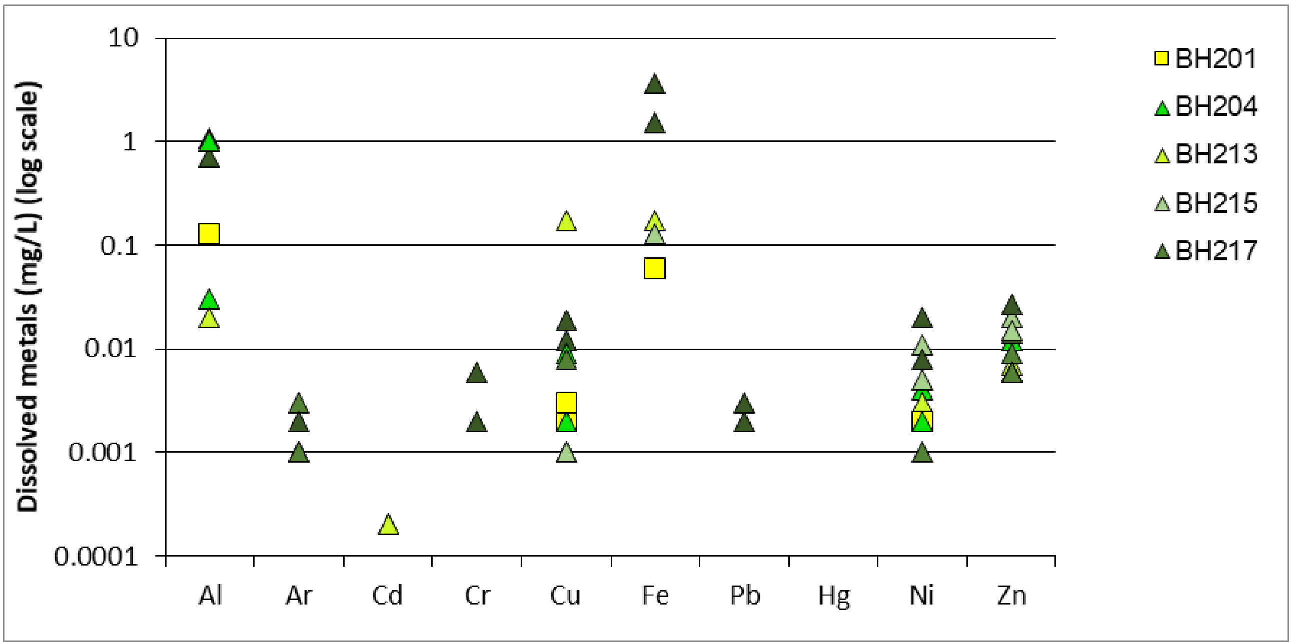


Figure 4.7 Dissolved metal concentrations (above LOR) within the groundwater monitoring bores

The major ion characteristics of groundwater samples collected during the GMEs are shown on the piper diagram in Figure 4.8. A piper diagram is a graphical representation of the relative concentrations of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-} and SO_4^{2-}), and is used to distinguish the chemical profile of major water types. Groundwater within the proposal is dominated by the following characteristics:

- **Lachlan alluvial:** low salinity water (Na-Cl-HCO_3).
- **Fractured rock:** major ions of sodium and bicarbonate and to a lesser extent by magnesium and chloride (Na-Cl, Na-Mg-Cl or Na-Mg-Cl-SO_4) and low salinity water (Na-Cl-HCO_3).

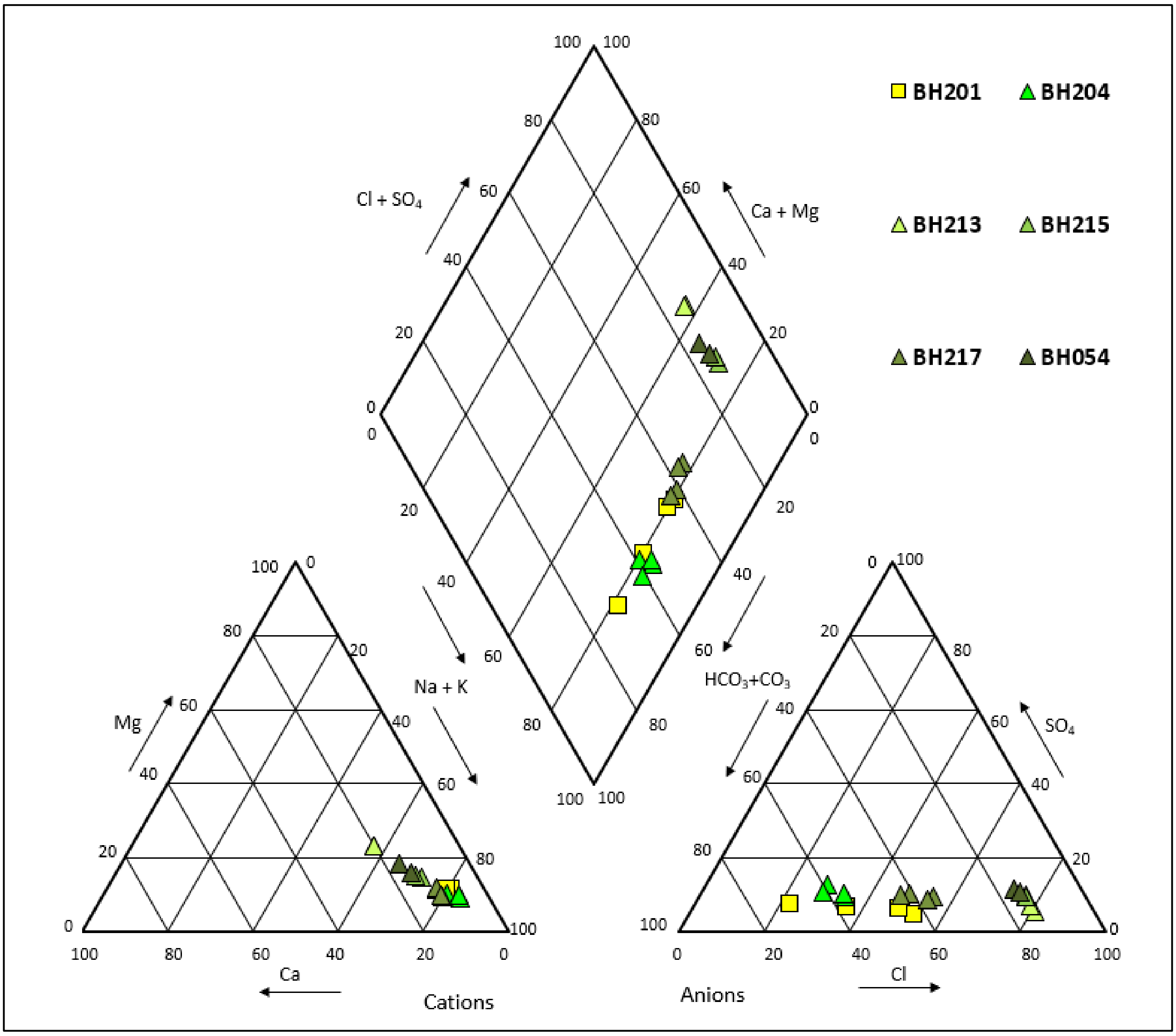


Figure 4.8 Piper diagram of groundwater samples collected during the GMEs

4.8.3 Water quality criteria exceedances

The follow subsections discuss water quality exceedances detected during the GMEs.

4.8.3.1 Heavy metals

Recorded elevated heavy metal concentrations of copper and zinc could potentially be sourced from contamination from local land practices where substances containing elevated levels of copper and zinc are used for the agriculture (e.g. copper based fungicides, zinc sulphate in nutrient sprays and heavy metals within early synthetic pesticides). However, naturally elevated levels of these analytes within the groundwater could occur via enrichment through weathering of source rocks. The proposal is underlain by geology (S-type granites and dacites) that are naturally enriched in these minerals within the Lachlan Fold Belt (GA, 2004). Exceedances for aluminium, cadmium and nickel were marginal or non-consistent. Further assessment would be required to determine whether this variation is natural, seasonal and/or due to a contaminant source.

4.8.3.2 Salinity

Recorded salinity values obtained within the Lachlan alluvial ranged from 1,351µS/cm to 1,764µS/cm and corresponds to a beneficial use category A3, which is generally suitable for all water use categories. The salinity values within the fractured rock range from 1,369µS/cm to 7,354µS/cm and corresponds to a beneficial use category A3 to C1. A category C1 is considered generally unsuitable for irrigation and raw drinking water. The lower salinity values possibly indicate potential local connectivity with the overlying alluvial units. The upper end of the range is consistent with background studies of the Lachlan Fold belt fractured rock groundwater resource (DPIE, 2017).

4.8.4 Hydrostratigraphy water quality summary

Table 4.10 summaries the groundwater quality of the Lachlan alluvial and deeper fractured rock aquifers.

Table 4.10 Summary of hydrostratigraphy water quality characteristics

	Lachlan alluvial (BH201)	Fractured rock (deep) (BH204, BH213, BH215, BH217 & BH054)
Characteristics	• Marginally saline • Slightly alkaline • Low abundance of dissolved metals • Na-Cl-HCO_3 dominant water type.	• Marginal to slightly saline • Slightly acidic to slightly alkaline • Variable groundwater quality based on location and across GMEs • Na-Cl, Na-Mg-Cl, or Na-Mg-Cl-SO_4 dominant water types.

4.8.5 Contamination

Technical Paper 14 – Contaminated land assessment assessed the potential for contamination to be present within a study area inclusive of the proposal site. The report states that potential contamination risks would be associated with:

- unknown fill and stockpiling of waste across sections of the proposal site to construct existing nearby roads and rail infrastructure
- agricultural use of land adjacent to the proposal site, presenting a low risk of diffuse agricultural chemical residues and moderate potential for isolated hotspots where machinery maintenance or chemical storage and transfer activities occurred
- use of the railway line, and in particular areas where historical maintenance may have occurred, predominantly around sidings and stations
- various building structures presenting a potential risk of the presence of hazardous and/or contaminated material
- waste dumping, particularly in locations near existing roads, road crossings, or potentially in infilled gully's or dams that may be discovered during the works.

Risk of groundwater contamination within the study area as a result of the risks identified above was noted as low.

4.9 Sensitive receptors

4.9.1 Groundwater users

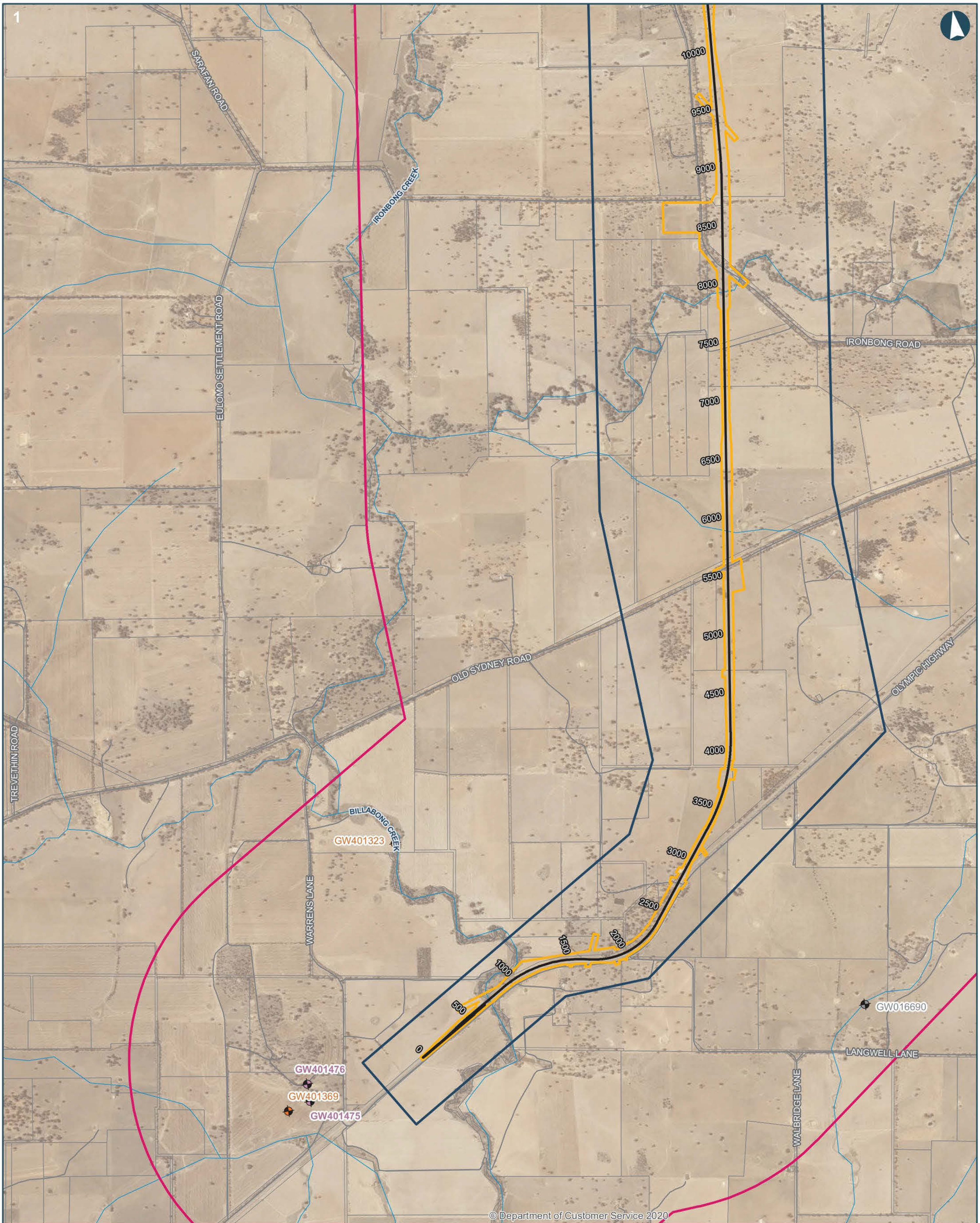
There are 55 registered groundwater bores within the Study area. All identified registered bores from the NGIS database (BOM, 2021) have been interpreted to take groundwater from the fractured rock HSU, with the beneficial use of the majority listed as monitoring (23), followed by stock and domestic (11). The remaining bores are listed as use for exploration (7), irrigation (1), household water supply (8), and unknown (5). Of the 55 bores located within the Study area:

- seven are functioning or in use
- 24 are in an unknown condition
- 24 bores are either non-functional, proposed or removed.

The locations of registered bores and their purpose are shown on Figure 4.9. Details of the 34 bores that are possibly in operation within 2km of the proposal are summarised in Table 4.11. Of the 34 possible bores in operation, only 22 are listed for use as household water supply, irrigation, livestock or unknown. The remaining are listed for use as monitoring or exploration, and therefore are not classified as a sensitive receptor.

No registered bores are located within the proposal's construction corridor. However, the following six are located within 100m:

- GW036748: Registered for exploration purposes and is located approximately 20m south of chainage 24,400.
- GW036754: Registered for exploration purposes and is located approximately 70m south of chainage 24,650.
- GW040732: Registered for monitoring purposes and is located approximately 80m south of chainage 25,100.
- GW040741: Registered for monitoring purposes and is located approximately 30m south of chainage 25,950.
- GW040745: Registered for monitoring purposes and is located approximately 70m south of chainage 24,650.
- GW040746: Registered for monitoring purposes and is located approximately 20m south of chainage 26,400.



ILLABO TO STOCKINBINGAL 4.9 Location of registered groundwater bores

MAP 1 OF 4

0 475 950 1,425 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 8/16/2021
Paper: A3
Author: IRDJV
Scale: 1:30,000
Data Sources: IRDJV, ARTC, LPI

- Proposal site
- Track alignment
- I2S Investigation Corridor
- Groundwater Study Area
- Roads
- Watercourse
- Lot Boundary

Groundwater Bores

- Household Water Supply
- Monitoring
- Unknown

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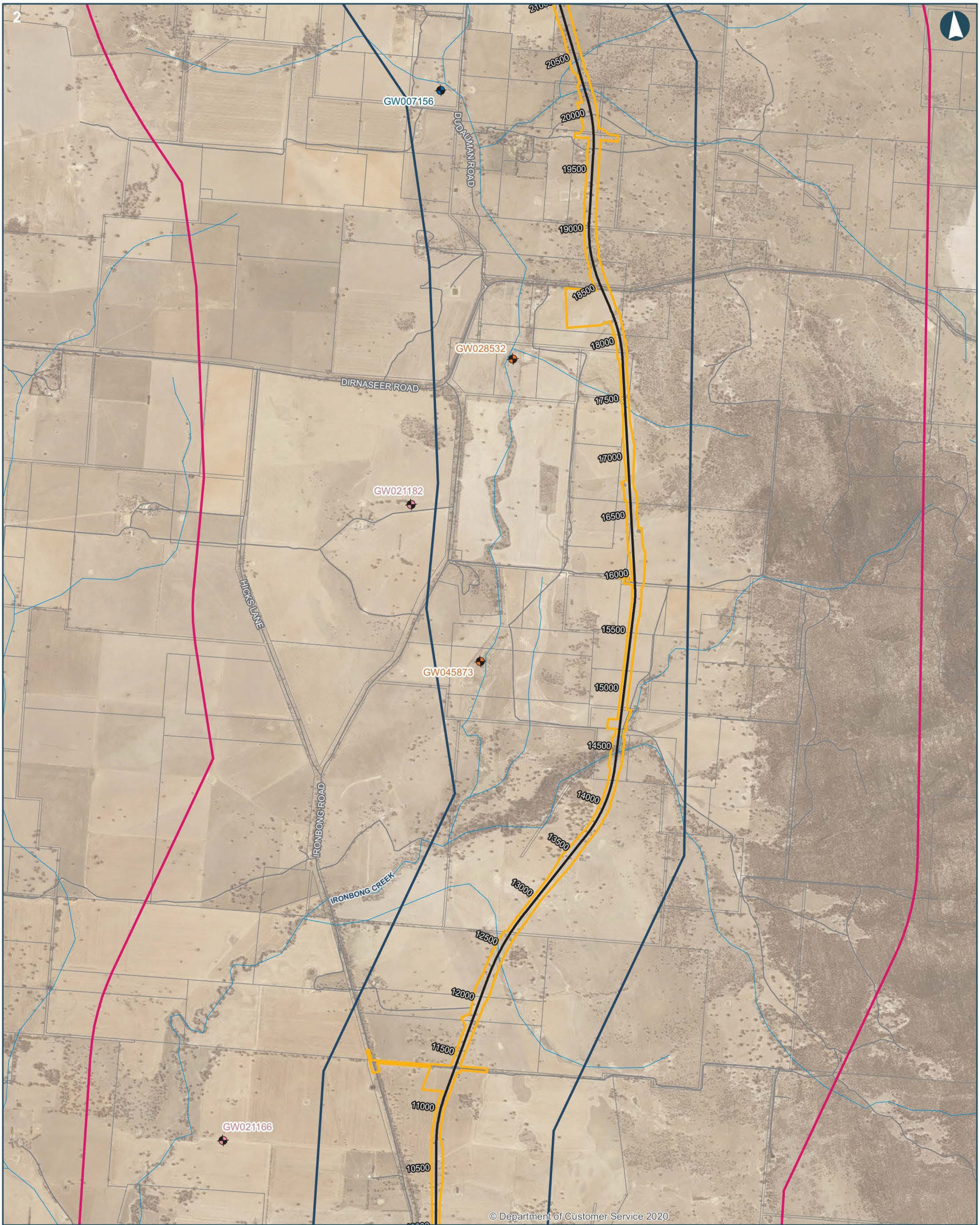

ILLABO TO STOCKINBINGAL 4.9 Location of registered groundwater bores

MAP 2 OF 4

0 475 950 1,425 m

Coordinate System: GDA 1994 MGA Zone 55

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- Proposal site
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Groundwater Bores

- Household Water Supply
- Irrigation
- Livestock

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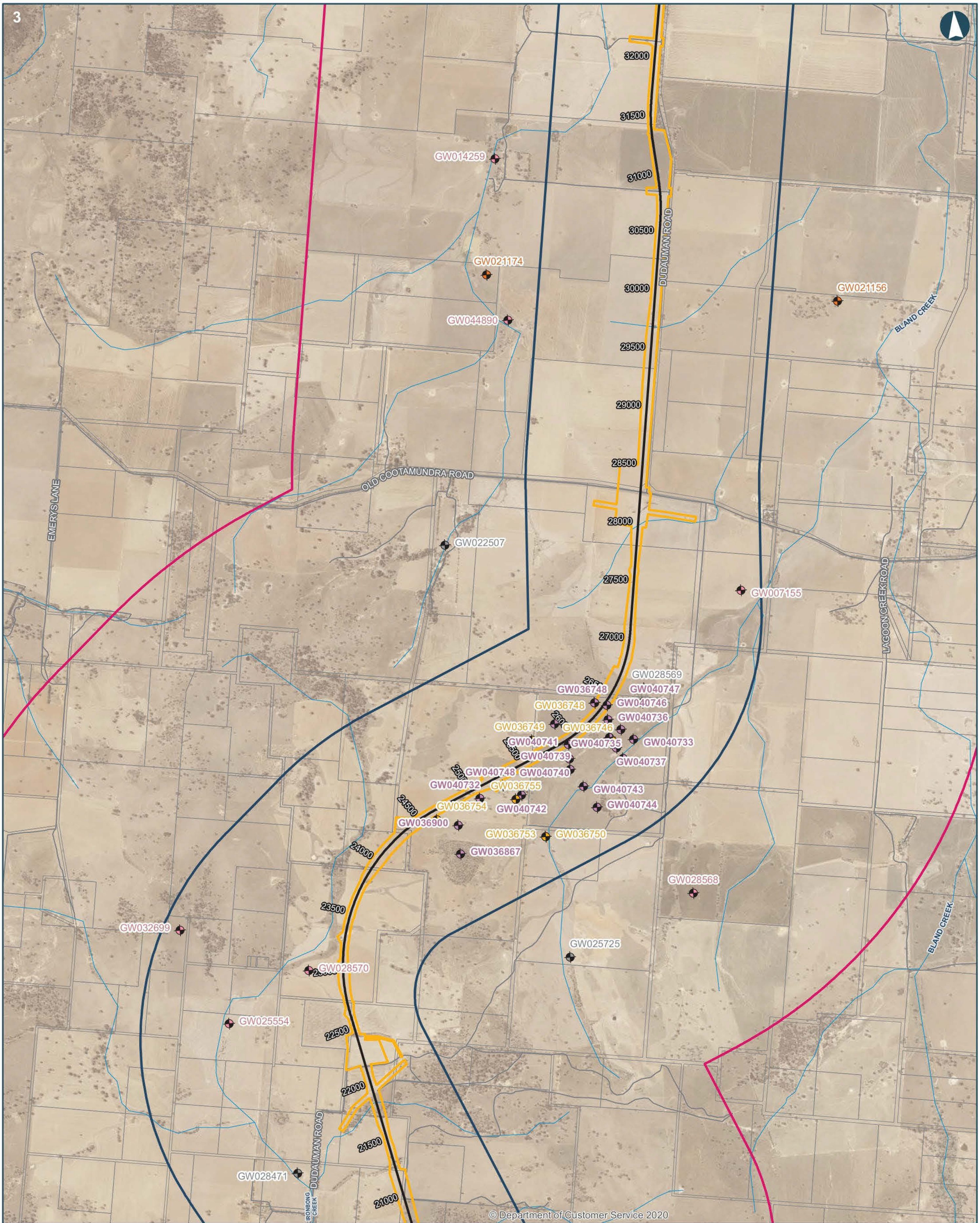

ILLABO TO STOCKINBINGAL 4.9 Location of registered groundwater bores

MAP 3 OF 4

0 475 950 1,425 m

Coordinate System: GDA 1994 MGA Zone 55

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- Proposal site
- Track alignment
- I2S Investigation Corridor
- Groundwater Study Area
- Roads
- Watercourse
- Lot Boundary

Groundwater Bores

- Exploration
- Household Water Supply
- Monitoring
- Livestock
- Unknown

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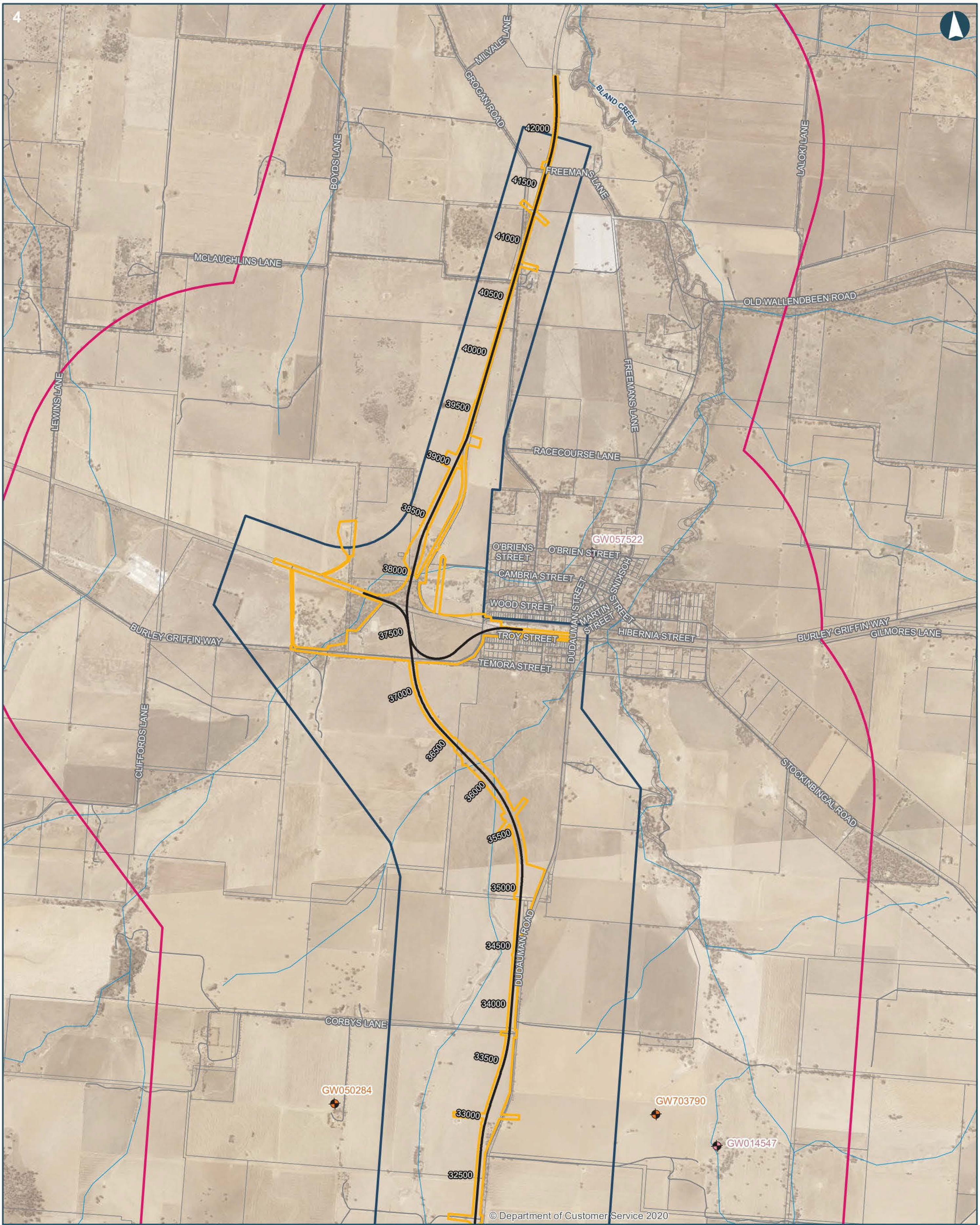

ILLABO TO STOCKINBINGAL 4.9 Location of registered groundwater bores

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Groundwater Bores

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- Livestock

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Table 4.11 Groundwater bores possibly in operation within 2km of the proposal

Bore ID	Beneficial use	Status	Bore depth (m)	Water bearing zone (approximate depth, mBGL)	Standing water level (mBGL)	Yield (l/s)
41010835	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
412134	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
GW007155	Livestock	Unknown	40.2	Fractured rock (38)	15.2	0.44
GW007156	Irrigation	Unknown	23.3	Fractured rock (23)	23.2	0.38
GW014259	Livestock	Unknown	56.1	Unknown	48.2	0.76
GW014547	Livestock	Unknown	85.3	Fractured rock (83)	75.6	0.25
GW014563	Livestock	Unknown	58.5	Fractured rock (46 – 59)	29.6	0.76
GW021156	Household water supply	Unknown	86.3	Fractured rock (67 & 85)	Unknown	Unknown
GW021166	Livestock	Unknown	75.3	Fractured rock (45 – 72)	42.7	1.26
GW021174	Household water supply	Unknown	71.5	Fractured rock (70)	Unknown	0.63
GW021182	Livestock	Unknown	55.6	Fractured rock (18 & 53)	Unknown	Unknown
GW022507	Unknown	Unknown	39.0	Unknown	Unknown	Unknown
GW025554	Livestock	Unknown	30.5	Fractured rock (23– 30)	12.2	2.91
GW025725	Unknown	In use (functioning)	33.5	Unknown	Unknown	Unknown
GW028471	Unknown	Unknown	44.8	Fractured rock (27)	9.5	Unknown
GW028532	Household water supply	Unknown	48.8	Fractured rock (45)	8.2	1.90
GW028568	Livestock	Unknown	38.1	Fractured rock (20 & 33)	13.7 – 15.2	0.20 – 0.43
GW028569	Unknown	Needs reconditioning	22.9	Fractured rock (15 – 19)	0.9	7.58
GW028570	Livestock	Unknown	45.7	Fractured rock (18 – 42)	12.2	1.90
GW032699	Livestock	Unknown	30.5	Fractured rock (21– 30)	12.2	2.91

Bore ID	Beneficial use	Status	Bore depth (m)	Water bearing zone (approximate depth, mBGL)	Standing water level (mBGL)	Yield (l/s)
GW033611	Unknown	Unknown	45.7	Fractured rock (40 - 41)	18.9	1.14
GW036748	Exploration	Unknown	52.0	Fractured rock (unknown)	7.9	Unknown
GW036754	Exploration	Unknown	55.0	Fractured rock (15 and 33-40)	6.7	1.0
GW036867	Monitoring	In use (functioning)	70.0	Fractured rock (35)	24.5	0.15
GW036900	Monitoring	In use (functioning)	35.0	Fractured rock (24 – 30)	9.0 - 20.7	1.15
GW04071	Monitoring	Unknown	15.9	Unknown	3.0	Unknown
GW040732	Monitoring	Unknown	11.0	Unknown	Unknown	Unknown
GW040734	Monitoring	Functioning	19.0	Unknown	1.8	Unknown
GW040741	Monitoring	Unknown	15.9	Unknown	Unknown	Unknown
GW040742	Monitoring	Functioning	15.7	Unknown	1.5 – 3.5	Unknown
GW040745	Monitoring	Functioning	5.0	Unknown	Unknown	Unknown
GW040746	Monitoring	Functioning	5.3	Unknown	Unknown	Unknown
GW040747	Monitoring	Functioning	8.3	Unknown	2.0	Unknown
GW043192	Monitoring	Unknown	60.9	Fractured rock (52 & 58)	51.8	0.23
GW045873	Household water supply	Unknown	9.1	Alluvium (unknown)	Unknown	Unknown
GW050284	Household water supply/stock	Unknown	99.1	Fractured rock (89)	73.2	0.63 – 0.88
GW057522	Livestock	Unknown	105.1	Fractured rock (87 & 102)	67.0	0.20 – 1.20
GW401323	Household water supply/stock	Unknown	54.5	Fractured rock (19, 32, 42 & 51)	Unknown	0.10 – 0.70
GW401369	Household water supply/stock	Unknown	54.5	Fractured rock (19, 32, 42 & 51)	Unknown	0.10 – 0.70
GW703790	Household water supply/stock	In use (functioning)	68.0	Fractured rock (unknown)	46.0	0.05

4.9.2 Groundwater dependent ecosystems

Groundwater dependent ecosystems are communities of plants, animals and other organisms that depend on groundwater for survival (Department of Land and Water Conservation, 2002). A GDE may be either entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998).

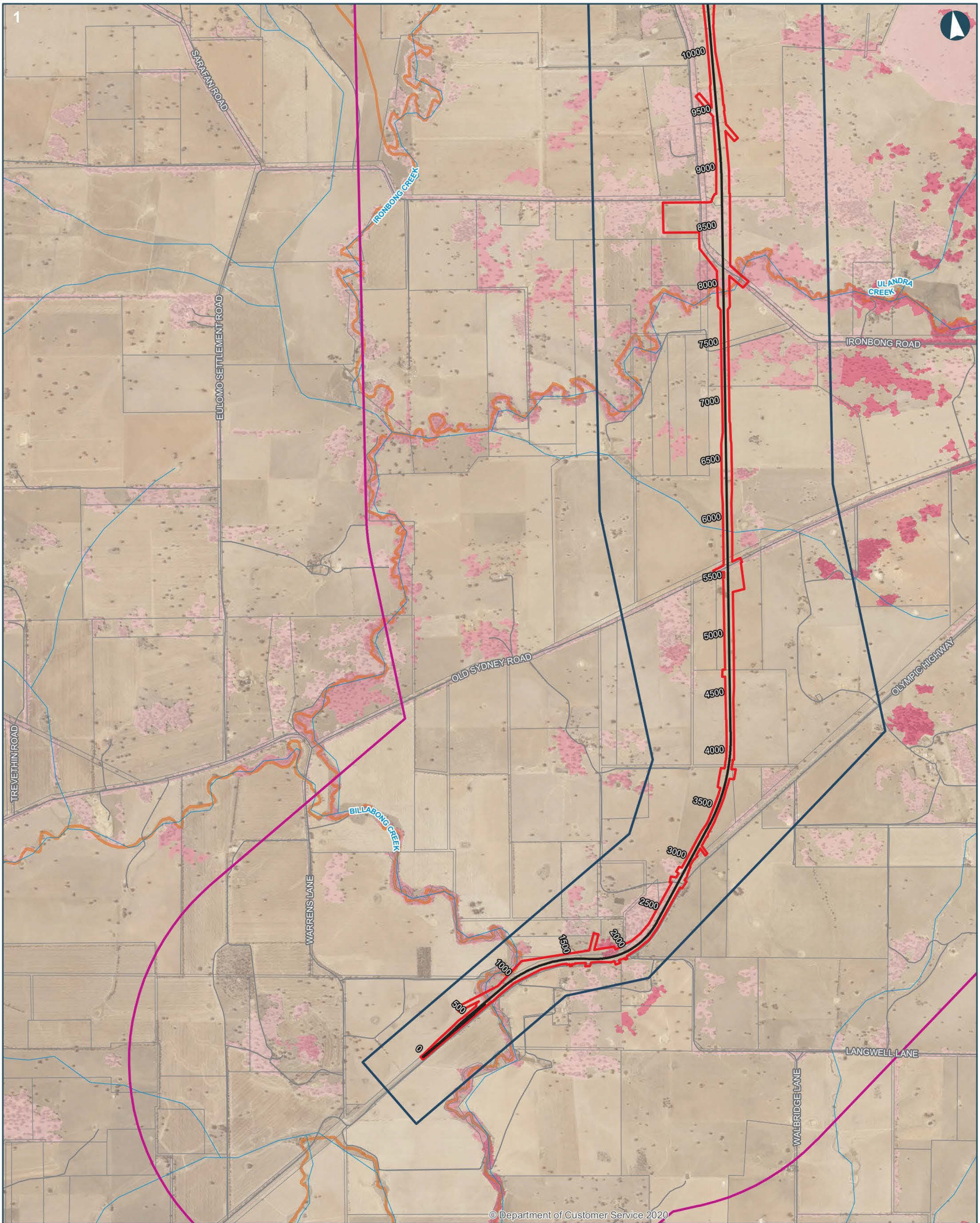
Groundwater dependent ecosystems include wetlands, vegetation, mound springs, river baseflows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems. The GDE Atlas (BOM, 2017b) categorises GDEs into three classes:

- ecosystems that rely on the surface expression of groundwater – this includes all the surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs
- ecosystems that rely on the subsurface presence of groundwater – this includes all vegetation ecosystems
- subterranean ecosystems – this includes cave and aquifer ecosystems.

Groundwater discharge can be important in maintaining baseflow in watercourses, 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, will 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 Study area, this relates to GDEs that are located overlying colluvial or residual soils associated with fractured rock HSU.

Eight ecosystems have been identified within the Study area that rely on the subsurface presence of groundwater. The location of these GDEs relative to the proposal are presented in Figure 4.10. Within these ecosystems, the following high potential GDEs have been identified:

- four high potential aquatic (river) GDEs were identified, Billabong Creek, Ulandra Creek, Ironbong Creek and Dudauman Creek
- four high potential terrestrial (vegetation) GDE species were identified, Blakelys Red Gum, Yellow Box, Western Grey Box and White Cypress Pine.



ILLABO TO STOCKINBINGAL 4.10 Groundwater Dependent Ecosystems

MAP 1 OF 4

0 500 1,000 1,500 m

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- Lot Boundary

Groundwater Dependent EcoSystem (BOM, 2021)

- High potential aquatic GDE
- Moderate potential terrestrial GDE
- Low potential terrestrial GDE
- High potential terrestrial GDE

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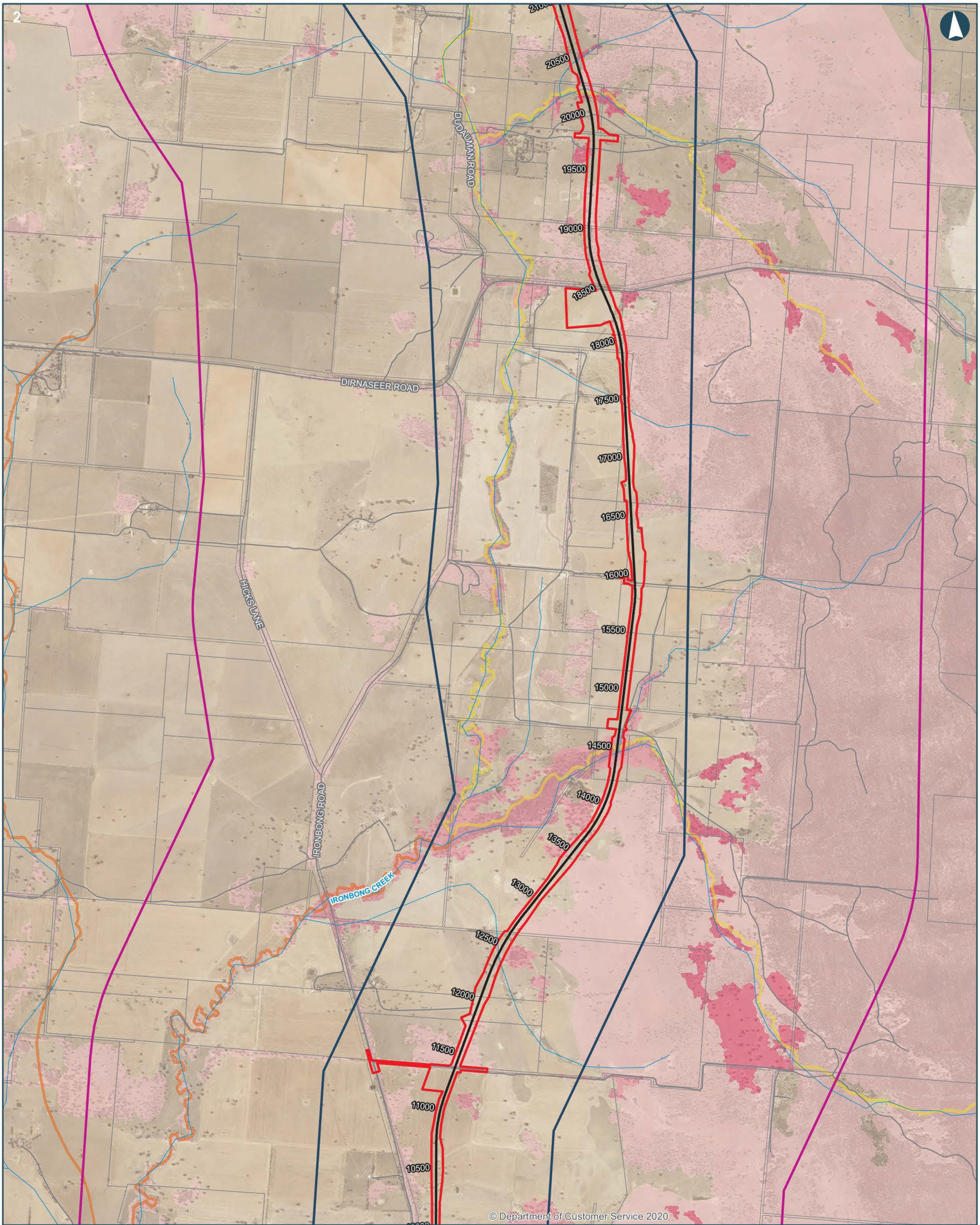

ILLABO TO STOCKINBINGAL 4.10 Groundwater Dependent Ecosystems

MAP 2 OF 4

0 500 1,000 1,500 m

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Groundwater Dependent EcoSystem (BOM, 2021)

High potential aquatic GDE
Moderate potential aquatic GDE
Moderate potential terrestrial GDE
Low potential terrestrial GDE
High potential terrestrial GDE

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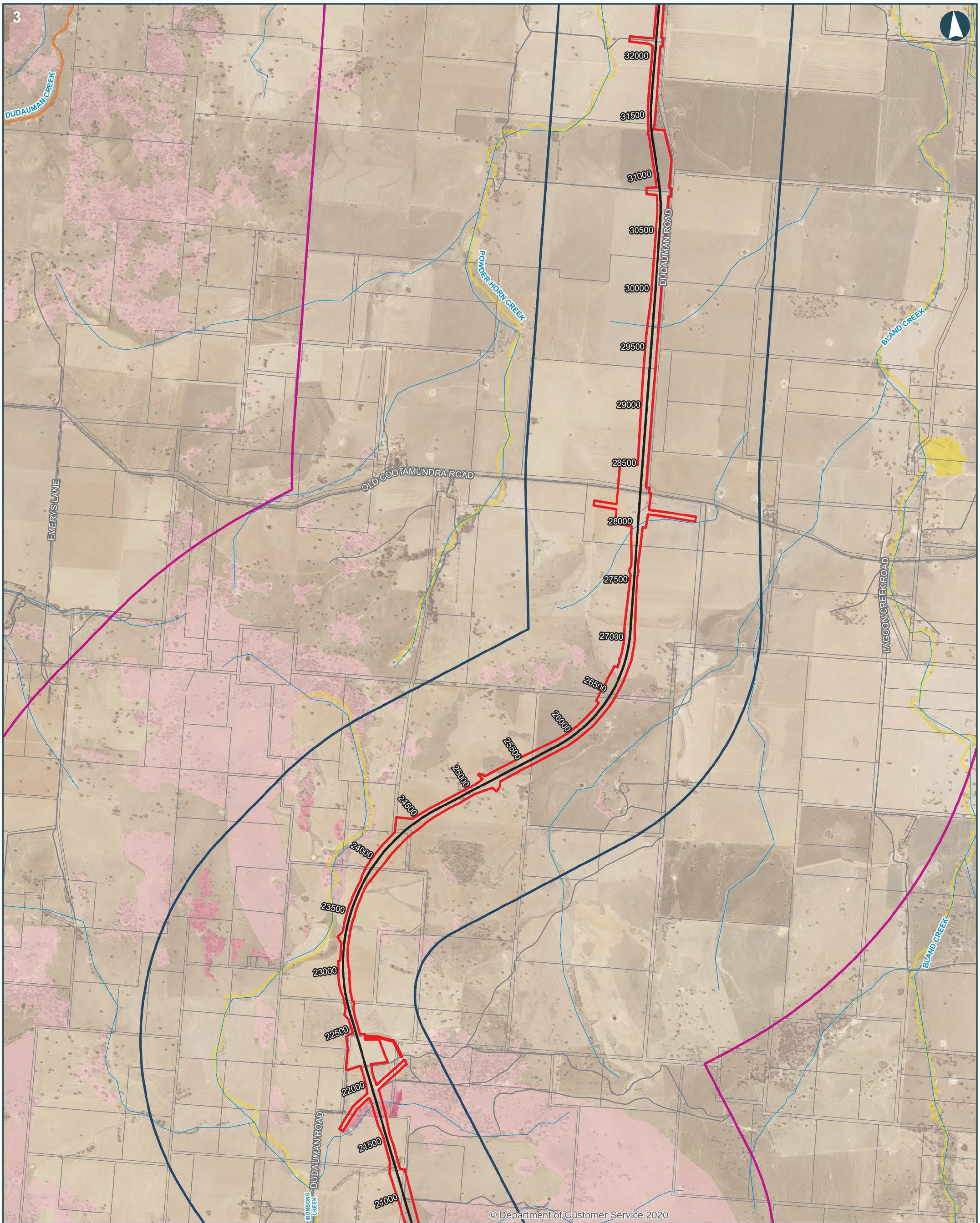

ILLABO TO STOCKINBINGAL 4.10 Groundwater Dependent Ecosystems

MAP 3 OF 4

0 500 1,000 1,500 m

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- Moderate potential terrestrial GDE
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- High potential terrestrial GDE

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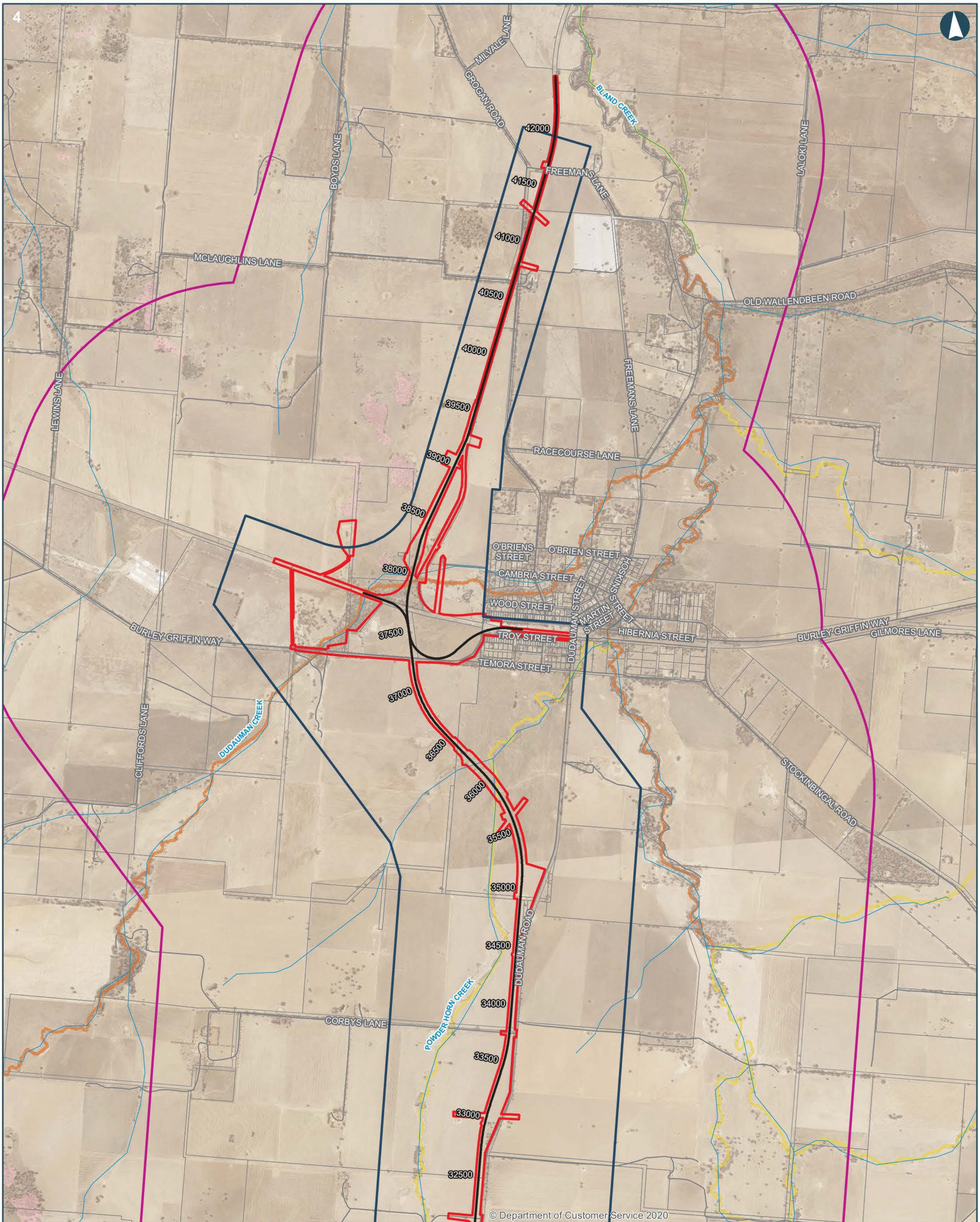

ILLABO TO STOCKINBINGAL 4.10 Groundwater Dependent Ecosystems

MAP 4 OF 4

0 500 1,000 1,500 m

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5 Conceptual hydrogeological model

A conceptual hydrogeological model (CHM) was developed for the proposal. Conceptual models are a useful tool that capture the existing environmental hydrological and hydrogeological aspects within the Study area and illustrate the interaction and functions between the two. The following section summarises the conceptual aspects of groundwater within the proposal and its interactions with both natural and anthropogenic elements.

5.1 Hydrogeology

5.1.1 Lachlan alluvial

Groundwater flow within the Lachlan alluvial is anticipated to flow regionally towards the west-northwest, where it may be locally altered due to topography and land use practices. The groundwater flow (conductivity and flux) will be stratigraphically controlled, with higher flows occurring along soil horizons within non-cohesive soils (sands and gravels). The Lachlan Alluvial is anticipated to be shallower within the Study area as the Study area is located on the fringe of the regional aquifer's extent.

Within the Lachlan Alluvial in the groundwater study area, faults may locally occur in the underlying fractured rock beneath the alluvial sediments, which act as local groundwater exchange zones between the Lachlan alluvial and fractured rock aquifers.

Groundwater levels within the Lachlan alluvial are anticipated to be at depths greater than 19mBGL proximal to Stockinbingal and greater than 7mBGL within the alluvial sediments of Billabong Creek, based on desktop and limited investigation findings.

5.1.2 Fractured rock

Two groundwater systems exist within the fractured rock HSU:

- a shallow upper, unconfined to semi-confined system formed immediately unconsolidated sediment contact zone and lying within the underlying shallower weathered rock
- a deeper semi-confined to confined system within the deeper underlying fractured bedrock.

5.1.2.1 Fractured rock shallow aquifer

The shallow, unconfined to semiconfined aquifer is expected to be largely controlled by localised topographic influences and primarily recharged via rainfall infiltration from local topographic highs. The aquifer is expected to be limited in depth, cover and potential volume of available groundwater. This aquifer would consist of either a perched water system at the soil/rock interface or groundwater within the shallow weathered bedrock. Generally, the aquifer is likely to contain limited groundwater or be temporary in nature and dependent on the localised hydrogeological controls.

The shallow system would interact primarily with the underlying deeper fractured rock aquifer through openings (defects, such as faults or fractures). Dependent upon hydraulic head differences between the upper and lower aquifer, groundwater flow may move between either system (upward or downward). Where no openings within the soil/rock interface are encountered, water will flow dependant on topography and potentially discharge into the Lachlan alluvial. Where topographic traps exist, the shallow, temporary groundwater may pool and become perched within localised depressions.

5.1.2.2 Fractured rock deep aquifer

The fractured rock deep groundwater system is the dominant source of groundwater within the unweathered (fresh) fractured rock HSU and represents the regional groundwater aquifer within the Study area.

Groundwater flow paths within the deeper system will be predominantly controlled by the degree of connectedness through secondary porosity (the extent and aperture of joints and fractures). Considering the region has undergone multiple structural deformation events (compression and extension, refer section 4.5.1.1), it is anticipated, where faults and regions of significant jointing are encountered, that the rock will likely be brittle and contain significant openings, and as such, act as preferential groundwater flow paths, and therefore constitute aquifers.

The average dip of the controlling structures within the Study area is near vertical (~86° – 87°) aligned along 344° – 356° (northwest to north), horizontal flow will be aligned north-northwest to north (the primary defect orientation), with limited perpendicular (east to west) horizontal flow or seepage (through pore pressure). This dominant structural orientation is referred to as S_3/F_3.

Faults, fractures and primary rock fabric, by their nature, are not perfectly linear or continuous, and are subject to localised anastomosing and disconnectedness. In such locations, the groundwater flow will preferentially follow and be constrained under the same features. Joints and fracture conduits within the rock, due to the intense structural deformation history of the region, are likely to also occur oblique to the primary S_3/F_3 fabric. However, these joints and fractures are expected to be discrete and discontinuous with minimal fracture aperture. This results in low groundwater flow and velocities along these joints and fractures, compared to the dominant S_3/F_3 alignment. In rare instances, a dominant structure perpendicular to the S_3/F_3 fabric can occur due to regional stress regimes. However, these instances and potential occurrences would be widely spaced and likely mapped on the regional government geological maps. Only one such feature has been identified as a possible fault within the Study area from the NSW geological sheet (Warren et al., 1996) and occurs underlying the Lachlan alluvial (below expected cut depths within this region).

Groundwater flow velocities are dependent on the hydraulic gradient and conductivity of the parent material (porosity and permeability). However, due to the observed and expected degree of fracturing, groundwater flow and volumes will largely be controlled by these features (secondary porosity) and their interconnectivity (permeability). Flow velocities will range over multiple orders of magnitude (refer section 4.7) and relate directly to the intersection of water bearing fault of fracture zones (WBFZ), with low hydraulic conductivity (in the order of (1.5×10^{-4}m/day) expected within competent rock and up to 10.1m/day in areas of considerable structural deformation.

WBFZs containing significant volumes of groundwater typically occur within the Lachlan fractured rock at depths greater than 40mBGL, however due to the increased structural deformation within the Study area, they may propagate into the shallower fractured rock aquifer.

Groundwater within the fractured rock deep aquifer is expected to be permanent and present underlying the study area. The system is considered to be less impacted by localised topographic controls.

Where information is limited, a permanent groundwater table of 15mBGL for the deeper fractured rock has been applied to areas within the proposal where shallow rock is expected at and along slopes of topographic highs. The deeper fractured rock aquifer may be shallower at topographic lows, where the aquifer is regionally connected.

5.1.3 Potential unidentified geological structures

The impact of intersecting unidentified areas of structural defects (e.g. faults) can, under certain circumstances, lead to severe consequences depending on the depth, permeability and storativity (volume) of groundwater within these structures and neighbouring receptors (such structures can be readily dewatered if intersected).

The structural deformation of the region has strongly influenced topography and geological control on the encountered fractured rock HSU domain. The intense folding and faulting from multiple compressional and extensional events, resulting in near vertical structures and topographic highs and lows has given preference to quaternary sediments forming in these troughs (known as synclines). These synclines are likely to represent and form a 'V' shape, where faults tend to propagate from the apexes of the underlying rock, as well as their inverse (anticlines, representing topographic highs), and extend down along the fold limbs. The 'V' shape relates to expected gradients and thicknesses of adjoining geological (and consequently HSU) domains.

For the Study area and conceptual model, this represents the Study area as containing sharp and steep contact (gradients) between, and within, geological units. Unit thickness is expected to change considerably over short distances perpendicular to the preferential structural orientation. That is, the depth of the geological unit will increase rapidly up to the maximum depth in a general east to west direction, until the opposing fold structure is encountered, or offset by faults. This will create in places of alternating elevation (hills and ridgelines) and steep hydraulic gradients within the fractured rock HSU.

This deformation sequence and resulting regional structures therefore can provide insight to identifying unmapped structures and WBFZs that may exist within the study area that have the potential to cause increased groundwater discharge into cut earthworks during construction. These unmapped structures are at a higher probability to be encountered near topographic lows, highs and along areas with steep gradients (representing the fold limbs) exist. This can be visually identified by saddles within topographic high locations, regions where volcanic outcrop steeply intersects quaternary cover, as well as regions where watercourse tributaries and drainage channels occur and are controlled by 'bedrock' (generally towards the centre of the quaternary cover) within the fractured rock HSU sub catchment. Preliminary identification of these structural features that potentially result in WBFZs across the Study area were interpreted to generally occur once every 100m to 500m across the fractured rock HSU.

Unidentified faults and regions of structural deformation will occur throughout the regional geological terrain and are inherently difficult to predict, especially in areas of quaternary cover. They are likely to follow pre-existing weakness in the geology that may be unexpectedly encountered during earthworks, and structural interpretation can only identify areas of potential higher risk. These areas of potential unidentified structures, such as faults, that present higher risks to construction and groundwater sensitive receptors have been incorporated, where reasonably possible, into the impact and risk assessment in Chapter 6, with mitigation and management measures documented in Chapter 7.

5.2 Potentiometric Groundwater Levels within the Fracture Rock HSU

The deeper fractured rock HSU is inferred to be under semi-confined to confined conditions and where structures intersect the topography, groundwater levels may exhibit a potentiometric effect. Multiple groundwater level measurements identified during the desktop study (BOM, 2019) around chainage 23,500–27,500 (refer sections 4.6.2 and 4.9.1), are shallow, typically recorded between 1.5–2.5mBGL. However, bores within the Study area have generally been drilled and installed to significantly greater depths, from between 23 to 100mBGL (BOM 2019). In addition, the registered user database contains information indicating that WBFZs occur from between 15 to 89mBGL (refer Table 4.11). This suggests that any groundwater level measurements obtained through desktop studies may not refer to the actual depth of the groundwater table, but rather the potentiometric surface of the deep, regional fractured rock underlying semi-confined to confined aquifers.

Additional evidence of this potentiometric effect was gathered during site investigations, where within BH217, no free groundwater was encountered during drilling until past 9mBGL (exact groundwater depth past 9mBGL could not be determined due to drilling method), but consequent field investigations involving manual dip measurements and digital groundwater level monitoring, documented the standing water level to be around 1.8mBGL. This groundwater level likely represents the potentiometric surface of the deep fractured rock aquifer within this specific area.

5.3 Groundwater recharge

A key recharge mechanism for the HSUs is considered to be direct rainfall infiltration (DPI-Water 2016). The Lachlan alluvial and shallow fractured rock will primarily be recharged at a local scale, whilst the deeper fractured rock will be recharged from regional sources. The proportion of net rainfall recharging the groundwater systems depends largely on the characteristics of the surface geology, soils, the land use and depth to the water table. Recharge is expected to be lower in areas where the surface is covered by residual clayey soils with a low hydraulic conductivity and specific yield.

Recharge also occurs via leakage from surface water features in areas where the groundwater table is below a flowing watercourse. Recharge rates will largely depend on the watercourse stage, hydraulic characteristics of the riverbed material and underlying geology. Contribution of watercourse recharge to the deep fractured rock aquifer is considered to be negligible within the proposal due to the limited connectivity between shallow aquifers and the fractured rock and the ephemeral nature of watercourses. Recharge to the underlying Lachlan alluvial from watercourses may be significant during periods of intense rainfall and flooding.

Irrigation can also play an important component to recharge within a hydrogeological unit (Wang et al, 2018). The proposal is in an area dominated by stock grazing and dryland crop irrigation that will likely contribute a component of recharge to the underlying unconsolidated sediments within both HSUs.

The shallow fractured rock aquifer is recharged locally by rainfall where it outcrops and by limited vertical leakage from the overlying, where present, Lachlan alluvial or unconsolidated sediments.

5.4 Groundwater discharge

Groundwater can discharge from shallow perched aquifers into watercourses via seepage depending on the hydraulic gradients and permeability of the sediments within the HSUs. Sediments within the proposal are dominated by clays with low permeability that are situated upon typically moderately undulating bedrock, with considerable structural deformation. This combination of sediments, topography and deformation has the potential to create localised topographic traps (troughs) for the collection of perched water, resulting in a discontinuous and localised perched system that may support GDEs. Removal of perched water would predominately be from natural climatic processes like evapotranspiration, with minimal portions of perched water expected to contribute as discharge to watercourses.

Extraction of groundwater through registered bores within the Study area is a mechanism of discharge from the HSUs. Evapotranspiration from the water table is another mechanism of groundwater discharge, where groundwater is removed from the processes of evaporation and plant transpiration to the atmosphere. In areas where the water table is shallow and within the rooting depth of vegetation, evapotranspiration can be a significant component of the discharge. Groundwater levels within the Study area indicate that the current water table within the Lachlan alluvial is within an extended evapotranspiration extinction depth of 10mBGL. Whereas, within the deep fractured rock aquifer, the expected water bearing zones are below the evapotranspiration extinction depth and within a medium (rock) that is difficult for deep rooting vegetation to access. Therefore, loss due to evapotranspiration is expected to be a significant discharge within the Lachlan alluvial, and negligible for the deeper fractured rock aquifer during current climatic conditions.

5.5 Water balance model calculation

Table 5.1 lists the parameter relevant to each domain and their associated contribution to the WBM.

Table 5.1 WBM estimated parameter quantities per annum

Parameter[1]	Lachlan alluvial[2] (Lachlan upper and lower slopes)	Fractured rock[2] (Murrumbidgee)
Catchment area (km^2)	230	320
$R_{(inf)}$ (m^3/yr)	2,928,000	1,629,000
$S_{(c)}$ (m^3/yr) [3]	501,000	Negligible
$I_{(inf)}$ (m^3/yr)	170	240
$GWBF_{(in)}$ (m^3/yr)	0	Negligible
$Q_{(pump)}$ (m^3/yr)	Negligible	1,444,000
$GWBF_{(out)}$ (m^3/yr)	2,890,000	Negligible
dv/dt (m^3/yr)	+539,170	+185,240

(1) Values listed to nearest 1,000m^3/yr, except for I(inf) and balance which are calculated to nearest 10m^3/yr.

(2) Refer to section 3.6 for background information on the calculation of the WBM.

5.5.1 Water balance model summary

5.5.1.1 Lachlan alluvial

The Study area returned a positive water balance within the Lachlan alluvial that is dominated by the positive contribution from rainfall infiltration and the negative contribution from baseflow. Recharge from watercourse flow can influence the water balance significantly. A flood event with a 2.5 per cent annual exceedance probability for the Study area was calculated to contribute up to 17 per cent of the annual recharge volume to the groundwater source. However, the degree of influence will be based on the significance (annual exceedance probability) of the flooding event and would vary each year. In years absent of flooding or significant rainfall leading to watercourse flow conditions, the contribution to the annual water balance could be negligible. Recharge from irrigation was determined to contribute a negligible amount of recharge to the overall WBM (<0.1 per cent) and would be seasonally dependent.

Hydrographs (section 4.6) and manual dip measurements of groundwater levels of the Lachlan alluvial taken during the GMEs indicated oscillating groundwater levels, likely in response to climatic conditions. This would correlate on average a zero change in storage of the water balance model.

The water balance provided above is a high-level conceptual snapshot of the Study area, however, in reality the balance and contributing factors would change over time. Changes to assigned stream contribution, baseflow and evapotranspiration values would likely account for discrepancies between the observed trends in hydrographs and calculated values.

5.5.1.2 Fractured rock

The identified water balance within the fractured rock HSU is dominated by the positive contribution from rainfall infiltration and the negative contribution from pumping. Loss due to pumping would be localised to regions encompassing and surrounding registered users and would likely be less than the calculated number. In addition, recharge from infiltration would be located to outcropping rock, which is not present across the entire sub-catchment, resulting in likely exaggerated positive contribution from rainfall infiltration. A lower contribution from rainfall infiltration would have the potential to generate a negative water balance, which would align with the decreasing groundwater level trends observed in some of the fractured rock hydrographs (section 4.6) and manual groundwater dip measurements.

6 Risk and impact assessment

Construction and operation of the proposal, if undertaken without adequate management controls in place, has the potential to impact on the identified groundwater resources and environmental values through changes to groundwater availability and groundwater quality. This Chapter identifies the associated risks, impact pathways, and qualitative and quantitative impact assessment of the risks.

6.1 Key issue

The proposal will involve 46 cuts and 45 fill earthworks (totalling 91 transitions across natural grade) that may alter the local groundwater environment. The key issue identified for the proposal is the risk associated with proposed cuts that intersect saturated and permanent Lachlan alluvial or fractured bedrock. Dewatering of the cuts for construction, or during operational phases of the project 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 pilings are to occur, impedance to groundwater flow can also occur.

6.2 Construction risk and impact assessment

6.2.1 Risk assessment

Table 6.1 provides a summary of key potential risks and their resulting impact to the groundwater environment as a result of the construction of the proposal. Recommended mitigation and management measures are provided in Chapter 7. All risks not discussed Table 6.1 and the following sections are considered to have negligible risks.

Table 6.1 Key groundwater risk summary during construction of the proposal

Risk	Description	Potential construction impacts
Dewatering	• Construction dewatering resulting in an unacceptable impact to the groundwater resource and sensitive receptors, including GDEs and registered bores.	• Cuts for the rail alignment and piling for bridge foundations. • Groundwater take for construction water supply.
Salinity	• Changes to groundwater flow paths, including groundwater flow barriers or groundwater discharge may mobile salts and impact surface water and 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. • Changes in groundwater levels.
Settlement	• Changes to soil moisture content causing compression or settlement.	• Cuts for the rail alignment that result in dewatering.
Contamination	• Degradation of water quality through the introduction of new contaminants or the movement of potentially existing contamination plumes within the groundwater environment.	• Storage, spillage and leaks of hazardous substances used during construction. • Cuts for the rail alignment and piling for the bridge foundations.
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 impervious surfaces including greenfield rail corridor, construction camps, access paths and removal of vegetation.

6.2.1.1 Dewatering

No groundwater 'take' for use as construction water supply is proposed for the proposal. However, groundwater dewatering may occur during the construction if excavations (cuts) or piling for bridge foundations intersect the groundwater table. The drawdown or decline in groundwater levels associated with the dewatering may pose a risk to groundwater resource availability and/or quality.

The key risk of dewatering comes from the proposed cuts. The proposed alignment involves 46 cuts, that range from less than 0.1mBGL to 13.7mBGL, illustrated in Figure 6.1. Note this figure is a projection, bore may be located over 220m off alignment and may distort the perception of relative groundwater levels. All cuts have been assessed for their risk of intersecting groundwater based on the current level of available information, site investigations and conceptualisation. The identified risks are summarised below:

- Proposed cuts within the Lachlan alluvial HSU are not anticipated to intersect the groundwater as the groundwater was observed to be deeper than cut depths at 7mBGL (in the alluvial sediments associated with Billabong Creek, chainage 750) and 19mBGL (at Stockinbingal, chainage 37,524).
- Proposed cuts within the fractured rock HSU are not expected to intersect the shallow fractured rock aquifer. However, due to unidentified structures and localised topographic influences on the shallow fractured rock HSU, a low risk is still present.
- No proposed cuts are anticipated to intersect the deeper regional fractured rock HSU.
- Depending on final construction methodology for bridge piling, groundwater may be intersected. However, groundwater take would be negligible using appropriate mitigation measures, such as a tremie system.

To reduce the risk of unaccounted for groundwater dewatering, refer to Chapter 7 for mitigation and management measures.

Figure 6.1 displays shallow groundwater in BH213, BH215 and BH217, relative to the underlying and inferred water level of the regional fractured rock (deep) aquifer.

BH213 and BH217 exhibit a piezometric effect, where the bores were dry until the regional fractured rock (deep) aquifer was intersected. The groundwater proceeded to rise to the shallower piezometric head level of the aquifer. This relatively shallow water was expected to have a low risk to the development as proposed cuts are not anticipated to intersect the regional fractured rock aquifer. It is noted that BH213 is approximately 220m off the section alignment.

The shallow water level within BH215 is thought to be part of a localised system. The bore is located approximately 9m above and 175m off the section alignment, and is in the proximity of other dry bores. The shallow water observed in BH215 is expected to pose a low dewatering risk.

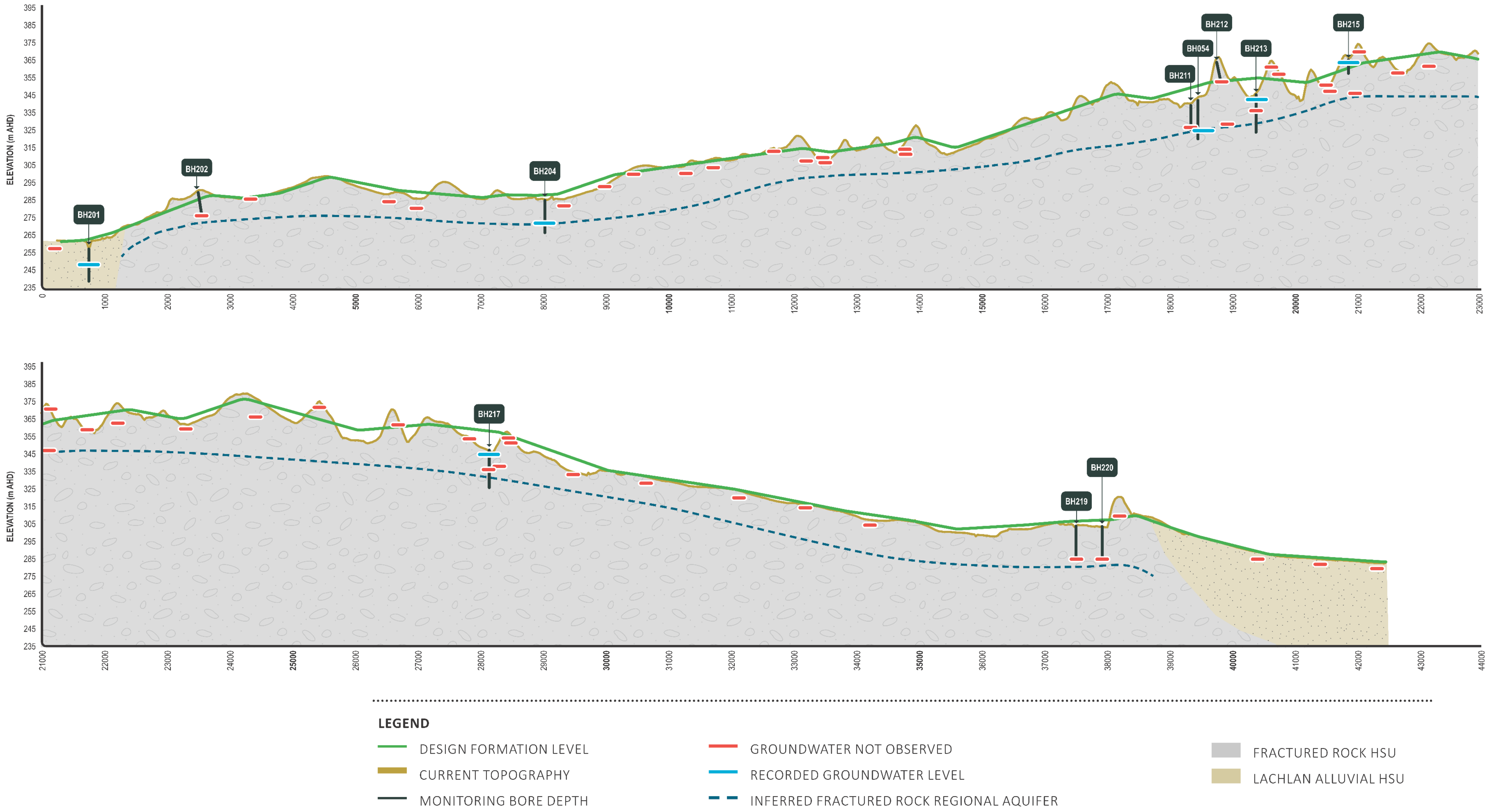

Figure 6.1 Simplified cross section of proposed earthworks depicting cut location, design level, observed groundwater and inferred groundwater tables

6.2.1.2 Salinity

Changes to groundwater (and surface water) flow patterns located around these chainages contain a higher likelihood and risk of mobilising salts and impacting groundwater quality downgradient. This could cause adverse effects to GDEs where present. Where practical, the proposal has minimised changes to flow paths through multiple realignments. The majority of proposed watercourse crossings are to be designed as pipe and box culverts and will have negligible to low impacts to changes of groundwater levels, flow paths and consequently salt mobilisation (salinity). Within these areas the risk of groundwater quality degradation due to salinity is considered low.

Diversion of flows may impact downstream groundwater receptors through the mobilisation of salts, particularly in areas identified as saline. One surface flow diversion has been nominated for the proposal and is located at chainage 16,000 with flows diverted to a culvert at chainage 15,400. This area is proximal to saline identified land (Junee LEP 2012), listed above. However, the saline affected soil is on the western side of the rail alignment, where the surface flow diversion is designed to divert flows to the east. Therefore, there is a low risk that salts may be mobilised within these regions due to the construction of the proposal.

Risk to groundwater salinity changes associated with localised modification to groundwater level due to piling for bridges is considered low. Bridge pilings are not anticipated to significantly impact groundwater levels as the majority of piles have been designed with pile diameters less than 900mm.

6.2.1.3 Settlement

Settlement occurring due to changes in soil moisture resulting from groundwater take is likely to occur where cuts intercept groundwater. Considering cuts are not anticipated to intersect the regional groundwater table, the risk to settlement is low. Where cuts unexpectedly intersect the groundwater, the soil moisture levels are not expected to change outside of the normal climatic variance, which will be seasonally controlled. If appropriate drainage measures are installed, natural moisture levels of residual clays are unlikely to be permanently altered by the proposal during the construction, limiting the risk and impact caused from settlement.

6.2.1.4 Contamination

Contamination may occur during the construction of the proposal and may occur anywhere along the proposal site, with higher probability in areas where groundwater is intersected or shallow or in identified areas of potential concern (refer Chapter 5). The consequence of groundwater contamination can be significant depending on the quantity and type of contaminate involved.

The proposal has the potential to result in risk to groundwater quality from hazardous chemicals (e.g. fuel) that may leach through surface infiltration during the construction of the proposal can be appropriately mitigated and managed to reduce the risk of contamination to low. This is due to the typical volumes of these chemicals present, the implementation of standard operating procedures and staff training in handling hazardous chemicals, the depth to the groundwater table and the low permeability of the groundwater HSUs.

A summary of potential sources of contamination that may leach to groundwater identified in Technical Paper 14 – Contaminated land assessment is provided in Table 6.2. Soil was identified as the primary potentially affected media and represents an anticipated low risk of contamination. However, localised hot spots around areas of concern may contain a low to medium risk. Where encountered, soil contamination is significant, and as such, it may have the potential to leach and migrate from the soil to the groundwater. This would be particularly relevant if significant soil impacts are identified during construction, contamination is present in unsealed areas and areas which cross waterways. However, given potential sources of contamination are minor and surface related, the migration of contamination to groundwater is considered low risk.

Table 6.2 Summary of potential contamination sources/contaminants of concern to groundwater sources

Activity along proposal site	Potential contaminants of concern[1]	Anticipated quantity in groundwater
Roadway and general use	Heavy metals, PAHs, PFAS, TRH, BTEX, solvents, OCPs and OPPs	Negligible to low
Agricultural land adjacent to the proposal site	Heavy metals, TRH, BTEX, OCPs and OPPs	Negligible to low
Existing railway line	Heavy metals, TRH, BTEX, PAHs	Negligible to low

(1) PAH = polycyclic aromatic hydrocarbon, PFAS = per and polyfluoroalkyl substances, TRH = total recoverable hydrocarbons, BTEX = benzene toluene ethylbenzene and p-xylene, OCP = organochlorine pesticides, OPP = organophosphorus pesticides.

For further information regarding contamination risk and impact, refer to Technical Paper 14 – Contaminated land assessment.

6.2.1.5 Recharge

Changes in land use and topography are likely to impact recharge patterns. However, the proposal presents a low risk to regional groundwater availability through altering catchment recharge patterns and the creation of impervious surfaces, due to its minimal construction and footprint compared to the sub-catchments. In addition, the proposal has mitigated the risk through multiple design phases, where the alignment has been redesigned to minimise impact to groundwater recharge.

6.2.2 Impact assessment

The impact associated with the identified risks in section 6.2.1 have been quantified, where practicable, or qualitatively assessed below. Impacts have been separated based on identified risks in section 6.2.1.

6.2.2.1 Dewatering

Dewatering is not anticipated for the proposal. Where groundwater is unexpectedly encountered, such as the low risk associated with potentially intersecting the shallow Fractured rock HSU, the groundwater seepage is anticipated to be limited in volume and contained by topographic influences. Due to the expected limited connectivity between the shallow and deeper regional Fractured rock HSU, the impact on the regional groundwater environment would therefore be limited and low. Mitigation measures for the unexpected take of groundwater is outlined in Chapter 7.

The impact to registered users or GDEs due to construction of the proposal is considered to be negligible to low due to no groundwater take anticipated.

6.2.2.1 Salinity

Groundwater salinity impacts associated with localised modification to groundwater levels because of watercourse diversions is considered to be low to medium. The degree of impacts due to increased salinity will be based on the availability of salts within the soil and the volume of soil affected. Only one diversion has been designed for the proposal and exists within the higher tributaries (classified as first order Strahler tributaries). These diversions are minimal in scale compared to the sub-catchment regions and it is unlikely that significant quantities of salt will be mobilised to significantly impact downgradient receptors. The diversion does not occur on land identified as saline.

Groundwater salinity changes associated with localised modification to groundwater level due to piling for bridges is considered low. Bridge pilings are not anticipated to significantly impact groundwater levels as the majority of piles have been designed with pile diameters less than 900mm. These diameters are minor compared to the width of the watercourse sediments. One bridge, located at chainage 19,996 (Isobel Creek Underbridge) is proposed as a 3500mm x 1500mm blade pier, however the Lachlan alluvial sediments at this location are approximately 250m wide and the blade pier is therefore expected to have negligible to low impact on natural groundwater level variations.

6.2.2.2 Settlement

Permanent construction earthworks (embankments) that do not intersect groundwater can also impact groundwater availability by causing settlement or compaction of the underlying sediments. This can alter groundwater conductivity by reducing the permeability of the sediments. This may cause groundwater mounding (on the upslope hydraulic gradient) or groundwater drawdown or 'shadowing' (on the downslope hydraulic gradient side of the embankment). Whilst these potential effects are caused by the construction of the proposal, the impacts tend to eventuate in the medium to long term, typically during the operational phase of the proposal.

Results for laboratory soil reactivity (Atterberg and linear shrinkage) testing undertaken during geotechnical field investigations indicated that encountered cohesive soils (clay or silt dominated) are of low and medium plasticity. In addition, in-situ consistency testing encountered typically very-stiff to hard residual clays. The impact to increasing compressibility is considered negligible to low due the encountered very-stiff to hard clays.

6.2.2.3 Contamination

The impact from hazardous chemicals (e.g. fuel) that may leach through surface infiltration during the construction of the proposal can be significant if not mitigated. If the groundwater is impacted through surface infiltration, the impact to groundwater quality will be localised and may be managed accordingly to minimise the impact. Mitigation and management measures will act as critical controls to reduce the overall impact of potential groundwater contamination from the proposal to a negligible to low classification.

The presence of reactive natural soils that may undergo changes to its chemical composition because of construction activities (e.g. presence of acid sulphate soils or soil aggressively) and have been assessed within Technical Paper 14 – Contaminated land assessment. Provided the recommendations are implemented, the potential impact to the groundwater from contamination is negligible to low.

6.2.2.4 Groundwater recharge

The impact of the proposal to groundwater availability through altering catchment recharge patterns is considered low. The presented WBM (section 5.5) depicted that recharge through rainfall infiltration was the primary critical factor for positively influencing groundwater availability within the proposals sub catchment domains. The proposal site would alter minimal surface area in comparison to the surface area of the contributing groundwater catchments.

The WBM also identified that ephemeral watercourses during periods of significant rainfall contribute a significant contribution to groundwater recharge into the Lachlan alluvial or shallow fractured rock aquifers. The proposal construction has been designed to minimise impact to ephemeral waterways through management or design mitigation measures as presented in Technical Paper 4 – Hydrology and flooding impact assessment.

6.2.2.5 Proposals impact on the existing environments water balance

The proposals key impact to the Study areas water balance will be controlled by the number cuts that result in dewatering or amount of groundwater to be used for construction supply. As no cuts are anticipated to intersect the regional groundwater aquifers and groundwater is currently not considered suitable for construction water supply, the proposal will have negligible impact on the regional groundwater balance during construction.

For further information regarding construction water supply and the proposals water balance, refer to Technical Paper 4 – Hydrology and flooding impact assessment.

6.3 Operation risk and impact assessment

6.3.1 Risk assessment

Table 6.3 provides a summary of risks to the groundwater environment as identified as a result of the operation of the proposal. Recommended mitigation and management measures are provided in Chapter 7 that will help reduce and mitigate the assigned likelihood, consequence and risk classification.

Table 6.3 Groundwater risk summary during operation of the proposal

Risk	Description	Related operation resulting in risk
Salinity	• Changes to groundwater flow paths, including groundwater flow barriers or groundwater discharge may mobile salts and impact surface water and 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 operation of the proposal. • Piling for foundations.
Settlement	• Changes to soil moisture content causing compression or settlement.	• Cuts for the rail alignment that result in dewatering.
Contamination	• Degradation of water quality through the introduction of new contaminants or the movement of potentially existing contamination plumes within the groundwater environment.	• Maintenance works and spillage or leakages during transportation.
Recharge & dewatering	• Changes to groundwater recharge through altering surface infiltration, degree of evapotranspiration and groundwater seepage dewatering along the high wall of cuts leading to changes in groundwater availability for sensitive receptors, including GDEs.	• Constructed cuts and drainage diversions.

6.3.2 Salinity risk and impact

The risk and impact of mobilising salts that may cause an increase in groundwater salinity remains low, as no additional drainage works or piling following construction are proposed. The risk pathways are similar to those identified during construction of the proposal (refer to section 6.2.1.2).

6.3.3 Settlement risk and impact

Whilst the risk and impact of settlement due to groundwater dewatering typically eventuates overtime and would become more prominent during the operation of the proposal, the risk and impact remains low for the same reasons identified in section (6.2.1.3 and 6.2.2.2).

6.3.4 Contamination risk and impact

The degree of impact to reduced groundwater quality by contamination through the operational phase of the proposal would be dependent on the type and quantity of hazardous chemicals or materials transported or used during maintenance activities. The typical volumes of hazardous materials used for maintenance or transported in a single shipment would be negligible in comparison to the regional groundwater HSU. If the groundwater is impacted through surface infiltration, the impact to groundwater quality will be localised and may be managed accordingly to minimise the impact. Provided appropriate mitigation measures and management plans are implemented the risk would be considered low.

6.3.5 Groundwater recharge and dewatering risk and impact

The operation of the proposal has a low risk of impacting groundwater recharge and through seepage dewatering of cuts. The primary risk is through the proposal impacting groundwater recharge via surface infiltration and potential groundwater seepage dewatering from cuts. The risk and potential impact are considered low due to the small operational footprint of the proposal across both HSUs and the expected low connectivity between the shallow perched groundwater systems with the underlying regional fractured rock aquifer. If groundwater is unexpectedly encountered due to intersecting unidentified structures, it would likely be an isolated structure that can be managed according through the mitigation measures identified in Chapter 7.

6.3.6 Existing environments water balance risk and impact

The operation of the proposal has a negligible to low risk to impact the existing environments water balance. The primary risk is through the proposal impacting groundwater recharge via surface infiltration and potential groundwater seepage from cuts. The risk and potential impact is considered low due to the reasons outlined in section 6.3.5.

6.4 NSW Aquifer Interference Policy

Interference approvals under the *Water Management Act 2000* have yet to commence. However, the aquifer interference policy is used to guide proponents and DPE in assessing aquifer interference activities.

As stated in section 2.3.2, the Aquifer Interference Policy (AIP) includes minimal impact considerations for assessing the impacts of all aquifer interference activities. NSW groundwater sources need to be categorised as being either highly productive or less productive, based on the general character of the water source meeting or not meeting the criteria of 1,500mg/L total dissolved solids and a bore yield rate of greater than 5L/s. This categorisation applies to a whole groundwater source as it is defined in a water sharing plan, not to the specific groundwater conditions at a specific location. The groundwater resources within the Study area identified within this report are considered less productive due to their respective water quality and expected typical yield rates

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 is provided in Table 6.4 and Table 6.5.

The assessment of the proposals 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 as acceptable.

Table 6.4 Aquifer Interference Policy minimal impact consideration for a 'less productive fractured rock aquifer' – Lachlan Fold Belt MDB (other)

Feature	Item	Minimal impact considerations	Response
Water table	1	• Less than or equal to ten per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: – high priority groundwater dependent ecosystem; or – high priority culturally significant site listed in the schedule of the relevant water sharing plan. • A maximum of a two metres decline cumulatively at any water supply work.	• There is a low risk of the proposal causing groundwater level change. Any potential change would be minimal due to the expected groundwater depth and appropriate construction methodologies. No groundwater take is anticipated for construction or operation of the proposal.
	2	• If more than ten per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: – high priority groundwater dependent ecosystem; or – high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. • If more than two metres decline cumulatively at any water supply work then make good provisions would apply.	• Refer to Item 1 response that indicates this condition is not triggered.
Water pressure	3	• A cumulative pressure head decline of not more than a 2m decline, at any water supply work.	• Pressure heads are not anticipated to be lowered (or raised) as no groundwater take is anticipated for construction or operation of the proposal. If groundwater is unexpectedly intercepted during construction, it is to be assessed by a hydrogeologist and appropriate mitigation measures implemented, such as, if pressure heads are observed to decline as a result of the proposal, make good provisions would apply.
	4	• If the predicted pressure head decline is greater than Item 3 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	• Refer to Item 3 response.
Water quality	5	• Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	• Groundwater quality is not anticipated to be impacted by the proposal due to the expected depth to groundwater and appropriate mitigation measures.
	6	• If Item 5. is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	• Refer to Item 4 response that indicates this condition is not triggered.

Table 6.5 Aquifer Interference Policy minimal impact consideration for a 'less productive alluvial water sources' – Upper Lachlan alluvial

Feature	Item	Minimal impact considerations	Response
Water table	1	• Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: – high priority groundwater dependent ecosystem; or – high priority culturally significant site listing in the schedule of the relevant water sharing plan; or • A maximum of a 2m decline cumulatively at any water supply work unless make good provisions should apply.	• There is a low risk of the proposal causing groundwater level change. Any potential change would be minimal due to the expected groundwater depth. No groundwater take is anticipated for construction or operation of the proposal.
	2	• If more than 10% cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variations, 40m from any: – high priority groundwater dependent ecosystem; or – high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. • If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	• Refer to Item 1 responses that indicates this condition is not triggered.
Water pressure	3	• A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	• N/A – the assessed aquifer is not a confined system.
	4	• If the predicted pressure head decline is greater than Item 3 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	• Refer to Item 3 responses that indicates this condition is not triggered.

<table>
<tr><th>Feature</th><th>Item</th><th>Minimal impact considerations</th><th>Response</th></tr>
<tr><td rowspan="2">Water quality</td><td>5</td><td>Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and
No increase of more than 1% per activity in long-term average salinity in a highlight connected surface water source at the nearest point to the activity.
redesign of a highly connected surface water source that is defined as a “reliable water supply” is not an appropriate mitigation measure to meet considerations 5.(a) and 1.(b) above.
No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial material – whichever is the lesser distance) of a highly connected surface water source that is defined as a ”reliable water supply”.</td><td>There is a low risk that the proposal will lower the beneficial use of the groundwater quality due to the expected depth to the water table and selection of appropriate construction methodologies.
The proposal is not a mining activity.</td></tr>
<tr><td>6</td><td>If Item 5.(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.
If Item 5.(b) is not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.
If Item 5.(c) is not met, then appropriate studies are required to demonstrate to the Minister’s satisfaction that:
there will be negligible river bank or high wall instability risks
during the activity’s operation and post-closure, levee banks and landform designs should prevent the Probable Maximum Flood from entering the activity’s site; and
low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.</td><td>Refer to Item 5 responses that indicates this condition is not triggered.</td></tr>
</table>

7 Mitigation and management measures

7.1 Approach to mitigation

Environmental management for the proposal would be carried out in accordance with the approach detailed in Chapter 27 (Approach to environmental management and mitigation) of the EIS.

This would include a groundwater management sub-plan, prepared as part of the Construction Environmental Management Plan (CEMP) and an operational environmental management framework (EMF).

7.2 Summary of mitigation measures

The mitigation measures to manage impacts to groundwater from the proposal during detailed design/ pre-construction, construction and operation phases are outlined in Table 6.3.

Table 7.1 Proposal-specific mitigation measures for groundwater

Issue/impact	Mitigation and management measure	Project phase
Management of groundwater bores	Any bores that are decommissioned will be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia– Edition 4* (NUDLC, 2020).	Detailed design/ pre-construction
Management of groundwater bores	Any existing groundwater bores that are destroyed during construction would be replaced subject to discussion with the registered owner.	Detailed design/ pre-construction
Avoid or minimise groundwater seepage	Appropriate drainage measures would be installed at the base of cuts and along high-walls to manage groundwater seepage, in the unlikely event that they be encountered.	Detailed design/ pre-construction
Groundwater management	A groundwater mitigation and management plan (GWMMP) would be prepared as part of the Construction Environmental Management Plan. The GWMMP would comply with the proposal conditions of approval and be implemented to monitor the effectiveness of mitigation and management measures applied during the construction phase of the proposal. The GWMMP would at a minimum: • provide details of the groundwater monitoring network, frequency of monitoring, and test parameters • be based on baseline studies developed for the proposal and establish baseline monitoring reports • contain procedures for the documentation and reporting of results. 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.	Construction
Monitoring groundwater drawdown and quality	A groundwater monitoring program would be developed and implemented as part of the GWMMP to monitor potential groundwater impacts. The program would define the following: • monitoring parameters • monitoring locations • frequency and duration of monitoring. The monitoring program would include baseline monitoring to determine the water quality of groundwater from the proposed bore field bores.	Construction
Unforeseen water table penetration by earthworks	If excavations intersect the water table, potential impacts would be assessed by a hydrogeologist and adaptive management measures implemented as required.	Construction
Management of groundwater seepage	Drainage measures would be maintained where required to manage ongoing groundwater seepage during operation.	Operation

7.3 Residual impacts

The management of any residual impacts is considered in Chapter 27 (Approach to environmental management and mitigation) of the EIS for both the construction and operation phase.

8 Conclusion

The impact of the proposal on the underlying groundwater sources was assessed to contain a negligible to low risk to the groundwater environment. This is principally due to the proposal's cut depths not anticipated to intersect the regional groundwater table for the Lachlan Alluvial or Fracture rock groundwater sources. In addition, groundwater is currently not a preferred option to be used to support water supply for construction.

The primary potential impact to groundwater during the operation phase would be related to accidental chemical spills impacting groundwater quality These impacts, if eventuated, would be expected to be localised and minor, due to the quantity of chemicals used during standard maintenance works and the area.

With the implementation of appropriate groundwater impact mitigation and management measures as discussed within this report, the risk for residual impacts to groundwater would be low.

The assessment of the potential impacts on aquifers and GDEs (in regard to the minimal impact considerations of the NSW Aquifer Interference Policy) was undertaken, with the predicted impacts less than the Level 1 minimal impact considerations and thus these impacts would be considered as acceptable.

9 References

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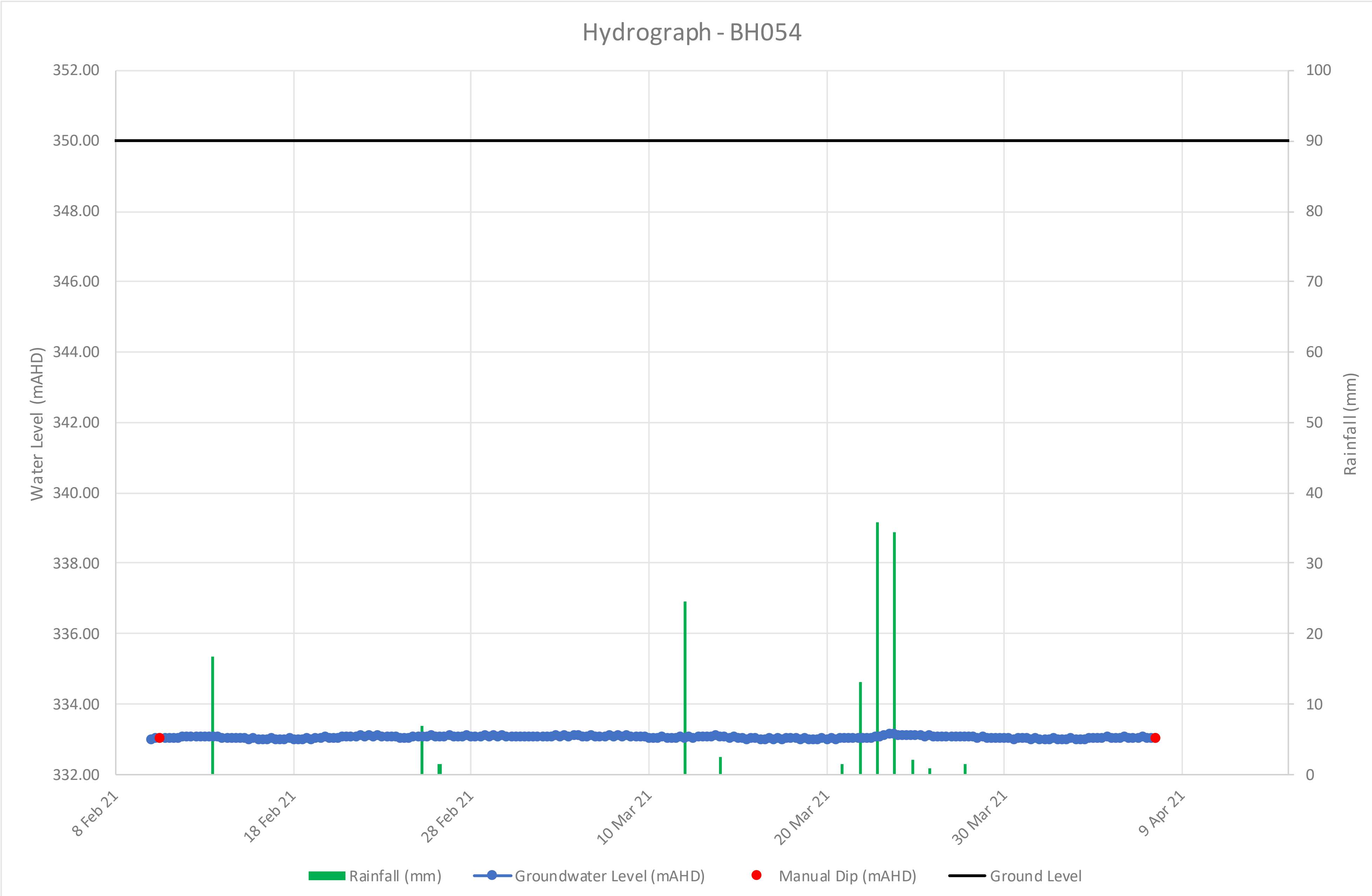
TECHNICAL REPORT 6

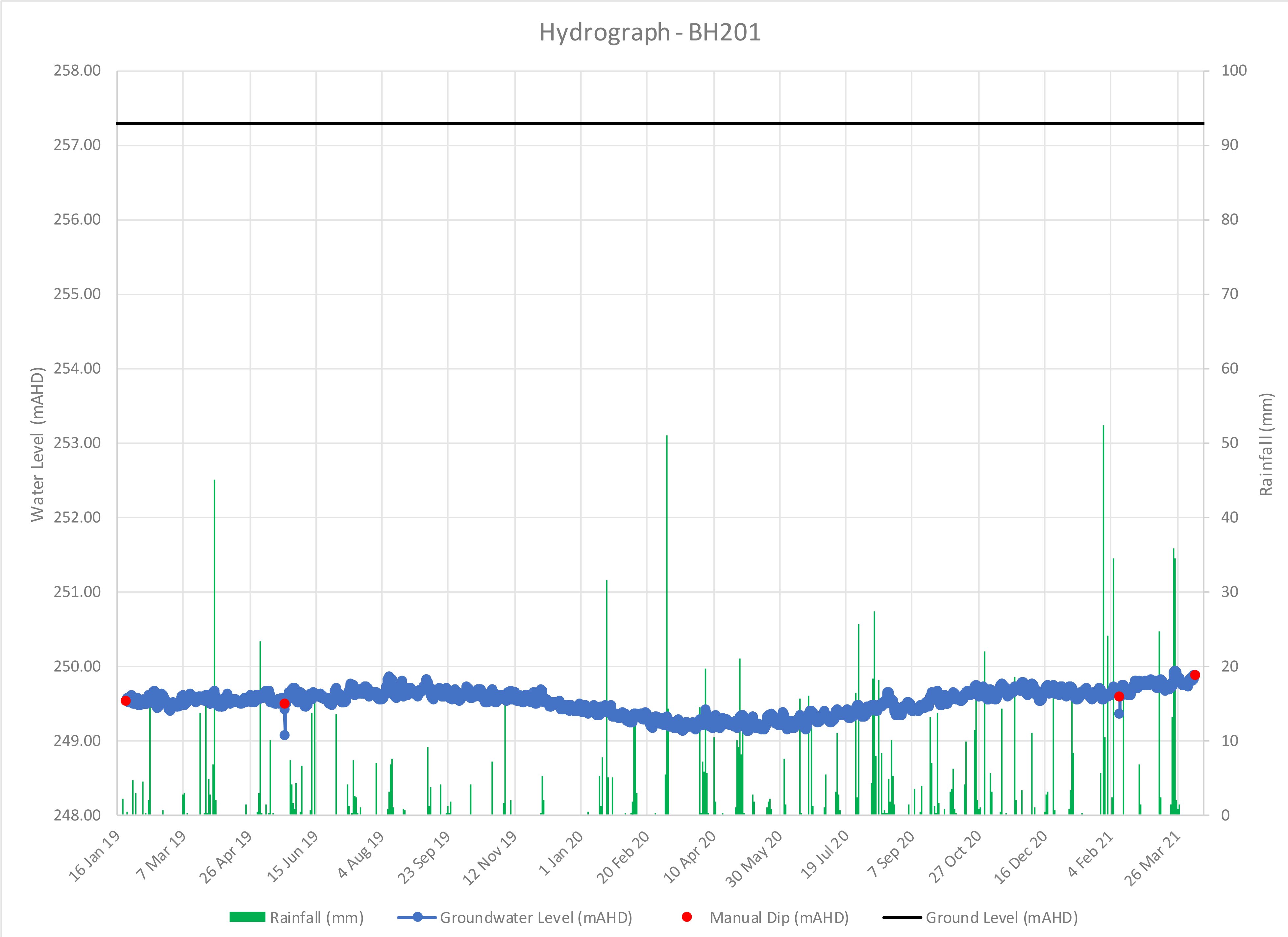
Groundwater Impact Assessment

Appendix A Hydrographs

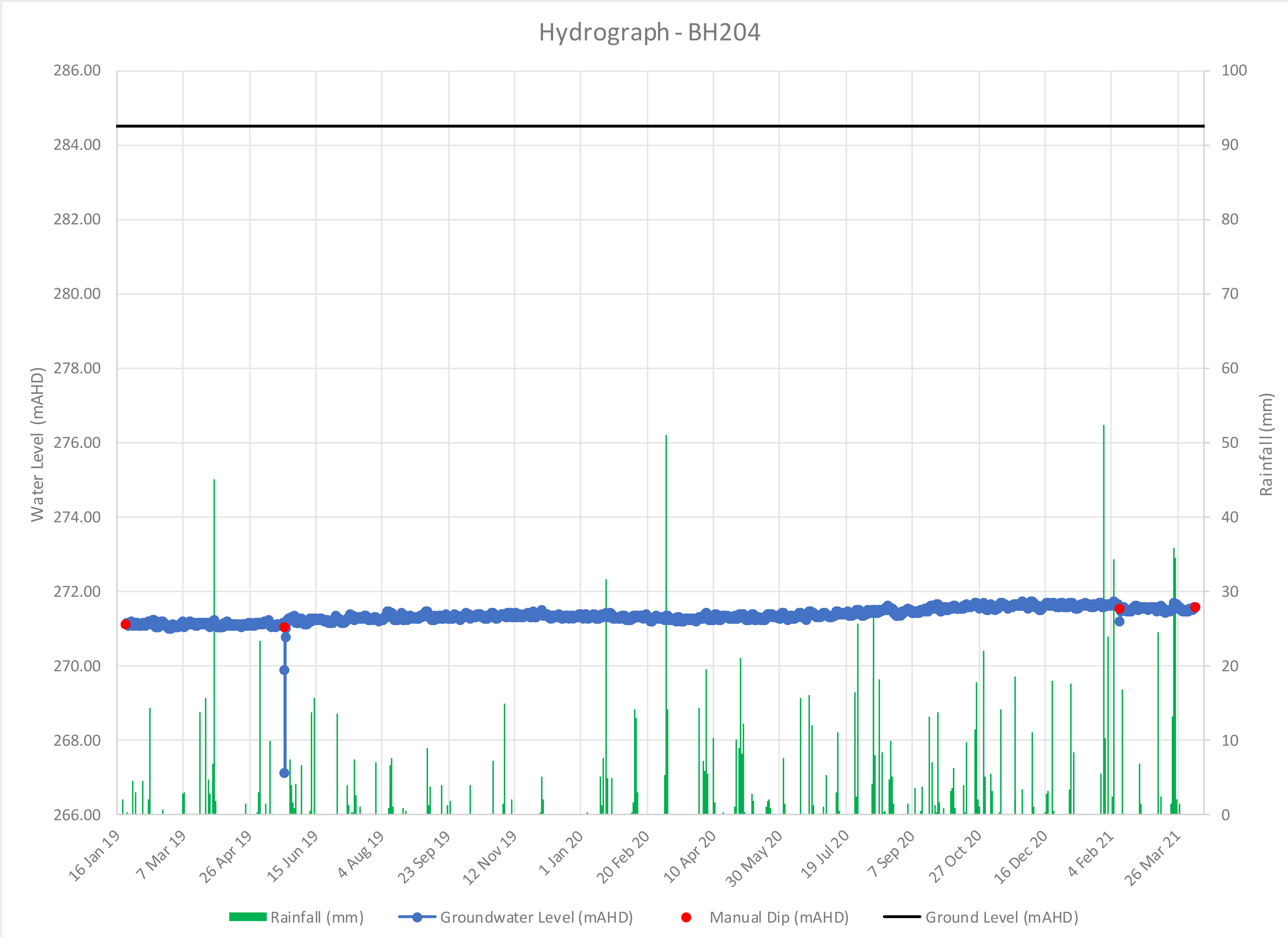
ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT



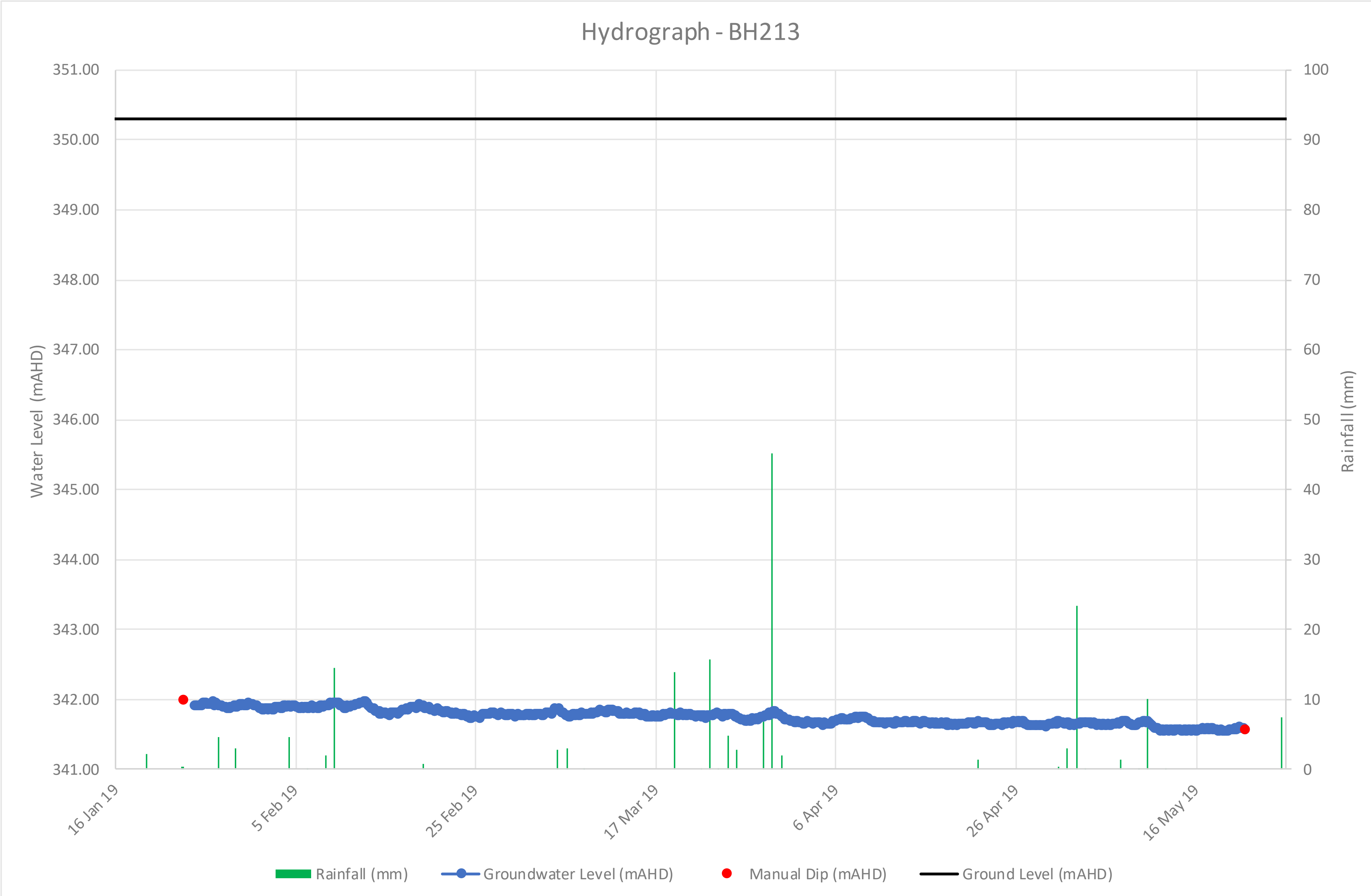
Hydrograph - BH054
Water Level (mAHD)
Rainfall (mm)
352.00
350.00
348.00
346.00
344.00
342.00
340.00
338.00
336.00
334.00
332.00
100
90
80
70
60
50
40
30
20
10
0
8 Feb 21
18 Feb 21
28 Feb 21
10 Mar 21
20 Mar 21
30 Mar 21
9 Apr 21
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level

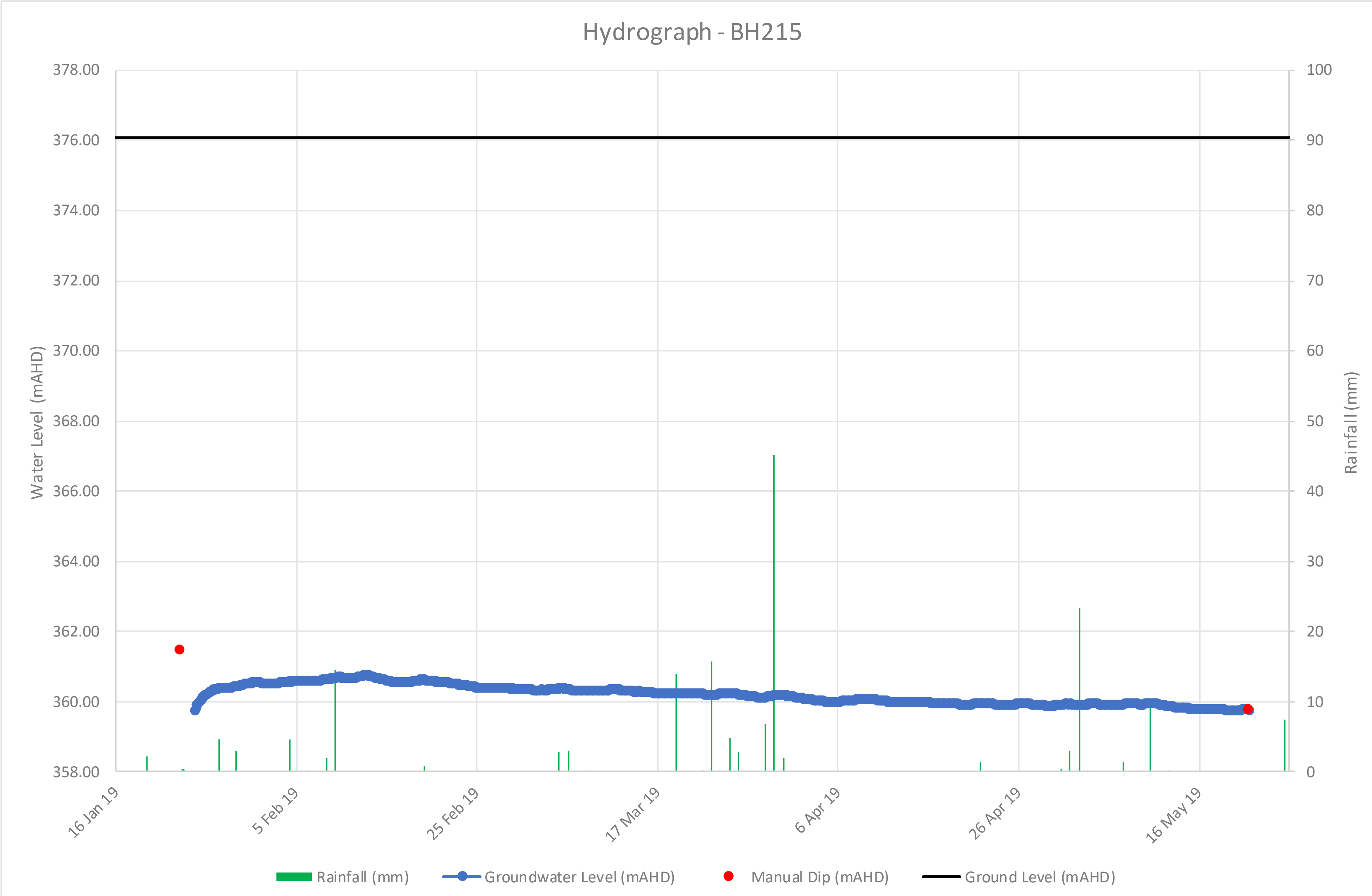


Hydrograph - BH201
Water Level (mAHD)
Rainfall (mm)
258.00
257.00
256.00
255.00
254.00
253.00
252.00
251.00
250.00
249.00
248.00
100
90
80
70
60
50
40
30
20
10
0
16 Jan 19
7 Mar 19
26 Apr 19
15 Jun 19
4 Aug 19
23 Sep 19
12 Nov 19
1 Jan 20
20 Feb 20
10 Apr 20
30 May 20
19 Jul 20
7 Sep 20
27 Oct 20
16 Dec 20
4 Feb 21
26 Mar 21
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)

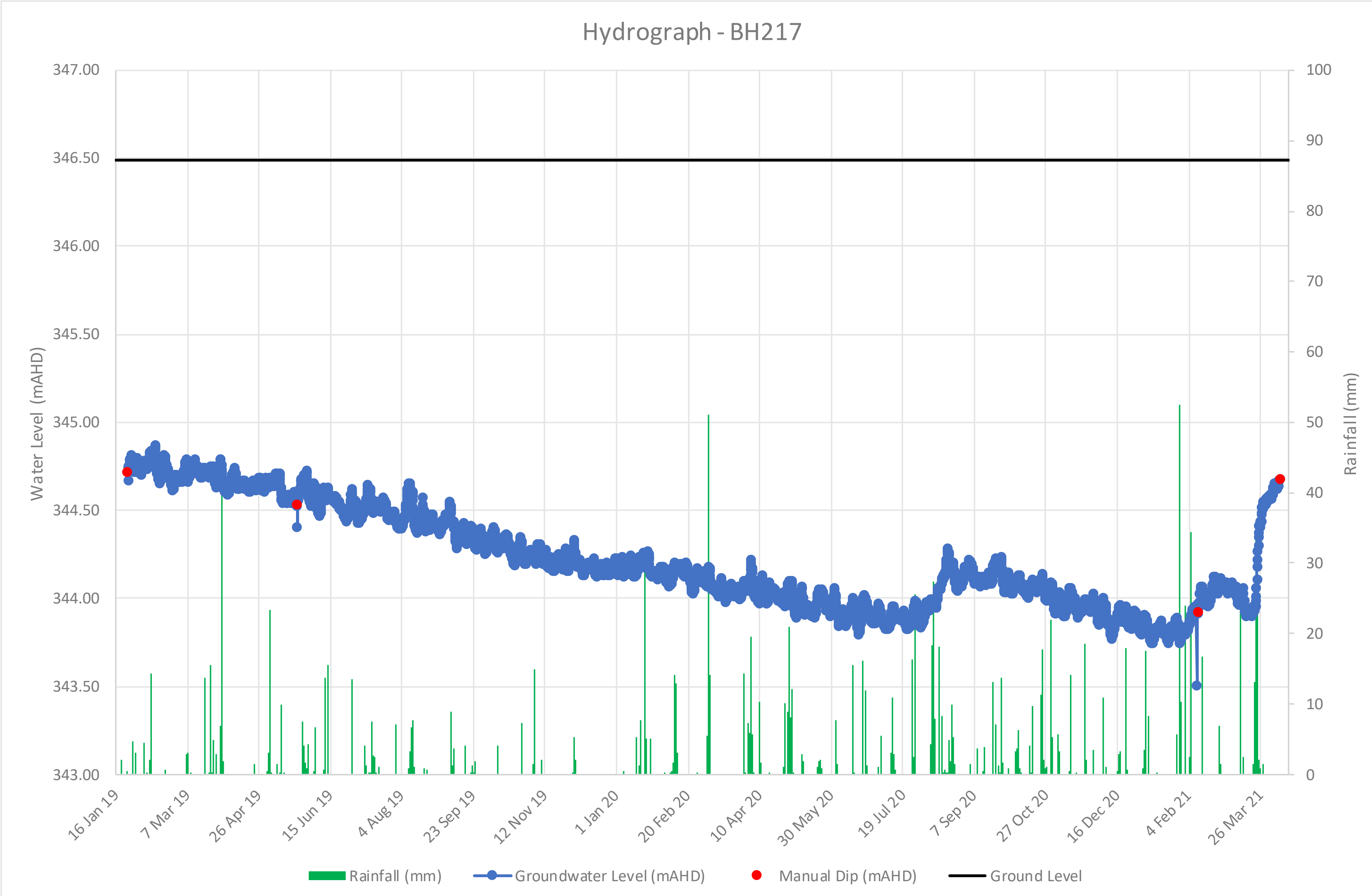


Hydrograph - BH204
Water Level (mAHD)
Rainfall (mm)
286.00
284.00
282.00
280.00
278.00
276.00
274.00
272.00
270.00
268.00
266.00
100
90
80
70
60
50
40
30
20
10
0
16 Jan 19
7 Mar 19
26 Apr 19
15 Jun 19
4 Aug 19
23 Sep 19
12 Nov 19
1 Jan 20
20 Feb 20
10 Apr 20
30 May 20
19 Jul 20
7 Sep 20
27 Oct 20
16 Dec 20
4 Feb 21
26 Mar 21
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)


Hydrograph - BH213
Water Level (mAHD)
Rainfall (mm)
351.00
350.00
349.00
348.00
347.00
346.00
345.00
344.00
343.00
342.00
341.00
100
90
80
70
60
50
40
30
20
10
0
16 Jan 19
5 Feb 19
25 Feb 19
17 Mar 19
6 Apr 19
26 Apr 19
16 May 19
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)



Hydrograph - BH215
Water Level (mAHD)
Rainfall (mm)
378.00
376.00
374.00
372.00
370.00
368.00
366.00
364.00
362.00
360.00
358.00
100
90
80
70
60
50
40
30
20
10
0
16 Jan 19
5 Feb 19
25 Feb 19
17 Mar 19
6 Apr 19
26 Apr 19
16 May 19
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)



Hydrograph - BH217
Water Level (mAHD)
347.00
346.50
346.00
345.50
345.00
344.50
344.00
343.50
343.00
Rainfall (mm)
100
90
80
70
60
50
40
30
20
10
0
16 Jan 19
7 Mar 19
26 Apr 19
15 Jun 19
4 Aug 19
23 Sep 19
12 Nov 19
1 Jan 20
20 Feb 20
10 Apr 20
30 May 20
19 Jul 20
7 Sep 20
27 Oct 20
16 Dec 20
4 Feb 21
26 Mar 21
Rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level

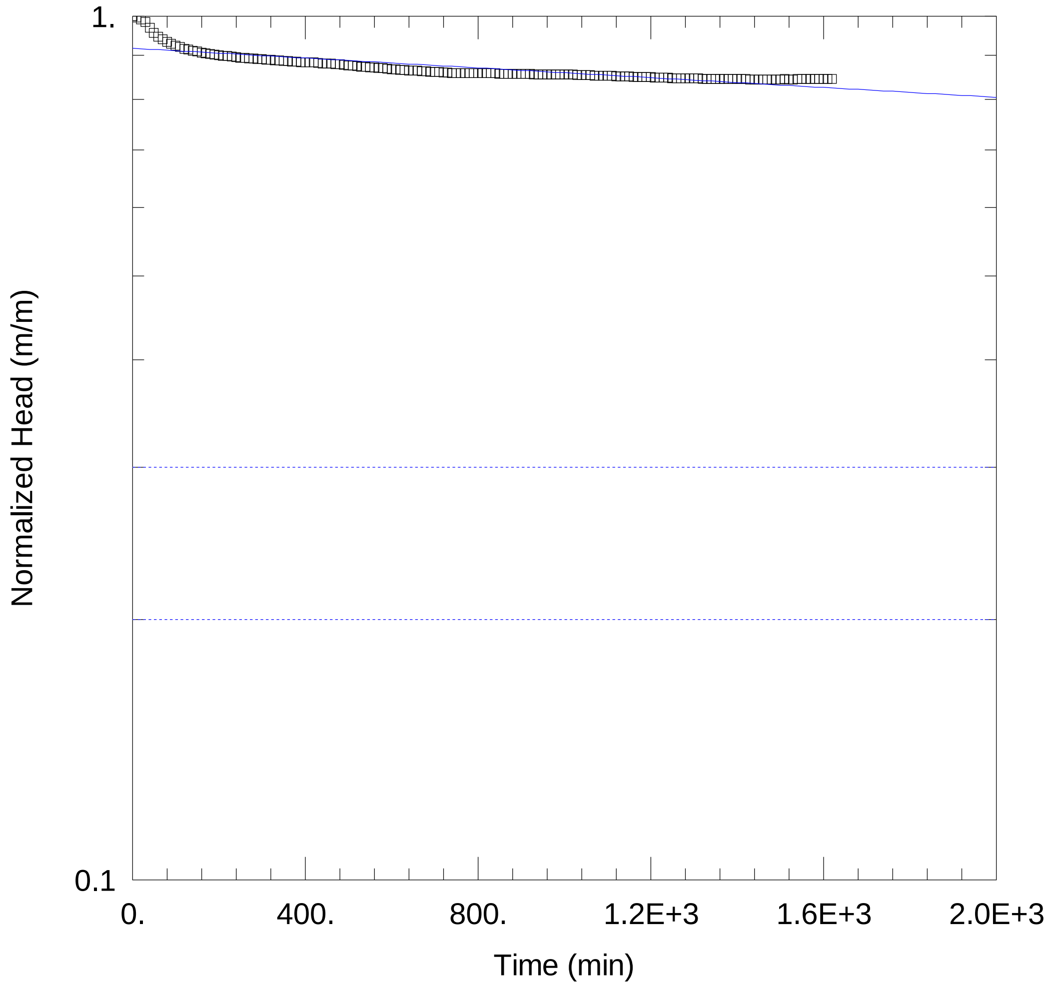
TECHNICAL REPORT

6

Groundwater Impact Assessment

Appendix B Slug test analysis

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH212\APM analysis\BH212_RHT1-BR.aqt
Date: 04/24/19 Time: 12:51:46

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH212
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

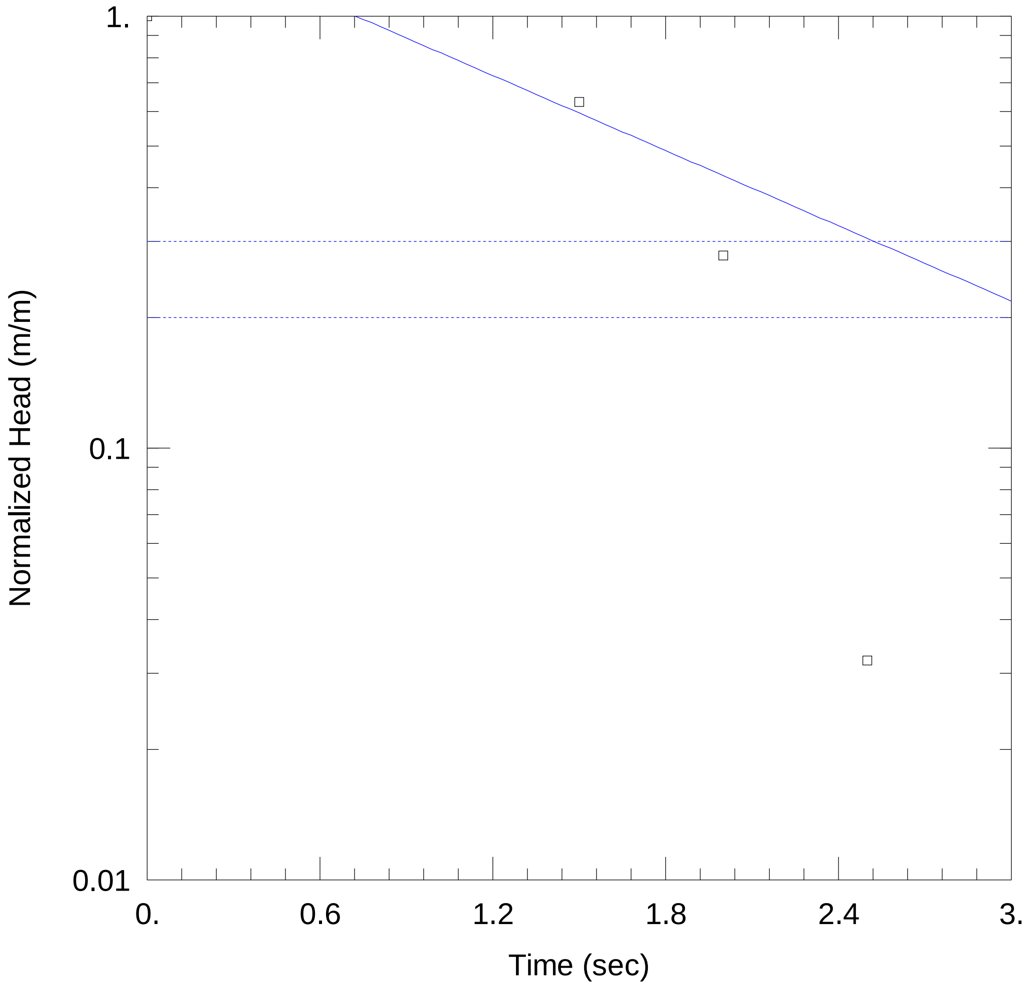
WELL DATA (BH212)

Initial Displacement: 5.108 m Static Water Column Height: 5.15 m
Total Well Penetration Depth: 13.15 m Screen Length: 5.15 m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.013E-5 m/day y0 = 4.686 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-FH5-BR.aqt
Date: 04/24/19 Time: 12:57:38

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

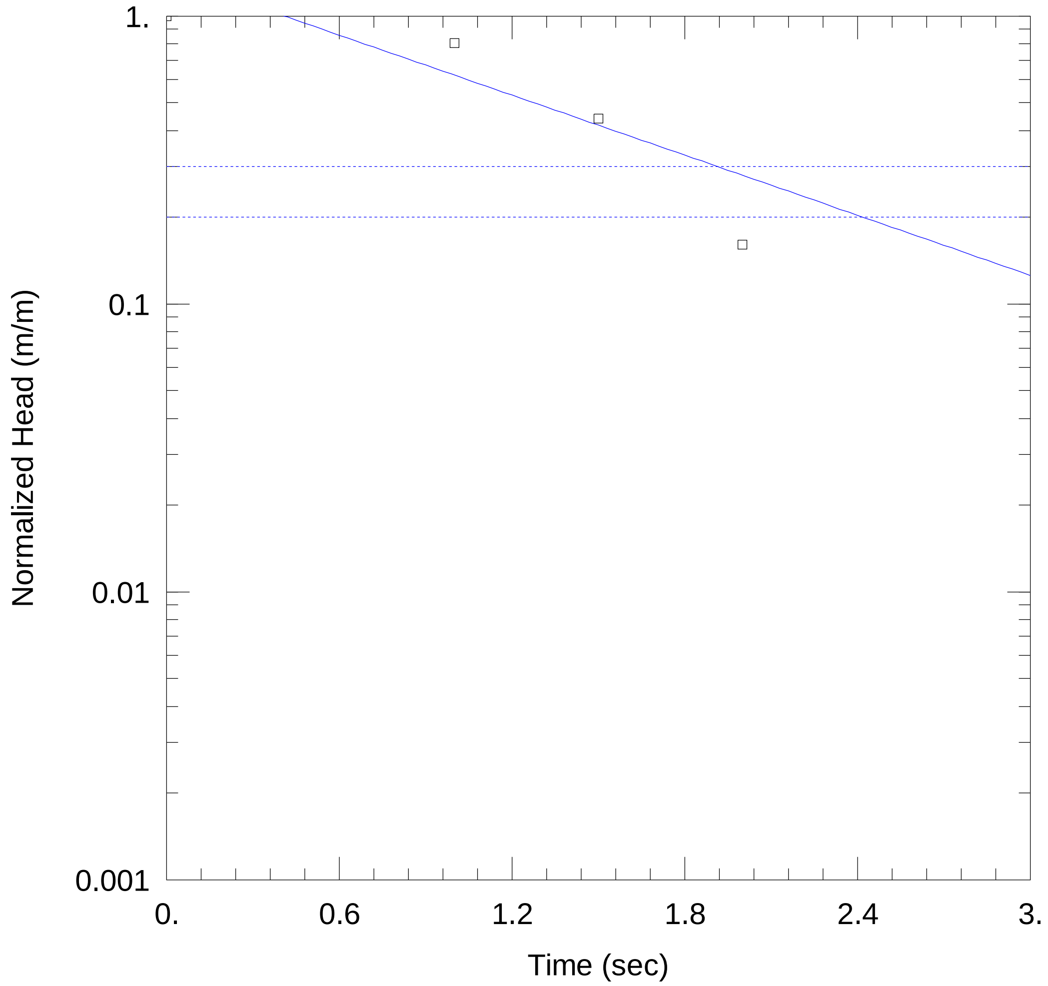
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 6.352 m/day y0 = 0.4539 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-FH9-BR.aqt
Date: 04/24/19 Time: 12:58:27

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

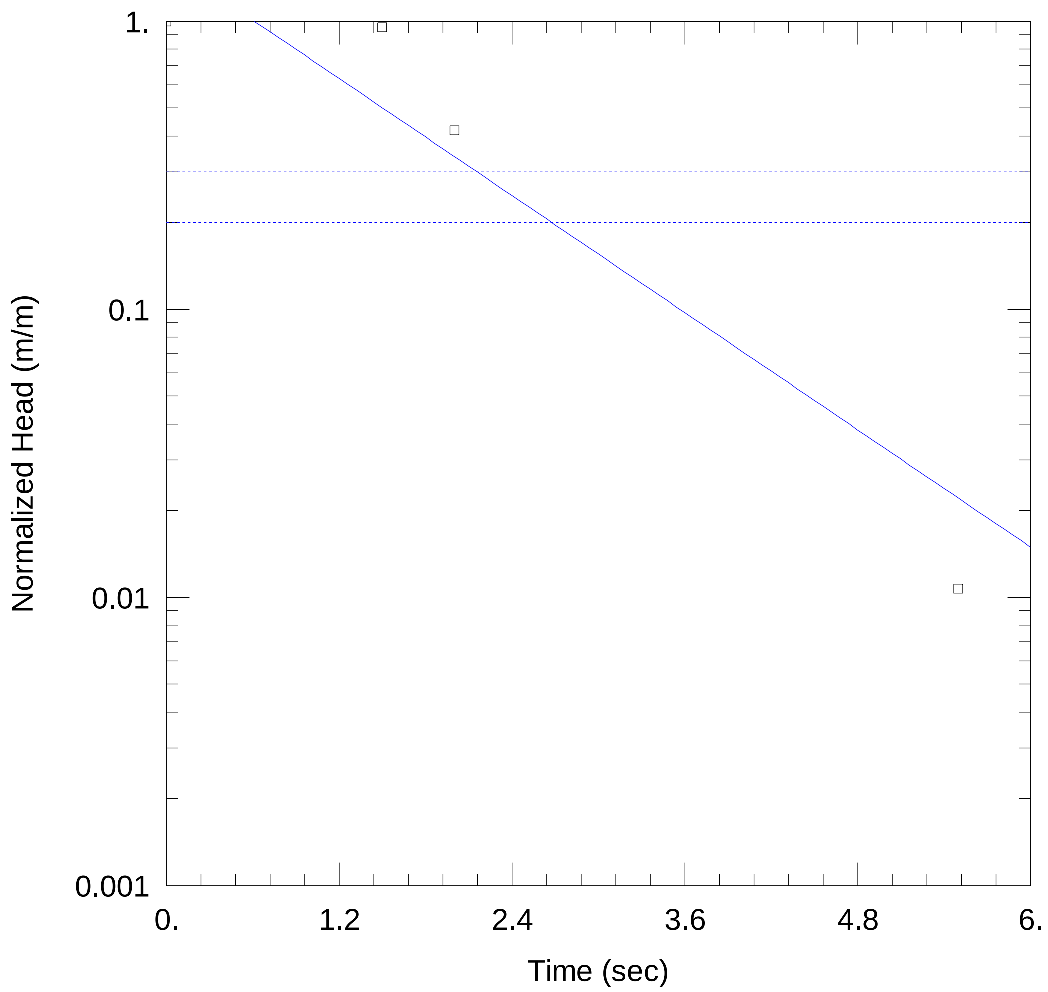
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 7.617 m/day y0 = 0.3881 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-FH11-BR.aqt
Date: 04/24/19 Time: 12:59:04

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

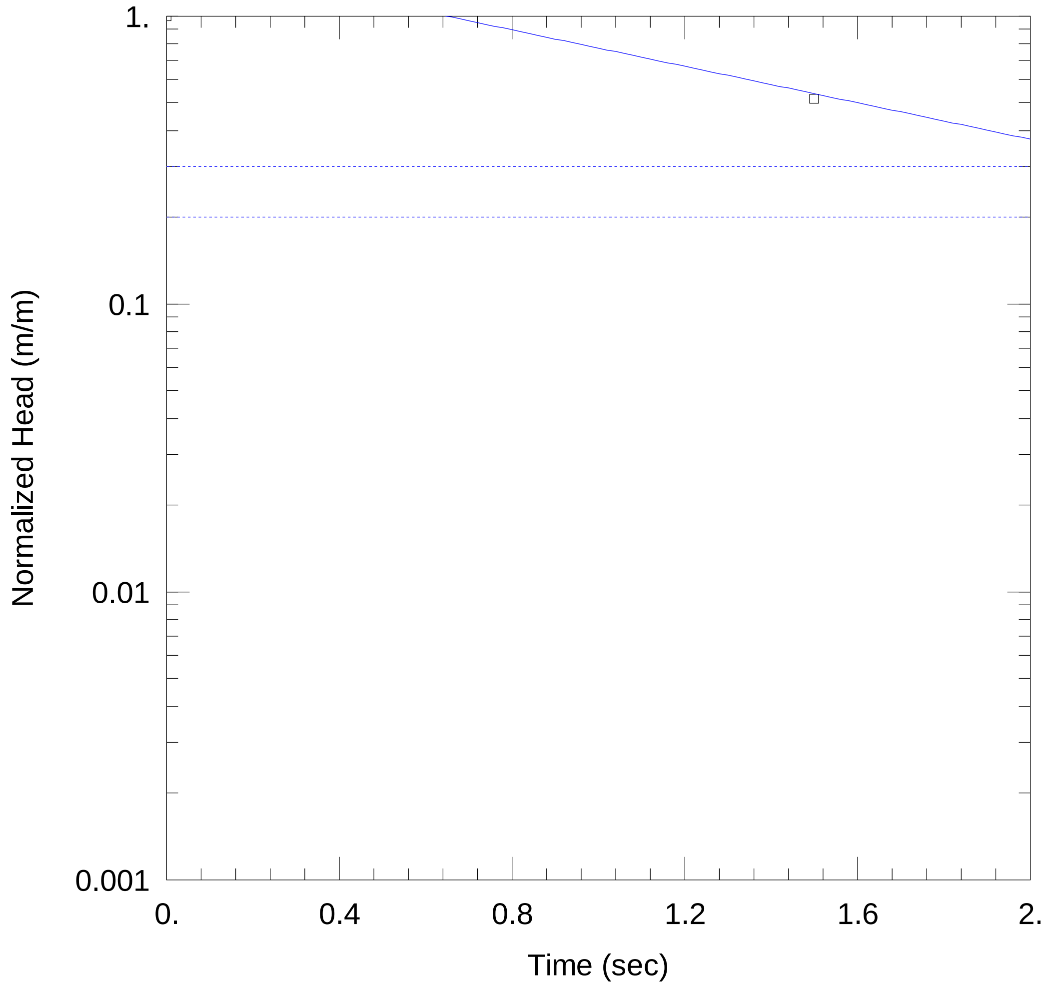
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 7.425 m/day y0 = 0.4514 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-FH17-BR.aqt
Date: 04/24/19 Time: 12:59:42

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

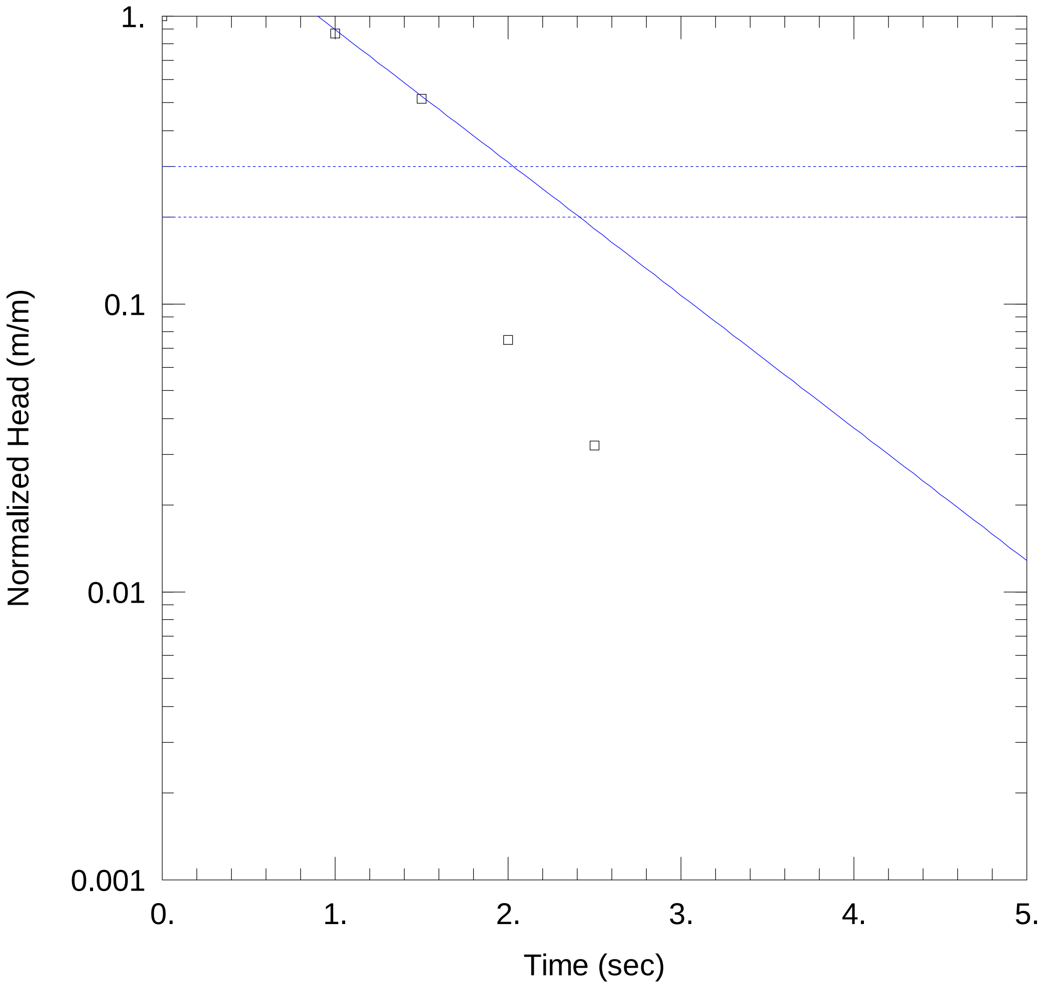
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 6.941 m/day y0 = 0.4488 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-RH1-BR.aqt
Date: 04/24/19 Time: 13:00:31

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m
Anisotropy Ratio (Kz/Kr): 1.

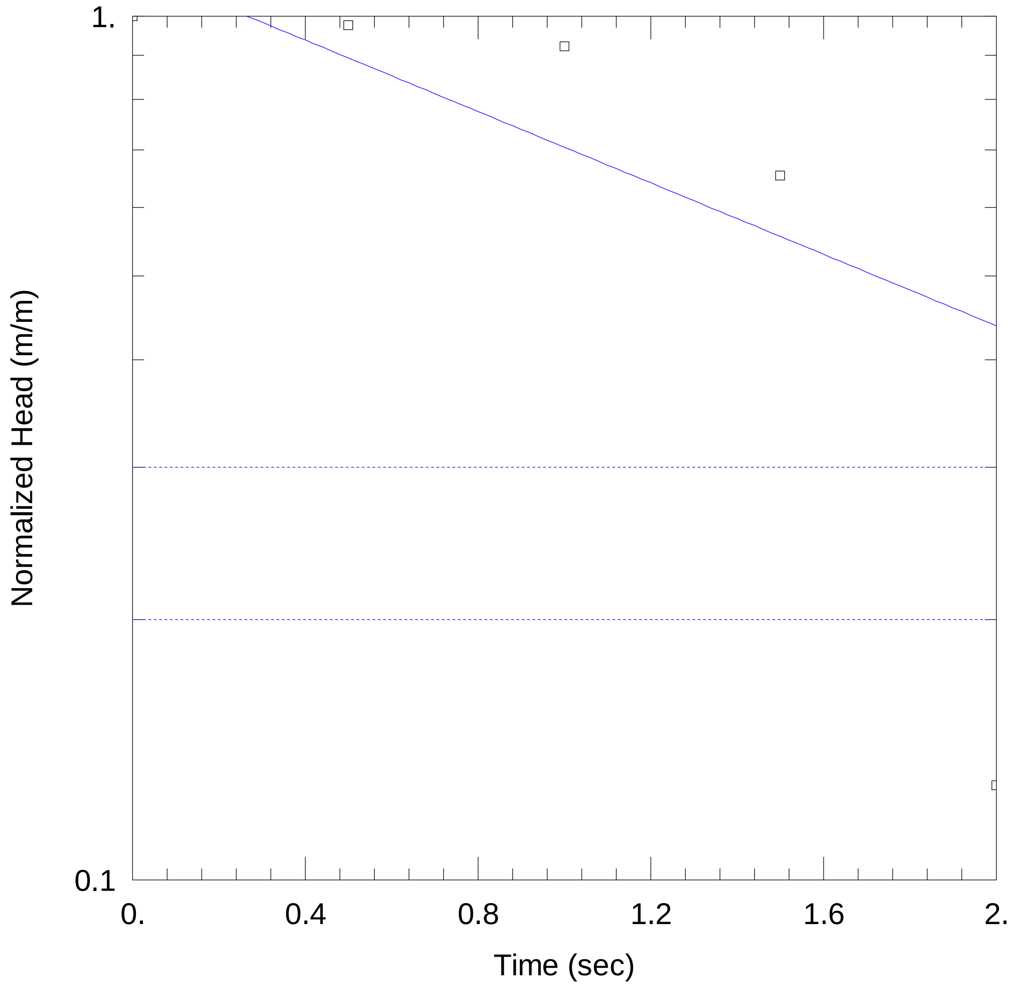
WELL DATA (BH213)

Initial Displacement: 0.28 m
Total Well Penetration Depth: 25.8 m
Casing Radius: 0.025 m
Static Water Column Height: 17.39 m
Screen Length: 12. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 10.1 m/day
y0 = 0.7254 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-RH4-BR.aqt
Date: 04/24/19 Time: 13:01:08

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

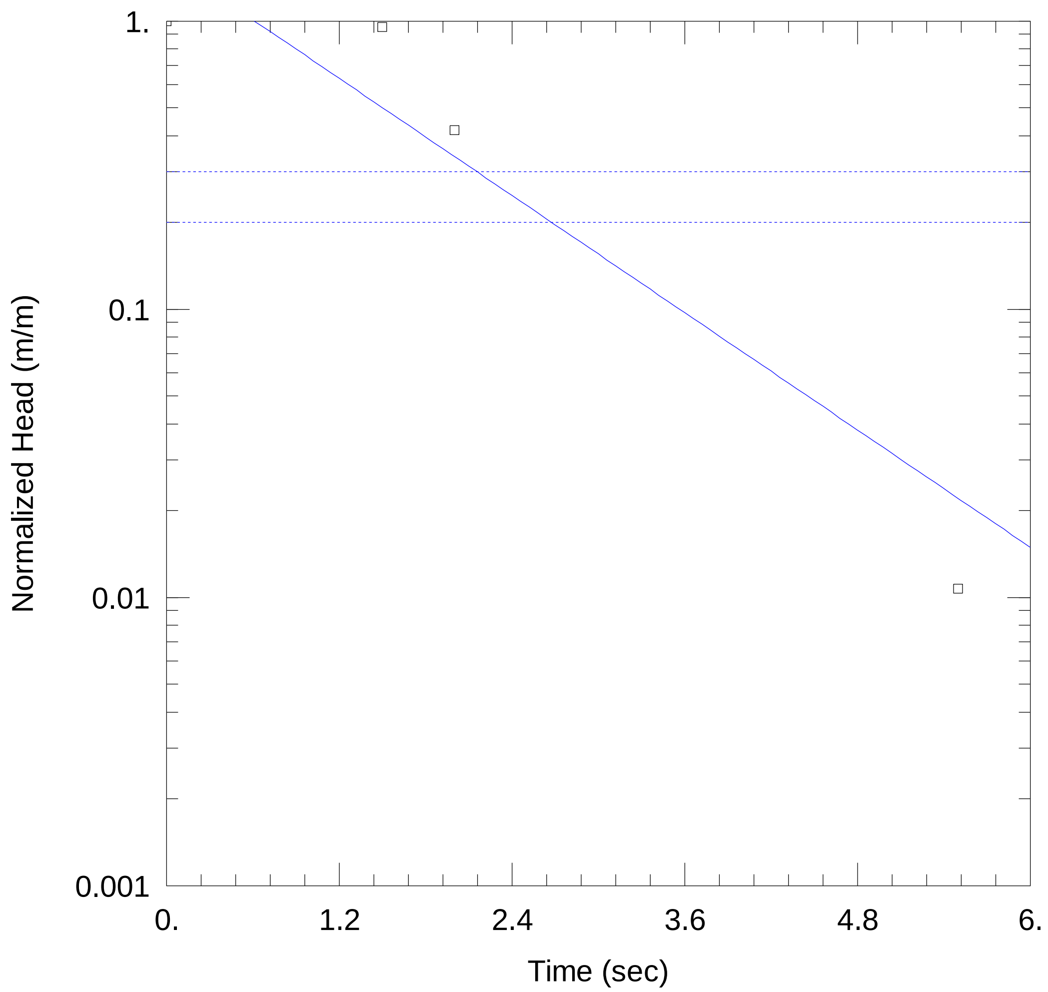
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 4.531 m/day y0 = 0.3176 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-RH12-BR.aqt
Date: 04/24/19 Time: 13:01:46

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m
Anisotropy Ratio (Kz/Kr): 1.

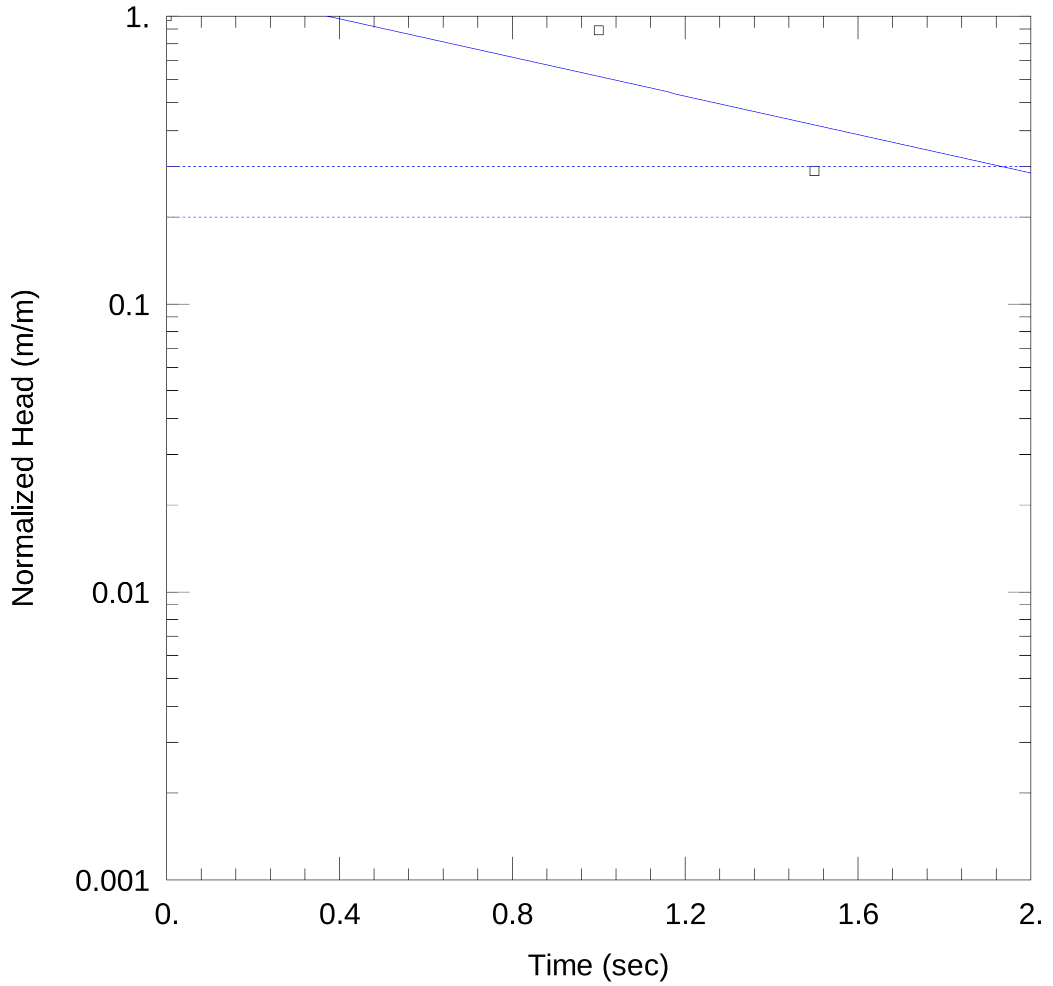
WELL DATA (BH213)

Initial Displacement: 0.28 m
Total Well Penetration Depth: 25.8 m
Casing Radius: 0.025 m
Static Water Column Height: 17.39 m
Screen Length: 12. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 7.428 m/day
y0 = 0.4515 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH213\APM Analysis\BH213-RH14-BR.aqt
Date: 04/24/19 Time: 13:02:20

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH213
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

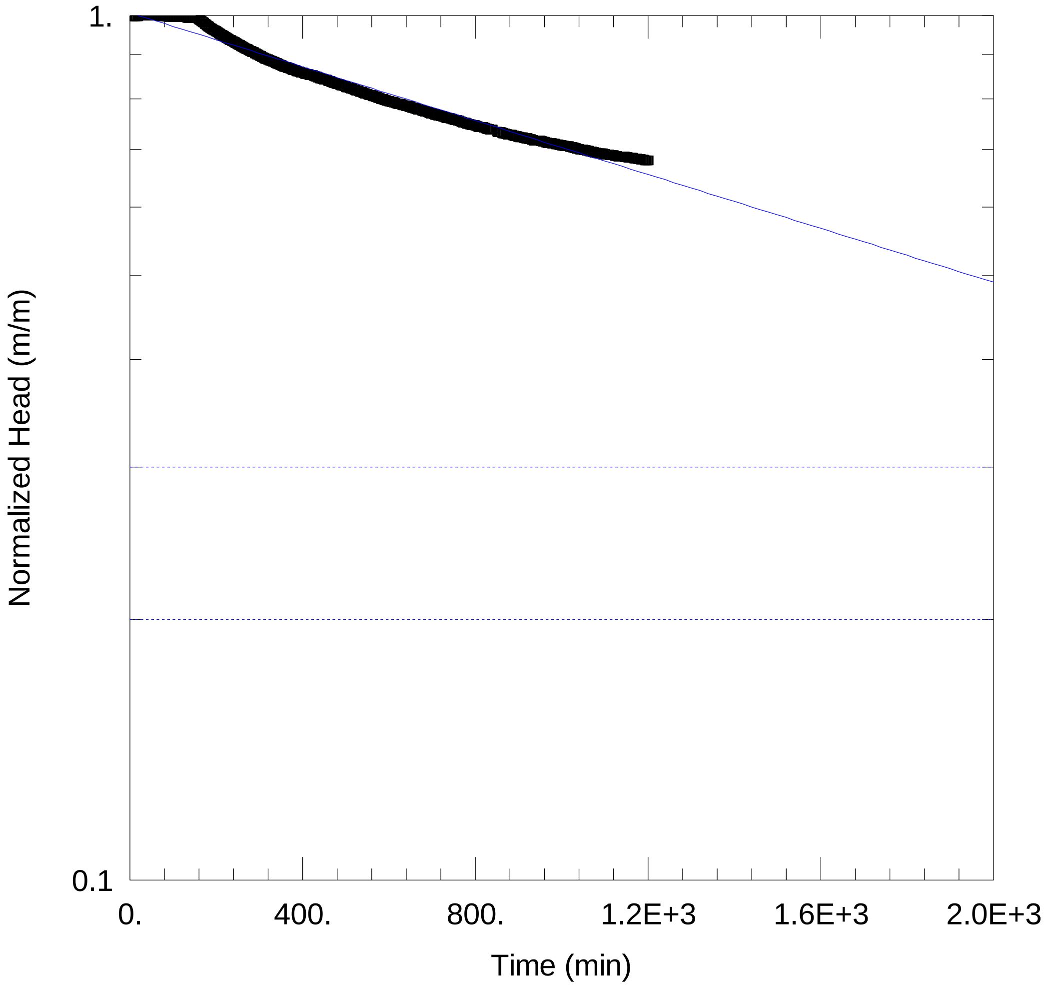
WELL DATA (BH213)

Initial Displacement: 0.28 m Static Water Column Height: 17.39 m
Total Well Penetration Depth: 25.8 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 7.331 m/day y0 = 0.372 m



WELL TEST ANALYSIS

Data Set: C:\Users\AUAM501557\Desktop\I2S Slug\BH215\APM analysis\BH215-RH1-BR.aqt
Date: 04/24/19 Time: 13:43:46

PROJECT INFORMATION

Company: WSP
Client: ARTC
Project: PS108286
Location: Illabo to Stockinbingal
Test Well: BH215
Test Date: 23.01.2019

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH215)

Initial Displacement: 3. m Static Water Column Height: 3.5 m
Total Well Penetration Depth: 12.5 m Screen Length: 3.5 m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.000153 m/day y0 = 3.021 m

TECHNICAL REPORT 6

Groundwater Impact Assessment

Appendix C Water quality results

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT

Inland Rail: Illabo to Stockinbingal water quality results summary table.

				BH201				BH204				BH213	
Hydrogeological unit				LUA - Billabong CK (QA)				MDFR (CF)				MDFR (FV)	
GME				GME1	GME2	GME3	GME4	GME1	GME2	GME3	GME4	GME1	GME2
Sample date				22/01/2019	22/05/2019	09-02-21	08-04-21	22/01/2019	22/05/2019	09-02-21	08-04-21	23/01/2019	21/05/2019
Analyte	Units	LOR	Trigger value										
General parameters			ANZECC 95% Freshwater										
pH (field)	pH units	0.01	-	7.25	7.33	7.43	7.04	7.47	7.37	7.43	7.05	6.65	6.57
pH (lab)			-	7.71	7.93	7.68	-	7.71	7.96	7.63	-	7.22	7.36
Electrical conductivity (field)	µS/cm	1	-	1351	1430	1764	1723	1369	1485	1783	1710	7310	7354
Electrical conductivity (lab)			-	1310	1480	1730	1730	1390	1730	1810	1770	7780	7910
Temperature	ºC	0.1	-	19.6	17.7	17.8	18.1	21.2	19.1	21.0	19.0	19.4	19.1
Dissolved oxygen	% sat	0.1	-	60.6	34.6	40.3	51.7	72.7	55.4	72.0	98.4	32.1	6.2
Total dissolved solids (field)	mg/L	1	-	878	-	-	1120	891	-	-	1111	4700	-
Total dissolved solids (lab)			-	852	962	1120	1120	904	1120	1180	1150	5060	5140
Redox	mV	-	-	48.2	227.3	128.3	139.8	22.4	222.7	151.2	97.4	-13.7	113.5
Absorption Ratio													
Sodium Adsorption Ratio (Filtered)	-	0.01	-	9.62	9.78	10.2	10.6	10	11.3	11.8	12.7	9.89	10.1
Major / Minor Ions													
Calcium (Filtered)	mg/L	1	-	24	26	24	32	29	20	23	28	273	284
Magnesium (Filtered)	mg/L	1	-	15	19	22	26	20	16	22	24	189	199
Potassium (Filtered)	mg/L	1	-	1	2	2	2	3	2	4	4	9	9
Sodium (Filtered)	mg/L	1	-	244	269	288	335	286	279	329	380	869	911
Alkalinity (Hydroxide) as CaCO3	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity (total) as CaCO3	mg/L	1	-	492	427	387	400	440	513	545	592	520	483
Sulfate as SO4 - Turbidimetric (Filtered)	mg/L	1	-	50	47	44	54	92	84	101	104	214	229
Chloride	mg/L	1	-	111	190	339	302	150	220	228	195	2160	1920
Dissolved Metals													
Aluminium (Filtered)	mg/L	10	0.055	<0.01	<0.01	0.13	<0.01	0.03	<0.01	1.23	<0.01	0.02	<0.01
Arsenic (Filtered)	mg/L	1	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium (Filtered)	mg/L	0.1	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
Chromium (Filtered)	mg/L	1	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Copper (Filtered)	mg/L	1	0.0014	0.002	<0.001	<0.001	0.003	0.002	<0.001	0.007	0.009	0.001	0.17
Iron (Filtered)	mg/L	50	-	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	1.05	<0.05	0.17	<0.05
Lead (Filtered)	mg/L	1	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
Mercury (Filtered)	mg/L	0.1	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel (Filtered)	mg/L	1	0.011	<0.001	<0.001	0.002	<0.001	0.004	<0.001	0.004	0.002	0.003	0.002
Zinc (Filtered)	mg/L	5	0.008	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	0.019	<0.005	0.007	0.006
Inorganics													
Alkalinity (Bicarbonate as CaCO3)	mg/L	1	-	492	427	387	400	440	513	545	592	520	483
Alkalinity (Carbonate as CaCO3)	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Notes:

-- not analysed.

Values in light grey are below laboratory limit of reporting (LOR).

Values in red indicate exceedance from adopted trigger values.

Inland Rail: Illabo to Stockinbingal water quality results summary table.

				BH215		BH217				BH054	
Hydrogeological unit				MDFR (FV)		MDFR (FV)				MDFR (FV)	
GME				GME1	GME2	GME1	GME2	GME3	GME4	GME3	GME4
Sample date				23/01/2019	21/05/2019	24/01/201	22/05/2019	09-02-21	08-04-21	09-02-21	07-04-21
Analyte	Units	LOR	Trigger value								
General parameters			ANZECC 95% Freshwater								
pH (field)	pH units	0.01	-	7.15	7.02	7.21	7.21	7.09	6.87	7.34	6.53
pH (lab)			-	7.43	7.69	7.67	7.89	7.48	-	7.35	-
Electrical conductivity (field)	µS/cm	1	-	5265	5778	2300	2353	2567	2349	4052	7030
Electrical conductivity (lab)			-	5630	6360	2390	2510	2510	2380	4050	6470
Temperature	ºC	0.1	-	23.3	18.7	20.0	18.0	18.0	18.7	19.8	18.9
Dissolved oxygen	% sat	0.1	-	530.3	15.5	75.4	70.0	75.5	84.1	24.0	17.6
Total dissolved solids (field)	mg/L	1	-	3410	-	1496	-	-	1528	-	4570
Total dissolved solids (lab)			-	3660	4130	1550	1630	1630	1150	2630	4200
Redox	mV	-	-	-7.02	-10	-64.2	220	121.1	100.8	-20.2	-16.6
Absorption Ratio											
Sodium Adsorption Ratio (Filtered)	-	0.01	-	12.8	13.4	11.7	11.1	11	12.2	9.31	13.7
Major / Minor Ions											
Calcium (Filtered)	mg/L	1	-	120	156	49	53	53	54	126	187
Magnesium (Filtered)	mg/L	1	-	82	100	26	32	35	32	85	123
Potassium (Filtered)	mg/L	1	-	21	21	2	2	2	2	22	16
Sodium (Filtered)	mg/L	1	-	742	872	408	414	421	459	552	985
Alkalinity (Hydroxide) as CaCO3	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity (total) as CaCO3	mg/L	1	-	322	388	480	432	512	516	335	441
Sulfate as SO4 - Turbidimetric (Filtered)	mg/L	1	-	228	253	118	111	116	116	234	319
Chloride	mg/L	1	-	1270	1520	405	473	521	399	1090	1610
Dissolved Metals											
Aluminium (Filtered)	mg/L	10	0.055	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.7	1.06
Arsenic (Filtered)	mg/L	1	-	<0.001	<0.001	<0.001	<0.001	0.003	0.001	0.001	0.002
Cadmium (Filtered)	mg/L	0.1	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Chromium (Filtered)	mg/L	1	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.006
Copper (Filtered)	mg/L	1	0.0014	0.001	0.003	0.003	<0.001	<0.001	0.008	0.012	0.019
Iron (Filtered)	mg/L	50	-	0.13	<0.05	<0.05	<0.05	<0.05	<0.05	1.54	3.7
Lead (Filtered)	mg/L	1	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003
Mercury (Filtered)	mg/L	0.1	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel (Filtered)	mg/L	1	0.011	0.011	0.005	0.001	0.002	<0.001	<0.001	0.008	0.02
Zinc (Filtered)	mg/L	5	0.008	0.02	0.015	0.009	<0.005	0.006	0.006	0.014	0.027
Inorganics											
Alkalinity (Bicarbonate as CaCO3)	mg/L	1	-	322	388	480	432	512	516	335	441
Alkalinity (Carbonate as CaCO3)	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1

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