Santos Ltd

South Western Queensland Cooper Basin

Underground Water Impact Report

Final

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EXECUTIVE SUMMARY

The impacts to groundwater from Santos' oil and gas operations in the Cooper Region of South Western Queensland (SWQ) have been assessed in this Underground Water Impact Report (UWIR), and are based on:

- A description of the geological settings of the gas and oil fields and the development of a conceptual geological cross section and geological contour maps for the top of, and thicknesses of, key formations.
- A review of the hydrogeological settings of the gas and oil fields and the development of a hydrogeological conceptual model and hydrogeological maps.
- An identification of environmental values related to the groundwater system, and in particular groundwater dependent ecosystems including Great Artesian Basin (GAB) artesian discharge springs.
- Characterisation of produced water volumes.
- An assessment of impacts from groundwater extraction on the target petroleum reservoir, surrounding formations, and on potential groundwater users.

The key conclusions of this UWIR are:

- The oil development will result in localised depressurisation of the GAB aquifers and associated oil target areas forming part of the Eromanga Basin.
- The Project will not impact surface waters, groundwater dependant ecosystems (GDEs) or spring complexes:
  - The Rolling Downs Aquitard limits propagation of drawdown from the petroleum targets to the surficial deposits. Technical investigations indicate that groundwater from regional GAB aquifers do not to contribute materially to surface water or GDEs.
  - No springs are located within Santos' SWQ tenements. The nearest springs are located more than 90 km beyond the tenement boundaries.
- Drawdown/depressurisation greater than the 2 m trigger threshold for unconsolidated aquifers, and 5 m for consolidated aquifers (under Section 362 of the Water Act) are not expected to affect any water supply bores.

This groundwater report demonstrates that impacts to GAB aquifers as a result of the Project is limited. Some depressurisation of the Eromanga layers used for petroleum production can be expected, with limited propagation to the layers immediately above it. It is considered that Santos' current SWQ activities pose little risk to the Cooper GBA region surface water, shallow groundwater systems and associated ecosystems.

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1 INTRODUCTION

KCB Australia Pty Ltd (KCB) has been commissioned by Santos Ltd (Santos[1]) to undertake the update of the South Western Queensland (SWQ) Cooper Basin Underground Water Impact Report (UWIR) (the Project). This UWIR is the three yearly update to the 2022 UWIR and will cover the period from 2025 to 2028.

This report has been prepared in accordance with the *Queensland Water Act 2000* (the Water Act) (State of Queensland 2021b) and the Guideline for Underground Water Impact Reports and Final Reports (State of Queensland 2024a).

1.1 Project Overview

Santos currently operates conventional oil and gas fields within the Cooper Basin of SWQ, located in the vicinity of the townships of Windorah and Thargomindah on the Queensland – South Australia border (Figure 1.1). Santos discovered natural gas at the Project site in 1963 and oil in 1970; and has since developed these resources for the production of natural gas, ethane, crude oil and gas liquids (Santos 2021).

Santos' Petroleum Licenses (PLs) occupy an area in excess of 8,160 km^2 in SWQ (Figure 1.1) and currently comprises 183 producing gas wells and 251 producing oil wells.

- *Conventional oil* originates from the formations of the Eromanga Basin, a sub-basin within the Great Artesian Basin (GAB) with minor secondary production occurring within the Tirrawarra Formation and basal Patchawarra Formation of the deeper Cooper Basin.
- *Conventional gas* production is from porous sandstone formations of the Cooper Basin at depths often exceeding 2,000 m. Unlike coal seam gas reservoirs, the formations of the Cooper Basin do not require the depressurisation of the target beds through the removal of groundwater to produce gas at economic quantities; some water may be produced from the formation as a by-product.

The Project area comprises active Santos tenements including PLs and exploration tenements (ATPs), in SWQ, which includes the Cooper and Eromanga Basins and is referred to collectively as the Cooper Basin (see Figure 1.1).

[1] "Santos" refers to Santos and its subsidiary companies that operate the oil and gas tenements on behalf of various joint venture parties.

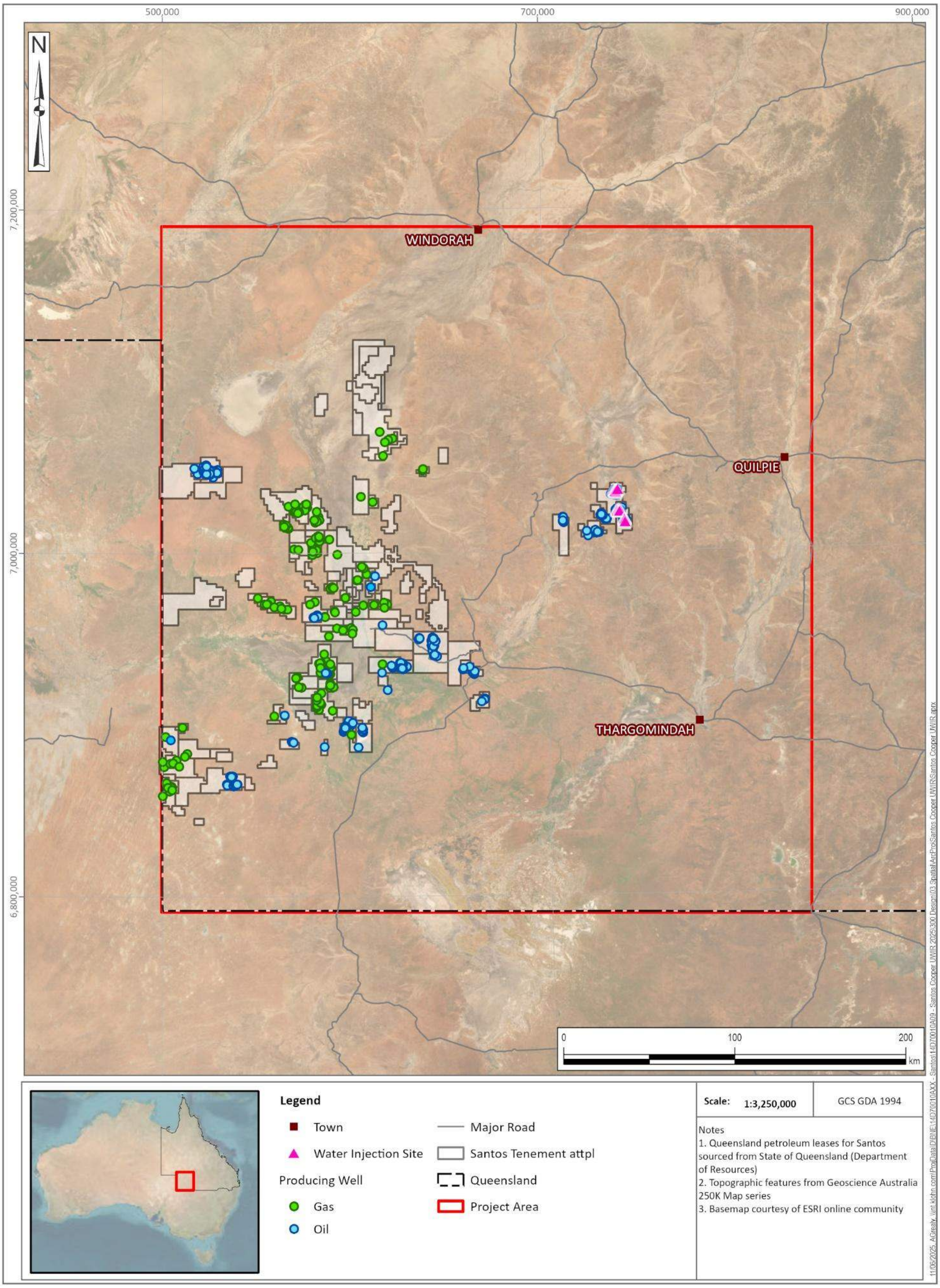

Figure 1.1 Project Study Area and Location of Active Tenements (PL and ATP)

1.2 Background to the UWIR

The *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020; 2021a) (P&G Act) and *Petroleum Act 1923 (Petroleum Act)* (State of Queensland 2024b) entitles the holder of a petroleum tenure to take or interfere with underground water (i.e. groundwater) as part of approved petroleum operations. This entitlement is termed the petroleum tenure holder's 'underground water rights'. Further detail on the P&G Act and Petroleum Act is provided in Section 2.1

Groundwater that is taken or interfered with while exercising the underground water rights is termed 'associated water'. The holder of the PL is entitled to use associated water for any purpose. In order to exercise the underground water rights for the Project, the PL holder must:

- Obtain an Environmental Authority (EA) under the *Environmental Protection Act 1994* (EP Act) (State of Queensland 2022a); and
- Comply with its reporting obligations under Chapter 3 of the Water Act. The administering authority for Chapter 3 of the Water Act is the Department of Environment, Tourism, Science, and Innovation (DETSI). Lease holder obligations under Chapter 3 of the Water Act include undertaking baseline assessments of the groundwater regime and water supply bores, preparing UWIRs to provide for ongoing assessment and reporting of groundwater take and (where necessary) entering into make good agreements with owners of affected water supply bores.

1.3 UWIR Scope and Structure

Santos submitted its initial UWIR for the Project in 2013 (Golder 2013), in accordance with the Water Act. Santos is required to update the UWIR for petroleum operations within the SWQ Cooper Basin every three years. The main purpose of the UWIR is to describe the groundwater take due to the proposed development and any associated impacts over a three-year period (the UWIR period).

This UWIR addresses the three-year period of Project development from 2025 to 2028, with the previous UWIRs also completed in 2016, 2019, and 2022. Planned operations in this period include operations associated with existing oil and gas fields as well as the construction and development of new operations, both within existing oil and gas fields, and PLs currently under application.

The UWIR has been prepared in accordance with the UWIR content requirements described in Section 376 of the Water Act and the DETSI guideline *Underground water impact reports and final reports* ESR/2016/2000 (the UWIR Guideline) (State of Queensland 2024a) where relevant. The requirements in Section 376 of the Water Act are complimentary to the information requirements of Sections 126A and 227AA of the EP Act.

The structure of this UWIR has been prepared in accordance with that outlined in the UWIR Guideline. The guideline specifies that a UWIR must contain information that has been outlined in each of the following parts of the guideline:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights (Section 6);

- Part B: Information about aquifers affected, or likely to be affected (Section 7);
- Part C: Maps showing the area of the affected aquifer(s) where underground water levels are expected to decline (Section 8);
- Part D: An assessment of the impacts to the environmental values from the exercise of underground water rights (Section 9);
- Part E: A water monitoring strategy (Section 10);
- Part F: A spring impact management strategy (not relevant to this assessment); and
- Part G: For a CMA, assignment of responsibilities to resource tenure holders (not relevant to this assessment).

2 REGULATORY FRAMEWORK

This section provides a summary of the key Queensland and Commonwealth legislative requirements related to the extraction of groundwater and management of produced water.

Santos' activities in the Cooper Basin are subject to general Queensland and/or Commonwealth regulation, and to site specific EAs determined under the EP Act.

2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) is an Act relevant to exploring for, recovering and transporting by pipeline, petroleum and fuel gas, and ensuring the safe and efficient undertaking of those activities. The key purpose of this Act is to facilitate and regulate the undertaking of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry.

This Act identifies underground water rights for petroleum tenures, and states that the holder of a petroleum tenure may take or interfere with underground water in the area of the tenure if the taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure.

The Act prescribes mandatory compliance with the Department of Natural Resources, Mines and Energy's (DNRME) '*Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 1'* (State of Queensland 2019a). The purpose of this Code is to provide guidance that all petroleum wells, CSG wells and associated bores are constructed, maintained and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and the protection of groundwater resources.

2.2 Water Act 2000

2.2.1 General Purpose of the Water Act

The *Water Act 2000* (Water Act) is an Act to provide for the sustainable management of water and the management of impacts on underground water, among other purposes. This Act provides a framework for:

- The sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water;
- The sustainable and secure water supply and demand management for designated regions;
- The management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- The effective operation of water authorities.

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

2.2.2 Water Act and CSG Related Activities

The Water Act provides for the identification and management of potential impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which are regulated under the P&G Act. The Act also outlines the requirements for make good agreements, if required, associated with the impacts to underground water.

Chapter 3 of the Water Act has a stated purpose to provide for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which includes petroleum tenure holders. To achieve the stated purpose, a regulatory framework is provided which requires:

- Resource tenure holders to monitor and assess the impacts of the exercise of underground water rights on water bores and to enter into make good agreements with the owners of the groundwater bores as necessary;
- The preparation of UWIR that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs; and
- Manage the cumulative impacts of the activities of two or more resource tenure holders' underground water rights on underground water.

2.2.3 Trigger Thresholds

Under Section 362 of the Water Act, a bore trigger threshold, for a consolidated aquifer, of 5 m applies (2 m for an unconsolidated aquifer). The 5 m threshold represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holder's activities, prior to triggering an investigation into the water level decline.

Under Section 379 of the Water Act a spring trigger threshold for an aquifer applies. This includes vent springs / complexes and watercourse springs (i.e., gaining streams). This threshold value (0.2 m) represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline.

2.2.4 UWIR Requirements

Section 376 of the Water Act specifies the UWIR content requirements. Table 2.1 lists the specific content requirements and provides an explanation of where each requirement is addressed in this UWIR.

Table 2.1 UWIR Content Requirements (State of Queensland 2024a)

Water Act Section No.	Water Act Section Content	UWIR Cross Reference
376(1)(a)	An underground water impact report must include each of the following — for the area to which the report relates: (i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and (ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3-year period starting on the consultation day for the report.	(i) Section 6.3 describes the reported quantities of water produced or taken in previous UWIR periods. (ii) Section 6.4 describes the estimated groundwater take over the UWIR period.
376(1)(b)	For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights: (i) a description of the aquifer; (ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and (iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i); (iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day for the report; and (v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time.	(i) and (ii) Section 7 describes the groundwater regime in the relevant aquifers. (iii) Groundwater level trends and analysis for aquifer within the Project study area are discussed in Section 0. Potential groundwater impacts from the Project for the UWIR period are discussed in Section 9.1.3. (iv)Figure 8.5 and Figure 8.6 show the areas where depressurisation due to the Project activities is predicted to exceed the bore trigger threshold during the UWIR period. (iv) Figure 8.7 and Figure 8.8 shows the areas where depressurisation due to the Project activities is predicted to exceed the bore trigger threshold during the life of the Project.
376(1)(c)	A description of the methods and techniques used to obtain the information and predictions under paragraph (b).	Section 3 describes the UWIR methodology.
376(1)(d)	A summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore.	Section 9.1.3 describes the third-party groundwater users within the Project. Section 9.2.2 describes the potential impacts to third-party groundwater users.
376(1)(da)	A description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights.	Environmental values are summarised in Section 2.4 and described in Section 5. Impacts on environmental values are assessed in Section 9. A discussion on groundwater level changes (which subsequently may impact environmental values) is provided in Section 7.3.2. Subsidence and impacts to formation integrity are discussed in Section 9.2.6.
376(1)(db)	An assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights: i. during the period mentioned in paragraph (a)(ii); and ii. over the projected life of the resource tenure.	Section 9.1.3 presents an assessment of potential groundwater impacts due to groundwater take.
376(1)(e)	A program for: i. conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and ii. giving the Chief Executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps.	Section 11 describes the UWIR review and reporting process for the affected aquifers.
376(1)(f)	A water monitoring strategy.	Section 10 describes the groundwater monitoring program.
376(1)(g)	A spring impact management strategy.	There are no springs within the Project site or its surrounds. Hence, a strategy for spring management is not required.
376(1)(h)	If the responsible entity is the office: i. a proposed responsible tenure holder for each report obligation mentioned in the report; and ii. for each immediately affected area—the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area.	Not applicable.
376(1)(i)	The information or matters prescribed under a regulation.	No other relevant information or matters have been prescribed under a regulation.
376(2)	However, if the underground water impact report does not show any predicted water level decline in any area of an affected aquifer by more than the bore trigger threshold during the period mentioned in subsection (1)(b)(iv) or at any time as mentioned in subsection (1)(b)(v), the report does not have to include the program mentioned in subsection (1)(e).	Section 11 describes the UWIR review and reporting process for the affected aquifers.

Section 378 of the Water Act lists the content requirements for the water monitoring strategy. Table 2.2 lists the specific water monitoring content requirements and provides an explanation of where each requirement is addressed in this UWIR.

Table 2.2 UWIR Water Monitoring Strategy Content Requirements

Water Act Section No.	Water Act Section Content	UWIR Cross Reference
378(1)	The responsible entity's water monitoring strategy must include the following for each immediately affected area and long-term affected area identified in its underground water impact report or final report: a) a strategy for monitoring— (i) the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and (ii) changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights; b) the rationale for the strategy; c) a timetable for implementing the strategy; d) a program for reporting to the office about the implementation of the strategy.	Section 6 describes associated water extraction rates, volumes and approach. Section 10.2describes the associated water monitoring methodology. Sections 0 and 7.4 describes water levels and quality. Section 10 describes the groundwater monitoring program.
378(2)	The strategy for monitoring mentioned in subsection (1)(a) must include: a) the parameters to be measured; b) the locations for taking the measurements; and c) the frequency of the measurements.	Section 10 describes the groundwater monitoring program.
378(3)	If the strategy is prepared for an underground water impact report, the strategy must also include a program for the responsible tenure holder or holders under the report to undertake a baseline assessment for each water bore that is: a) outside the area of a resource tenure; but b) within the area shown on the map prepared under section 376(b)(v).	Baseline assessment done as part of 2013 UWIR (Golder Associates, 2013). Section 9 describes the water bores identified from the Queensland GWDB. Section 9.2.2 includes recommendation for additional bore baseline assessment.
378(4)	If the strategy is prepared for a final report, the strategy must also include a statement about any matters under a previous strategy that have not yet been complied with.	Not applicable.

2.3 Other Applicable Water Regulations

Additional legislative requirements applicable to the Project are summarised in Table 2.3.

Table 2.3 Additional Legislative Requirements Related to Groundwater

Legislation/Section	Driver	Key Points as the Apply to the Santos Operation
Environmental Protection Act 1994[1]	Section 309Z can be imposed on a petroleum activity and cause the activity to prepare an environmental report and/or implement water management plans.	Conditions are issued through Environmental Authorities.
Environmental Protection (Water) Policy, 2009[2]	An environmental plan must be developed and implemented for water management, including plans for managing stormwater, sewage and trade waste for protection of surface and groundwater. In the case of produced water recycling, water releases on land, water releases to surface water or stormwater management, the administrating authority must consider the existing quality of waters that may be affected, the cumulative effect of the release in question, the water quality objectives for waters affected and the maintenance of acceptable health risks.	Contamination must be minimised or prevented and any release, or potential release, must be monitored against site baseline conditions.
Water Plan (Great Artesian Basin and other Regional Aquifers, 2017[3]*)*	Defines the maximum amount of water that can sustainably be extracted from the recognised aquifers within each groundwater management area. Requires monitoring for all licensed bores.	Santos production wells are not licensed for water extraction with DNRM as they are covered by the Petroleum Legislation.
Environmental Protection and Biodiversity Conservation (EPBC) Act 1999[4]	Provides the regulatory framework for Matter of National and Environmental Significance (MNES).	The most significant groundwater related MNES in the GAB are GAB artesian discharge springs.
Water Resource (Cooper Creek) Plan 2011[5]	The plan applies to surface water and overland flow within the Cooper Creek management area.	Defines rules and requirements for interacting and management of surface water within the region of the Project study area.

1) (State of Queensland 2022)
2) (State of Queensland 2016)
3) (State of Queensland 2017b)
4) (Commonwealth of Australia 2025)
5) (State of Queensland 2017a)

2.4 Environmental Values and Water Resource Management

The *Environmental Protection Act 1994* (Queensland Government 2022) defines an environmental value (EV) as:

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

Under the *Environmental Protection Act 1994*, the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019b) is established as subordinate legislation to achieve the object of the Act in relation to Queensland waters. The purpose of the *Environmental Protection (Water) Policy 2009* is achieved by:

- Identifying EVs and management goals for Queensland waters;
- Stating water quality guidelines and water quality objectives (WQOs) to enhance or protect the EVs;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

There are a number of environmental values associated with surface water bodies, however, these may or may not be related to groundwater systems. Environmental ecosystems depending on groundwater are referred to as Groundwater Dependent Ecosystems (GDE).

Environmental values relevant to groundwater resources in the study area are:

- Groundwater Dependent Ecosystems (including wetlands and springs).
- Drinking water.
- Sandstone aquifers of the Great Artesian Basin.
- Groundwater Users.

The hydrogeology of the Project area and the associated groundwater environmental value are described further in Section 5.

3 ASSESSMENT METHODOLOGY

This section describes the UWIR methodology, including the desktop study of relevant groundwater bores, geological and environmental information, and groundwater monitoring data. It also provides an overview of the groundwater modelling methodology. A detailed description of the groundwater modelling method is provided in Section 8.1.

3.1 Information and Data Sources

A desktop assessment was undertaken based on data and information from Santos and publicly available reports and data.

3.1.1 Datasets

Primary data and information sourced for this assessment include:

- Registered bore data from the Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Database (GWDB) (State of Queensland 2025b);
- Queensland Spring Register, published by the Queensland Herbarium (Queensland Herbarium 2018);
- Potential Groundwater Dependent Ecosystem (GDE) mapping (DETSI 2025);
- The Queensland Spatial Catalogue (QSpatial), via Queensland Globe – comprising records of petroleum and gas exploration, production and monitoring wells (State of Queensland 2025a);
- Geoscience Australia Geological and Bioregional Assessment Program, various datasets;
- Groundwater monitoring records (levels and quality); and
- Oil and gas production records from 2014 to 2024, and production forecast from 2025 to 2040 provided by Santos.

3.1.2 Database Searches for Groundwater Bores

A search of relevant Queensland Databases and Santos' records was undertaken for the Project area. The purpose of this search was to:

- Identify the presence of current and historical 'water bores' and groundwater monitoring bores; and
- Collate drilling records and groundwater level, yield and quality data from relevant bores.

The database search of bores in the Project area was considered suitably representative of the geological and hydrogeological setting of the Project area and includes the maximum potential extent of potential groundwater level drawdown as a result of the proposed Project activities.

The following databases and mapping tools were searched to support the assessment of bores and impacts for the assessment:

- The Queensland Government Groundwater Database (State of Queensland 2025b). This database provided information on bore location, groundwater levels, bore construction details, stratigraphic logs, hydrogeological testing and groundwater quality.

- The Queensland Spatial Catalogue (QSpatial), via Queensland Globe. Records of registered groundwater bores associated with petroleum exploration, production and monitoring wells are contained within this database.

3.1.3 Reports

A review of relevant groundwater studies and previous UWIR assessments was undertaken to collect local and regional hydrogeological data. This was undertaken to support the development and validation of the hydrogeological setting of the Project area (described in Section 7). The review included the following groundwater studies undertaken within the vicinity of the Project area and within comparable geological and environmental settings:

- UWIR annual groundwater monitoring reports for 2022 to 2024 were completed to comply with the monitoring strategy set out in the UWIR. The reports provided information on formation pressure, water levels and water quality in unconsolidated and consolidated aquifer formations (LBWco 2023; 2024; 2025).
- Previous UWIRs. Santos prepared the UWIR for 2016 and 2019, whilst Golder Associates prepared the previous UWIRs for 2011 and 2013. These UWIRs were prepared for the same Project area extent as this report (Golder Associates 2013b; Santos 2016; 2019a). KCB prepared the UWIR for 2022 (KCB 2022).
- The 'Impact Assessment for the Cooper Basin Geological and Bioregional Assessments (GBA) Region' report was completed by the Australian Government, the CSIRO and Geoscience Australia as part of the Australian Government GBA program (Commonwealth of Australia 2021). The GBA program aimed to increase the understanding of potential environmental impacts of unconventional gas resource and to inform regulatory frameworks and appropriate management approaches. The GBA program involved three stages, comprising, Stage 1: rapid regional basin prioritisation, Stage 2: Geological and environmental baseline assessments and Stage 3: Impact assessment. The Cooper GBA assessed the interactions between the deep unconventional resources of the Cooper Basin (below the conventional Cooper reservoirs) and the surface ecosystems but did not explicitly assess the Santos oil and gas operations targeting the Cooper and Eromanga Basins.
- Update to the groundwater impact estimations in 2021 to support an EA amendment application to increase the number of oil and gas wells on Santos' tenements. This report outlines the vulnerability of groundwater users to drawdown activities associated with the Project (Golder Associates 2021).

3.2 Impact Assessment Methodology

This assessment has been completed to identify potential impacts on the groundwater system from the Project for the UWIR period (Immediately Affected Areas (IAA)) and for the proposed overall development (long-term affected areas (LTAA)).

All relevant data (as identified in Section 3.1) was collated and analysed to develop a conceptual understanding of the groundwater regime, including the key geology, groundwater flow and groundwater quality characteristics. This conceptualisation served as the basis for the development and simulation of the numerical groundwater model, which was used to undertake the prediction of potential impacts to the groundwater regime. Details of the groundwater model are provided in the following section.

3.2.1 Numerical Groundwater Modelling

An analytical groundwater flow model was developed to predict the extents of depressurisation and the associated impacts on the groundwater regime and the surrounding environment. The physical structure of the groundwater model was based on the 2018 Cooper GBA assessments (Evans et al. 2020), and data sets sourced from the public domain. Model development was supplemented by published geological maps, digital geological surfaces, DRDMW groundwater database, and information from Santos operations and published approval documents.

The groundwater modelling platform adopted for this Project is AnAqSim software. AnAqSim employs the analytic element method (AEM), which superposes analytic solutions to yield a composite solution consisting of equations for head and discharge as functions of location and time. The model represents the key hydrostratigraphic units of the Cooper GBA region using seven layers and extends ~500 km north-south and ~700 km east-west. The Project area was located in the centre of the model domain. A detailed description of the groundwater model is provided in Section 8.1.

The groundwater model has specifically been developed to simulate the impacts of the extraction of groundwater co-produced as part of conventional oil and gas development in the Cooper and overlying Eromanga Basins in SWQ. The model does not include extraction of groundwater by other activities (e.g. water for town water supply and stock watering). Third-party groundwater extractions in the region predominantly target shallow hydrostratigraphic units such as the Winton-Mackunda partial aquifer and Cenozoic aquifers and not the deeper formations targeted for oil and gas production. The model was calibrated against measured groundwater levels and published pre-development pressure head distributions for the deeper Cooper Basin. Once calibrated, the model was used to identify the IAA and LTAA for the UWIR. These predictions have also been used to assess the impacts of the Project on groundwater users and potential groundwater dependent ecosystems (GDEs).

4 PROJECT SETTING

4.1 Project Location and Land Use

The Project area for the Santos Cooper operations in Queensland is situated in the South Western corner of Queensland near the localities of Ballera, Jackson, Eromanga and Thargomindah as shown in Figure 1.1.

The Queensland portion of the operations is situated in the central Cooper Basin. The geological Cooper Basin covers a total area of approximately 130,000 km^2 across southwest Queensland and northwestern South Australia and is overlain by formations of the Great Artesian Basin (GAB).

The Project area is dominated by sparse, riparian flora and fauna communities which have a high dependency on the frequency of flooding and occurrence of permanent waterholes. The existing land use is dominated by agriculture and oil/gas infrastructure.

4.2 Topography and Drainage

The Project area topography is generally flat and is defined by the heavily braided Cooper Creek and associated flood plains. Cooper Creek flows from north to south directly through the Project area to approximately 40 km south of Durham, where it meanders west and continues into South Australia discharging into Lake Eyre approximately 350 km west of the Project. Cooper Creek has several ephemeral tributaries across the Project area, which typically only flow during the wet season and discharge overland flow towards the Cooper Creek.

Santos operations within the Project area are predominantly situated with the Cooper Creek sub-catchment. ATP 1063 is located in the Bulloo River sub-catchment, flowing from northeast to southwest across the southeastern extent of the Project area. Numerous springs associated with regional GAB flow (Evans et al. 2020) discharge into the Paroo River catchment (DES 2022) to the east of the Project area.

The flood plains of Cooper Creek extend up to 60 km from the main channel and has a variable flow regime influenced by frequent flood events. The flood plains are characterised by channels, lagoons and waterholes that concentrate drainage to enable permeant water features throughout the dry season. In some areas, inundation of the flood plains results in the creation of a hydraulic gradient from the floodplain out to low lying depressions to the west of Cooper Creek, resulting in the creation of terminal lakes and associated fringe wetlands that receive regular discharge from the main channel (Commonwealth of Australia 2021). A similar topographic morphology is associated with the Bulloo River flood plains except the flood plains of the Bulloo River have a much narrower lateral extent of approximately 5 to 10 km from the main channel except along the southern border of the Project area where the Bulloo River heavily braids to form a large wetland environment (Commonwealth of Australia 2021).

Away from the flood plains of Cooper Creek and Bulloo River, the topography is characterised by low hills, mesas, clay pans and high sand dunes with poor drainage networks, resulting in the formation of temporary swale wetlands during the wet season due to the attenuation of meteoric water. Such features are short lived and typically absent throughout the dry season (Commonwealth of Australia 2021).

Approximately 30 permanent waterholes exist within the Project area. These waterholes form as depressions within the landscape that become inundated following the flooding of Cooper Creek. The majority of the waterholes are permanent due to bank storage in the alluvium along the Cooper Creek (Section 9.1.1) (State of Queensland 2025a).

The locations of key drainage features within the Project area have been provided in Figure 4.1.

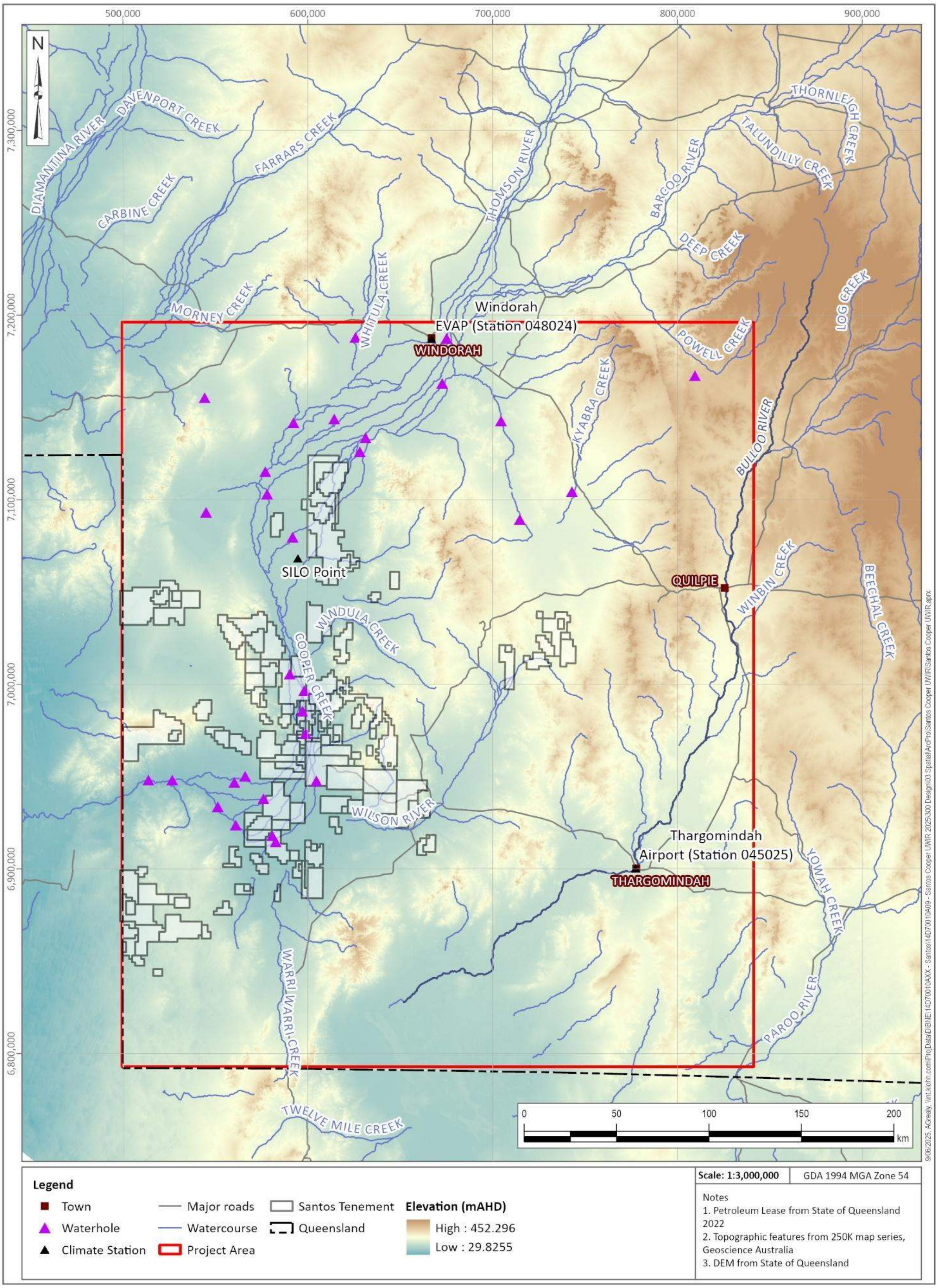

Figure 4.1 Topography and Drainage

4.3 Climate

The climate of the Project area is dry-arid, characterised by low total annual precipitation yet high seasonal variability in rainfall, temperature and evaporation, typical of the Central Australia regions, based on the modified Köppen classification system (BoM 2005).

The closest open BOM climate stations are the Thargominda Airport and Windorah stations, located to the north and southeast of the Project area, respectively. A review of the data shows consistent monthly trends between the two climate stations. Due to the distance of the climate stations from the Project, longer term synthetic rainfall data was sourced from the SILO grid point latitude -26.5, longitude 141.95 located within the Project area (Figure 4.1).

Climate statistics are presented in Table 4.1. A distinct wet season and dry season rainfall pattern can be observed, with highest rainfall occurring between January and March whilst the driest period occurring between May to October (Figure 4.2). Mean minimum and maximum monthly temperatures range from 7.2°C in July to 39.4°C in January, respectively. Evaporation data shows highest evaporation during the summer months (November to January), while the lowest evaporation occurs during the winter months (May to August).

Table 4.1 Climate Statistics for SILO Point -26.50, 141.95

Statistic Element	Site: -26.50, 141.95			
	Mean Monthly Maximum Temp (°C)	Mean Monthly Minimum Temperature (°C)	Mean Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
Period of Record	Jan 1985 to Feb 2025			
January	39.4	25.5	28.4	403.7
February	37.6	24.3	27.7	325.1
March	35.2	21.7	31.6	307.7
April	30.5	16.8	14.5	218.8
May	25.2	11.9	10.2	146.3
June	21.3	8.3	11.0	103.5
July	21.3	7.2	13.1	116.8
August	24.1	8.8	8.1	166.3
September	28.6	13.1	8.0	233.4
October	32.7	17.1	10.1	314.0
November	35.5	20.7	23.4	346.5
December	38.0	23.6	18.2	399.4
Monthly Average	**30.8**	**16.6**	**17.0**	**256.8**
Annual	**-**	**-**	**175.9**	**3081.5**

Figure 4.2 presents daily rainfall between 1985 and 2024 for the SILO point location rainfall station, and a cumulative rainfall excess / deficit (CRD) trend for the same period. CRD trends present a running deviation of long-term actual rainfall against the average. This provides seasonal-scale identification of trends (wet / dry) and longer term (e.g., decadal) deviation from

average conditions. These trends result in a natural tempering of peaks for rainfall events and therefore support the correlation of rainfall events to aquifer responses.

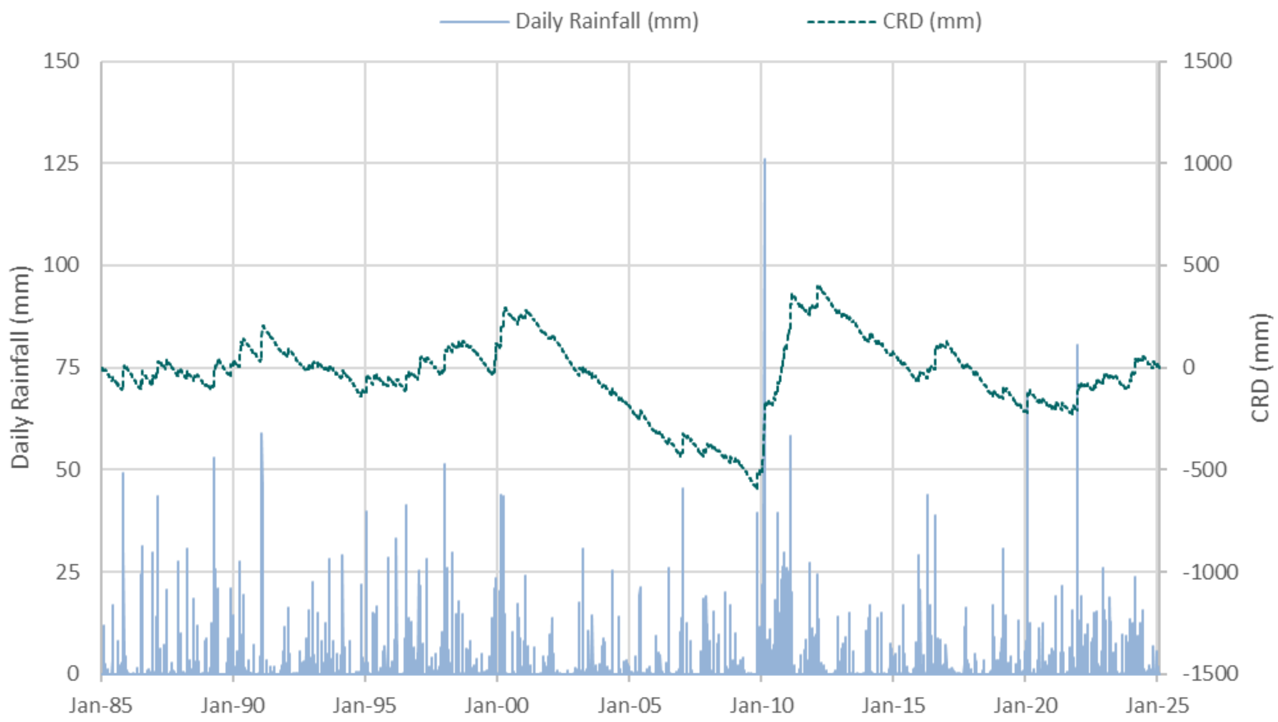

Figure 4.2 Rainfall and CRD – 1985 to 2025 for SILO Point Lat: -26.5, Long: 141.95)

Observations from the rainfall / CRD trend include:

- The overall rainfall trend is characterised by the cyclic nature of the wet and dry seasons, with a generally stable CRD trend from 1985 to 2000.
- Below average rainfall as represented by a decreasing CRD trend is observed from 2000 to 2009 is. The highest rainfall was recorded in 2010 at 126 mm.
- Below average rainfall conditions were observed again from 2012 to 2021 prior to resuming an upward CRD trend from 2022 to present.

5 REGIONAL GEOLOGY AND HYDROGEOLOGY

5.1 Geology

The surface geology of the Project area as shown in Figure 5.2 is dominated by Quaternary alluvium deposits associated with the flood plains, consolidated sediments of the Glendower and Marion Formations (Tertiary), or Winton Formation (Cretaceous).

The Eromanga Basin (the largest sub-basin within the Great Artesian Basin (GAB)) underlies the Quaternary alluvium in the Project area. The Eromanga Basin extends beneath a large portion of Queensland, South Australia, New South Wales and the Northern Territory.

The GAB is underlain by several older sedimentary basins, of which the Permian-age Cooper Basin is one example. A regional conceptual cross section through the GAB and underlying older sedimentary basins is shown in Figure 5.1. Layers within the Eromanga Basin represent the major aquifers and aquitards of the GAB. The stratigraphy of the Eromanga and Cooper Basins is presented in Figure 5.3.

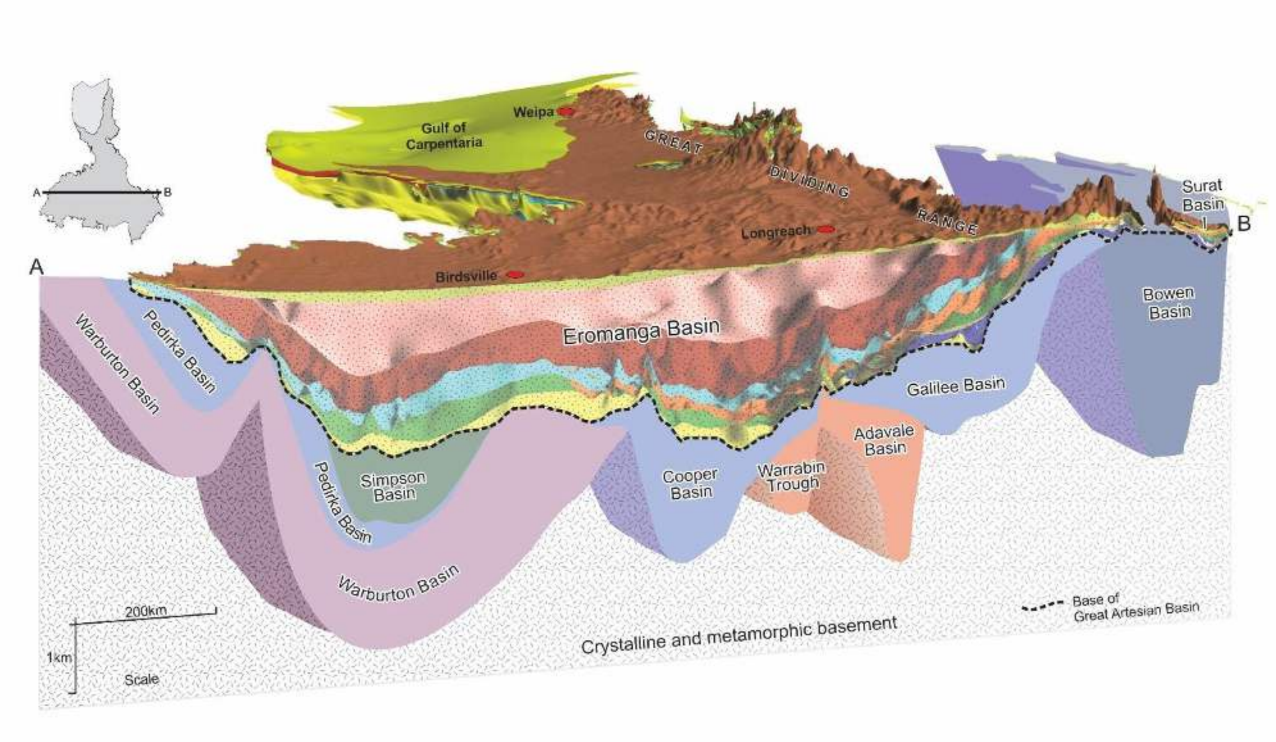

Figure 5.1 Conceptual Cross Section through the GAB and Underlying Basins (reproduced by Geoscience Australia from Smerdon et al) (Smerdon et al. 2012)

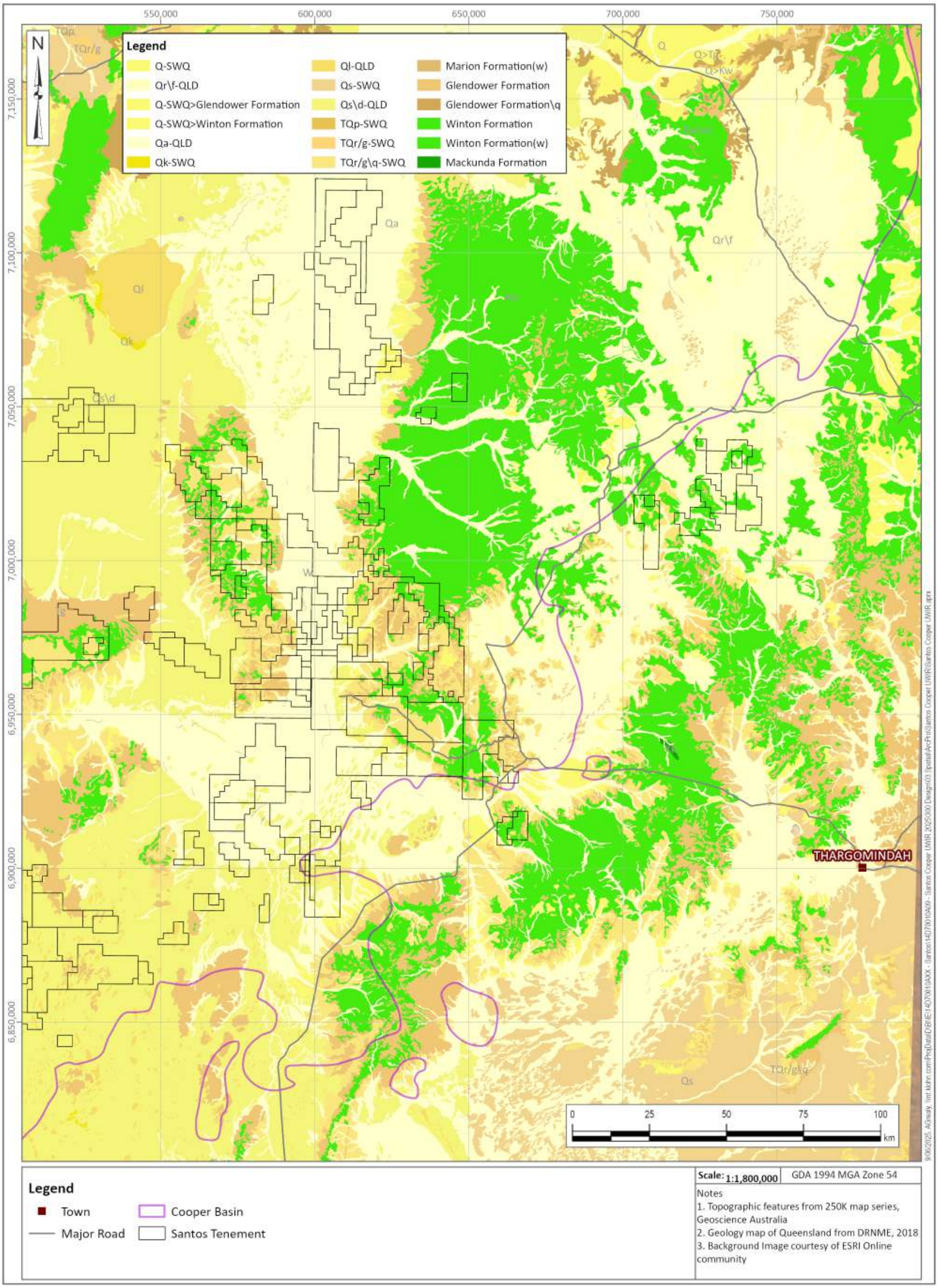

Figure 5.2 Surface Geology Map

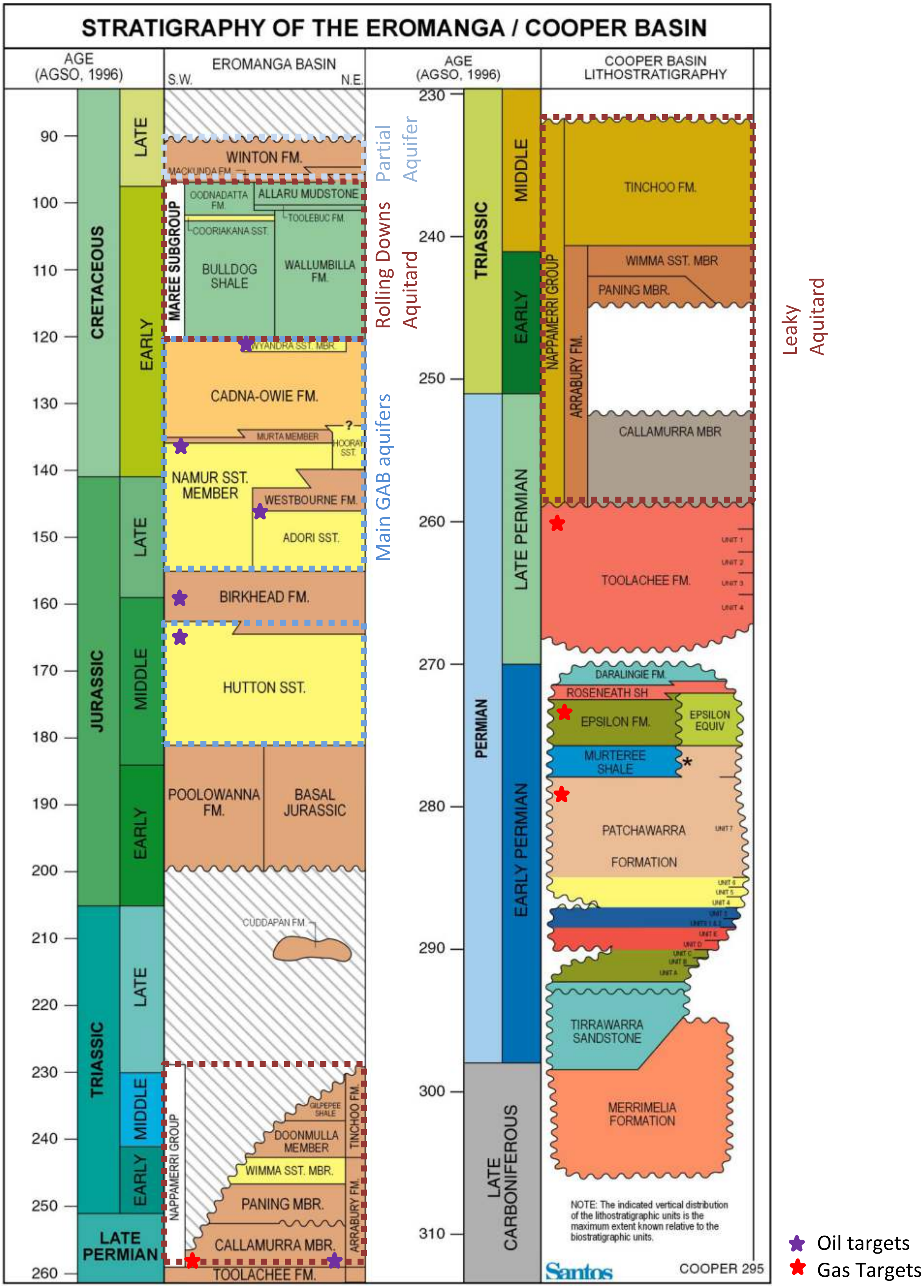

Figure 5.3 Regional Stratigraphy in the Cooper and Eromanga Basins

5.1.1 Cooper Basin

The Cooper Basin is of Carboniferous-Triassic age and occurs at depths of approximately 1,000 to 4,500 m below ground level.

The Cooper Basin is divided into North Eastern and South Western regions with different structural and sedimentary histories and are separated by northwest-southeast trending ridges associated with the Jackson-Naccowlah-Pepita Trend. Each region is further divided into discrete troughs / depressions and ridges / anticlines as shown in Figure 5.4.

The key source rocks for conventional petroleum resources are the coals and coaly shales of the Patchawarra and Toolachee Formations which extend from southeast to northwest across the northern part of the Project area. The Epsilon Formation and Roseneath and Murteree Shales also represent key source rocks, but their distribution is limited to the southeastern extent of the Project area as are dominantly situated within South Australia. The Roseneath Shale and Murteree Shale represent regional aquitards, acting as a geological traps to the Epsilon and Patchawarra Formations reservoirs, respectively (Geoscience Australia 2016).

The Nappamerri Group is generally regarded as a major basin wide seal to the underlying Gidgealpa Group due to the occurrence of basal mudstone and siltstones in the Arrabury Formation. The Arrabury Formation should be considered as a leaky seal with notable oil and gas accumulations being found within sandstone units due to the upward migration from the Gidgealpa Group through faults and conduits (Geoscience Australia 2015).

Refer to Figure 7.12 for a visual conceptualisation of the Cooper Basin, its associated troughs, and the Eromanga Basin (discussed in the next section).

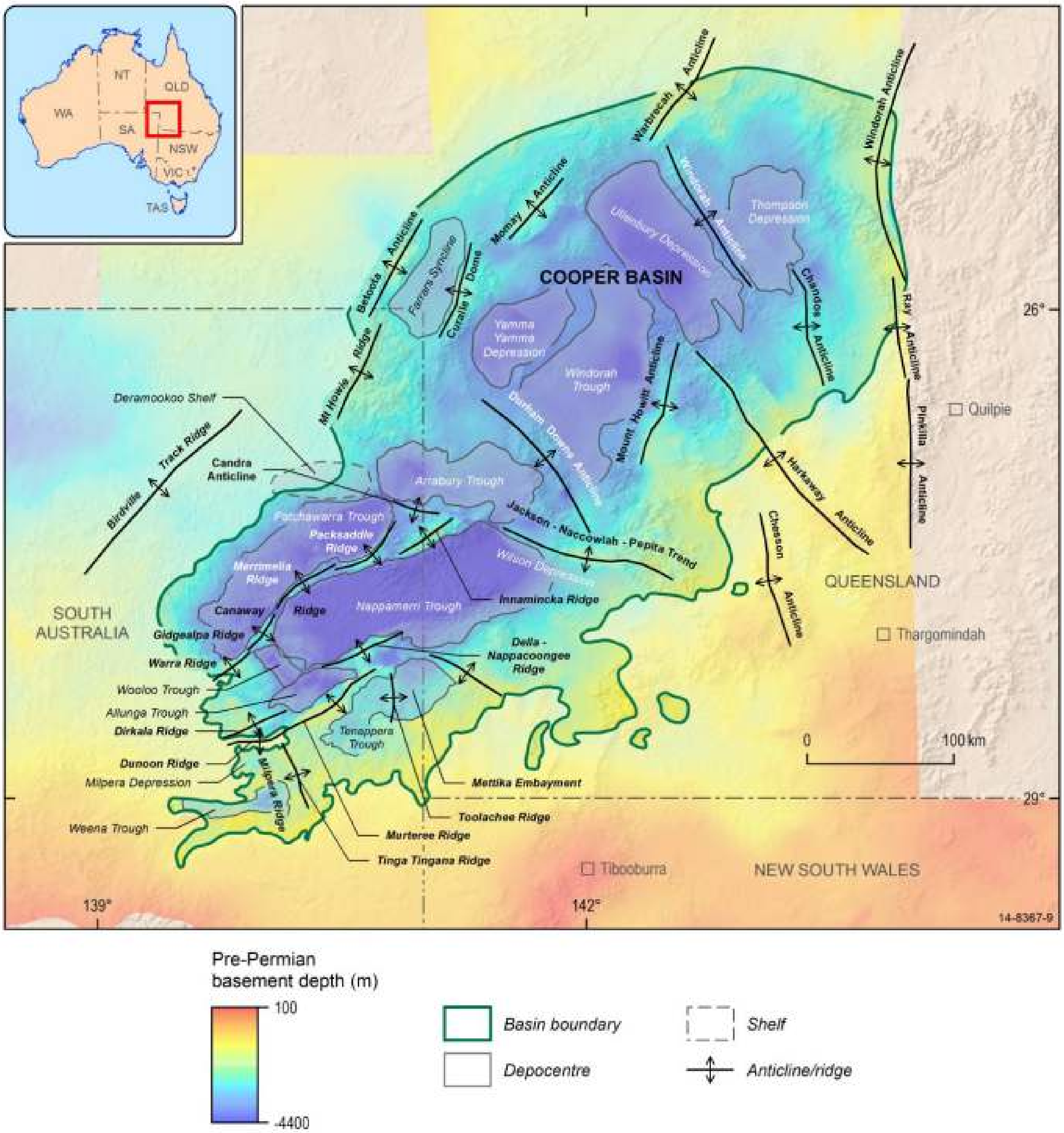

Figure 5.4 Structural Features in the Cooper Basin (Geoscience Australia 2015)

5.1.2 Eromanga Basin

The Eromanga Basin covers the entirety of the Cooper Basin and varies in thickness from around 1,000 m (near the Cooper Basin margins) to 2,800 m (over the Cooper Basin depocentres) (Owens et al. 2020). The hydrostratigraphic equivalents of these lithostratigraphic units (Figure 5.3) form a sequence of aquifers and aquitards that comprise a part of the GAB (Ransley and Smerdon 2012).

For some formations of the Eromanga Basin the lithology can vary considerably, making a simplified lithological based categorisation on a regional basis difficult. Broadly, the GAB aquifer sequence in the Eromanga Basin consists of the following (from oldest to youngest):

- Predominantly artesian GAB aquifers, of which the most widely utilised is the Cadna-owie–Hooray aquifer and equivalents;
- The Rolling Downs aquitard; and
- The sub-artesian Winton-Mackunda partial aquifer.

The Cadna-owie Formation, Murta Formation, Hooray, Namur and Algebuckina Sandstones constitute the uppermost, predominantly artesian, GAB aquifer sequence. Due to depth constraints of the deeper GAB aquifers, these units are predominantly the main artesian GAB aquifers utilised in the Cooper Basin region and are interpreted to be the source aquifer for some of the artesian GAB springs in the Eromanga Basin to the east of the Cooper Basin (Evans et al. 2020).

The Rolling Downs Group comprises a thick basal aquitard and upper unconfined partial aquifer. The aquitard, termed the Rolling Downs aquitard (Ransley et al 2015) consists of the Wallumbilla and Toolebuc Formations, Allaru Mudstone, Bulldog Shale, Coorikiana Sandstone and Oodnadatta Formation. The Coorikiana Sandstone forms a thin, discrete aquifer along the South Western margin of the Eromanga Basin, and is considered to be a source aquifer for some springs near the western margin of the Cooper Basin region (Keppel et al. 2016).

The sub-artesian Winton-Mackunda partial aquifer is the uppermost GAB aquifer system and is visible on the surface geology map provided in Figure 5.2. A partial aquifer is defined by Evans et al. 2020 as a permeable geological material with variable groundwater yields that are lower than in an aquifer and range from fair to very low yielding locally. Unlike the artesian GAB aquifers, this aquifer is in generally not confined by a regional aquitard. This aquifer is an important source of water for the Cooper Basin region due to its shallow depth and lower costs of drilling compared to deeper artesian GAB aquifers (DNRM 2016).

5.2 Hydrocarbon Trapping Mechanisms

The primary characteristics of unconventional and conventional reservoirs as described by Haines et al. (2024), are shown in Figure 5.5. In conventional reservoirs, petroleum—whether oil, gas, or both—typically overlies water, with minimal fluid mixing. In contrast, unconventional reservoirs contain fluids that are homogeneously mixed, and reservoir conditions tend to be continuous across large spatial areas.

In a conventional setting buoyancy causes petroleum - typically migrating from deeper source rock units - to migrate upwards. Its vertical movement is halted by low-permeability geological features that act as seals, trapping the fluids within structural and/or stratigraphic traps. Conventional oil and gas production targets these concentrated accumulations and does not require depressurisation of the reservoir through groundwater removal to enable production.

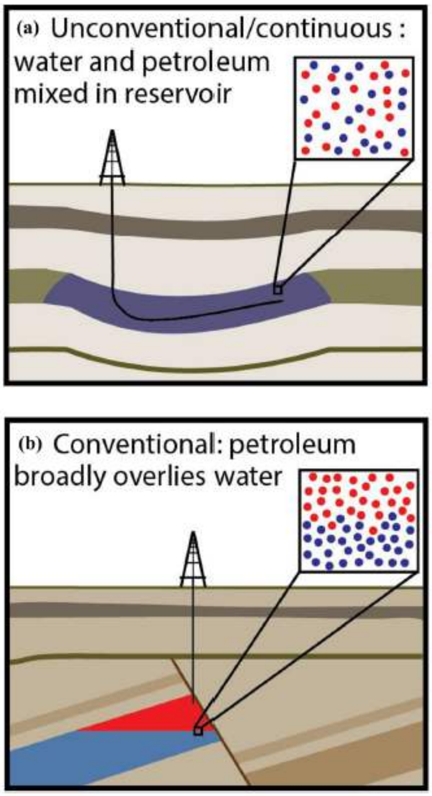

Figure 5.5 Primary Characteristics of Idealized Unconventional and Conventional Petroleum Reservoirs (Haines, S.S., Varela, B.A., Tennyson, M.E. et al 2024)

5.2.1 Cooper Basin

Economic oil and gas in the Nappamerri Group are hosted in reservoir sands, with the majority of mudrocks in this unit forming a regional seal to the Cooper Basin. Intra-formational shale and coals form local seals in the major reservoir units. Underlying the Daralingie Unconformity are two important early Permian regional seals - the Roseneath and Murteree Shales. The Roseneath Shale is the top seal of the Epsilon Formation and the Murteree Shale seals the Patchawarra Formation. Anticlinal and faulted anticlinal traps in the Cooper Basin have been relied on as proven exploration targets in the Cooper Basin, however there is potential for discoveries in stratigraphic and sub-unconformity traps in the basin, especially where the Permian sediments are truncated by the overlying Eromanga Basin succession.

5.2.2 Eromanga Basin

Trapping mechanisms in the Eromanga Basin are predominantly structural, with a minor stratigraphic component (e.g. Hutton–Birkhead transition, Poolowanna facies, McKinlay Member and Murta Formation). Seals consist of intraformational siltstones and shales of the Poolowanna, Birkhead and Murta Formations.

Where these units are absent, potential seals higher in the sequence include the Bulldog Shale and Wallumbilla Formation (SA DPI, 1998).

6 PART A: UNDERGROUND WATER EXTRACTION / INJECTION

6.1 Oil Production: Areas of Production and Target Beds

Oil is extracted primarily from the GAB formations within the Eromanga Basin at depth averaging 1,000 m below ground level. At the time of this UWIR, there are approximately 251 producing oil wells within Santos SWQ tenements.

Details on the geology of the Eromanga Basin is presented in Section 5.1.2.

The stratigraphic units that host the major oil include:

- The Murta Formation and the Namur Formation: these are the upper and lower formations of the Hooray Sandstone. Oil reservoirs are not frequent in the Namur Formation (a sandstone) but more abundant in the Murta Formation (interbedded mudstones, siltstones and fine-grained sandstones).
- The Birkhead Formation: the Birkhead Formation comprises interbedded siltstone, mudstone and fine sandstone. Oil reservoirs are mostly present in the basal strata of the Birkhead Formation, while some reservoirs are found in the middle Birkhead Formation.
- The Hutton Sandstone: this is the main extraction unit for oil over the Santos tenements in SWQ.

Minor oil reservoirs are also found in other formations in the Project area, including:

- The Wyandra Sandstone Member: this is the upper formation of the Cadna-Owie Formation; however, oil occurrence is not frequent.
- The Westbourne Formation and the Adori Sandstone.

Figure 5.3 summarises the occurrence of major oil reservoir through the stratigraphic profile.

6.2 Gas Extraction: Areas of Production and Target Beds

Gas is extracted primarily from the formations of the Cooper Basin. Details on the geology of the Cooper Basin is presented in Section 5.1.1.These major gas reservoirs are hosted within:

- The Toolachee Formation.
- The Epsilon Formation.
- The Patchawarra Formation.

These reservoirs are porous sandstone formations separated by finer grained siltstones and mudstone formations (refer to detailed stratigraphy in Figure 5.3 also showing major gat targets). As discussed, the finer grained siltstones and mudstone formations are typically referred to as the seal or cap rock beds located over the reservoirs.

At the time of this UWIR, there are approximately 183 producing gas wells within Santos SWQ tenements.

The deep geological setting, and water quality, of the gas targets prohibits access by domestic and municipal users.

6.3 Associated Water

Water is produced as a co-product of oil and gas operations in the Project area. This is referred to as associated water. The volume of associated water depends on a number of factors including (but not limited to) the type of well (i.e. oil well versus gas well), the hydrocarbon formation and the age of the well. By comparison, gas wells generate smaller volumes of water than oil wells.

Santos currently (2024) operate 251 oil wells and 183 gas wells in the Project area. This is a decline in the number of producing wells reported in the 2022 SWQ UWIR, where 257 oil wells and 258 gas wells were anticipated to be operational.

The historical total water production rates for Santos SWQ operations are provided in Figure 6.1 and Table 6.1. The decline in annual water production can be attributable to the reduced number of producing wells and the typical production profile, which features decreasing water volumes as the project matures.

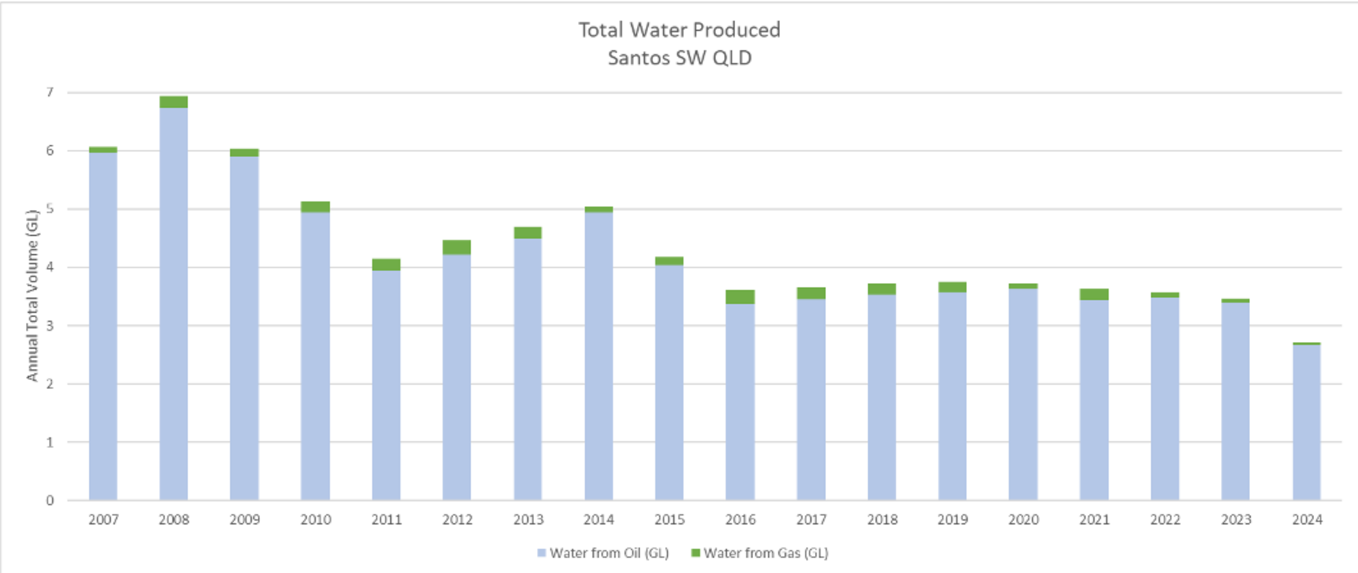

Figure 6.1 **Annual Total Estimated Water Production Rates for Santos SWQ Operations**

Table 6.1 Annual Total Estimated Water Production Volumes for Santos SWQ Operations by Basin

Year	Water from Cooper Basin (GL)^	Water from Eromanga Basin (GL)^	Total (GL)
2007	0.1	6.0	6.1
2008	0.2	6.7	6.9
2009	0.1	5.9	6.0
2010	0.2	4.9	5.1
2011	0.2	3.9	4.1
2012	0.2	4.2	4.5
2013	0.2	4.5	4.7
2014	0.1	4.9	5.0
2015	0.1	4.0	4.2
2016	0.3	3.4	3.6
2017	0.2	3.5	3.7
2018	0.2	3.5	3.7
2019	-	-	3.8
2020	-	-	3.7
2021	0.2	3.4	3.6
2022	0.1	3.5	3.6
2023	0.1	3.4	3.5
2024	0.04	2.7	2.7

^Co-produced water is not taken directly from aquifers within the Cooper or Eromanga Basins.

The methodology for monitoring associated water as a result of oil operations is described in Section 10.2.2.

6.3.1 Associated Water Monitoring – Oil

Associated water abstracted through oil production equates to approximately 4 GL/annum. This is considered a reasonable approximation of actual volumes based on the premise that the total volume for each well is recorded at two points i.e. a known gathering point and a fiscal metering point (Figure 6.1). Historical water production for oils and gas is presented in Figure 6.1.

6.3.2 Associated Water Monitoring – Gas

The volume of associated water as part of Santos' gas operations is estimated based on the average water content of the gas produced.

The certainty around the volume of water produced as a result of gas production is lower than that for oil. However, gas production via conventional methods accounts for only approximately 3.5% of the total volume of water produced (Figure 6.1). As a result, small variations in estimated versus actual produced volumes will not have a material impact on the overall drawdown calculations.

6.4 Methodology for Predicting Future Water Extraction

For the purposes of predictive modelling of the Eromanga and Cooper Basins, historical extraction data was used to estimate future extraction rates, taking into account an allowance for planned new wells within existing petroleum leases and also development of new leases. The history of activities in the Cooper and Eromanga Basins demonstrate an overall declining trend in water production rates (Figure 6.1). Assuming the water production rates (on a per well basis) do not decline over time is a conservative approach for estimating future produced water volumes, and therefore for assessing the depressurisation impact on groundwater. Current water production rates are likely to decline in the future, based on the observed long-term trend, resulting in potentially lower depressurisation effects than predicted by the method.

The methods used to determine these rates for both the IAA and LTAA periods for both the Eromanga and Cooper Basins are detailed below. For the purposes of predictive modelling:

- The water production rate from the last year of available historical data (2024) was used to represent future water production rates. The average annual water production rates from an oil well (mostly from the Eromanga Basin) were calculated by dividing the total water produced from oil wells by the number of oil wells. The average water produced per oil well is 29.61 m^3/day. The same was undertaken for the water produced from gas wells (mostly from the Cooper Basin) to obtain an average annual water production rate per gas well. The average water produced per gas well is 0.66 m^3/day;
- The number of oil and gas wells per petroleum lease area are multiplied by the average rates calculated above, to determine the distribution of water extraction spatially and between the Eromanga and Cooper Basins;
- For the purposes of assessing the IAA the current (2024) distribution and count of wells for each petroleum lease area were used. This equated to an annual water production of 0.04 GL/annum (3 year period = 0.24 GL total) from the gas wells in the Cooper Basin and 2.7 GL/annum (3 year period = 9.6 GL total) from the oil wells of the Eromanga Basin for the three IAA years; and
- For the purposes of LTAA, a long-term representative total extraction per lease was calculated using Santos' plans for the number of future wells (2025–2040) along with the count of existing operational wells in each petroleum lease area.

6.5 Water Flooding

Water flooding comprises the injection of water into the oil reservoir in order to restore and maintain pressure and enhance production (Golder Associates 2013b).Water flooding is being undertaken at Cuisinier, Cranstoun, Mulberry, Gimboola, Talgeberry and Endeavour fields (in ATP299P) with the objective of enhancing oil recovery by maintaining pressure in the Birkhead and Murta oil reservoirs and improving sweep efficiency[2]. Where water flooding is undertaken, water for the water flooding is sourced from treated produced water at the Tarbat treatment plant (Golder Associates 2013b).

The risks associated with water flooding activities comprise the risk of creating inter-formation hydraulic connection, degrading water quality of the receiving aquifer and over-pressurising the receiving aquifer. A risk assessment for water flooding was undertaken by URS (2010), which identified that the risks from water flooding were low. Risk management procedures for water flooding include adherence to the water flooding design, well integrity and effective management and monitoring of the water flooding program (Golder Associates 2013b).

[2] Sweep efficiency is the measure of effectiveness of an enhanced oil recovery process that depends on the volume of the reservoir contacted by the injected fluid.

Water flooding has been ongoing since 2014. Historical data shows the highest annual water injection volume recorded in 2014 (2.2 GL/annum). A steady decline was observed until 2018 (0.7 GL/annum) before increasing until 2022 and remaining stable at ~1.4 GL/annum from 2022 to 2024.

Water flooding is not represented in the UWIR groundwater analytical modelling. This increases the level of conservatism in the drawdown prediction.

7 PART B: AQUIFER INFORMATION AND UNDERGROUND WATER FLOW

7.1 Aquifer / Aquitard Hydraulic Properties

Intra-formational seals/aquitards can be identified in the Cooper Basin region with some units acting as regional seals or barriers to hydrocarbon migration from the deep oil and gas plays to the near surface environmental assets (Keppel et al. 2016). Due to the layered nature of the deposition environment, some degree of horizontal hydraulic conductivity can be expected in most of the hydrostratigraphic units. Some vertical heterogeneity can be conceptualised in the basin on a regional scale, but realistically virtually no vertical flow of oil, gas or water is expected near the conventional oil and gas traps associated with the Santos exploration and development. This will be a function of rock permeability, fluid viscosity and density as well as temperature.

The stratigraphic composition of the various formations with depth demonstrates limited hydraulic connectivity between the oil and gas target zones (stressors) and the overlying surficial groundwater systems and groundwater dependent ecosystems (GDEs).

The Rolling Downs aquitard sequence exhibits lateral continuity across the basin, with an average thickness of approximately 310 m and hydraulic conductivity values as low as 3×10^{-9} m/day. In the central-western region of the basin, the thickness of this low-permeability unit exceeds 970 m. Owing to its hydraulic properties—particularly its relatively uniform thickness across the basin—this unit is classified as a regional aquitard, with substantially lower hydraulic conductivity compared to overlying formations. While the potential for faulting to disrupt the aquitard's continuity and act as a conduit for vertical leakage from deep aquifers to shallower systems has been conceptually considered (Evans et al., 2020), published studies indicate limited evidence of such processes occurring, and thus this mechanism is not regarded as significant.

Dillinger et al. (2016) reported that the Hutton Sandstone within the Nappamerri Trough exhibited reduced hydraulic conductivity due to the presence of diagenetic clays (kaolinite and illite) combined with silica cementation. These factors contributed to anomalously low flow rates, even for a hot sedimentary aquifer targeted for geothermal development in the region. Furthermore, Evans et al. (2020) noted that horizontal groundwater flow in artesian GAB aquifers becomes nearly stagnant where these units directly overlie the Cooper Basin depocentres.

The thick siltstones of the Nappamerri Group can be regarded as an aquitard, acting as a regional seal to vertical gas migration at the centre of the Cooper Basin. However, the Nappamerri Group is heterogeneous and comprises various lithofacies and consequently contains both leaky aquitards and some aquifers. In addition, this unit abuts against basement highs, which in combination with faults could possibly create preferential pathways for vertical fluid migration on its boundaries (Evans et al. 2020). Only literature-based indirect hydraulic conductivity data is available for this unit, showing that porosity and hydraulic conductivity reduces with depth due to burial compaction and pore volume reduction (Evans et al. 2020). Areas where potential connectivity between the Cooper Basin and Eromanga Basin may exist (where the Napamerri Group and Gidgealpa aquitards are absent) along the edges of the Cooper Basin are shown in Figure 7.1.

A review of available hydraulic conductivity parameter based on literature values for aquifers in the vicinity of the site was conducted by Golder (Santos 2019b) as presented in Table 7.1. Limited to no information was presented for aquitards.

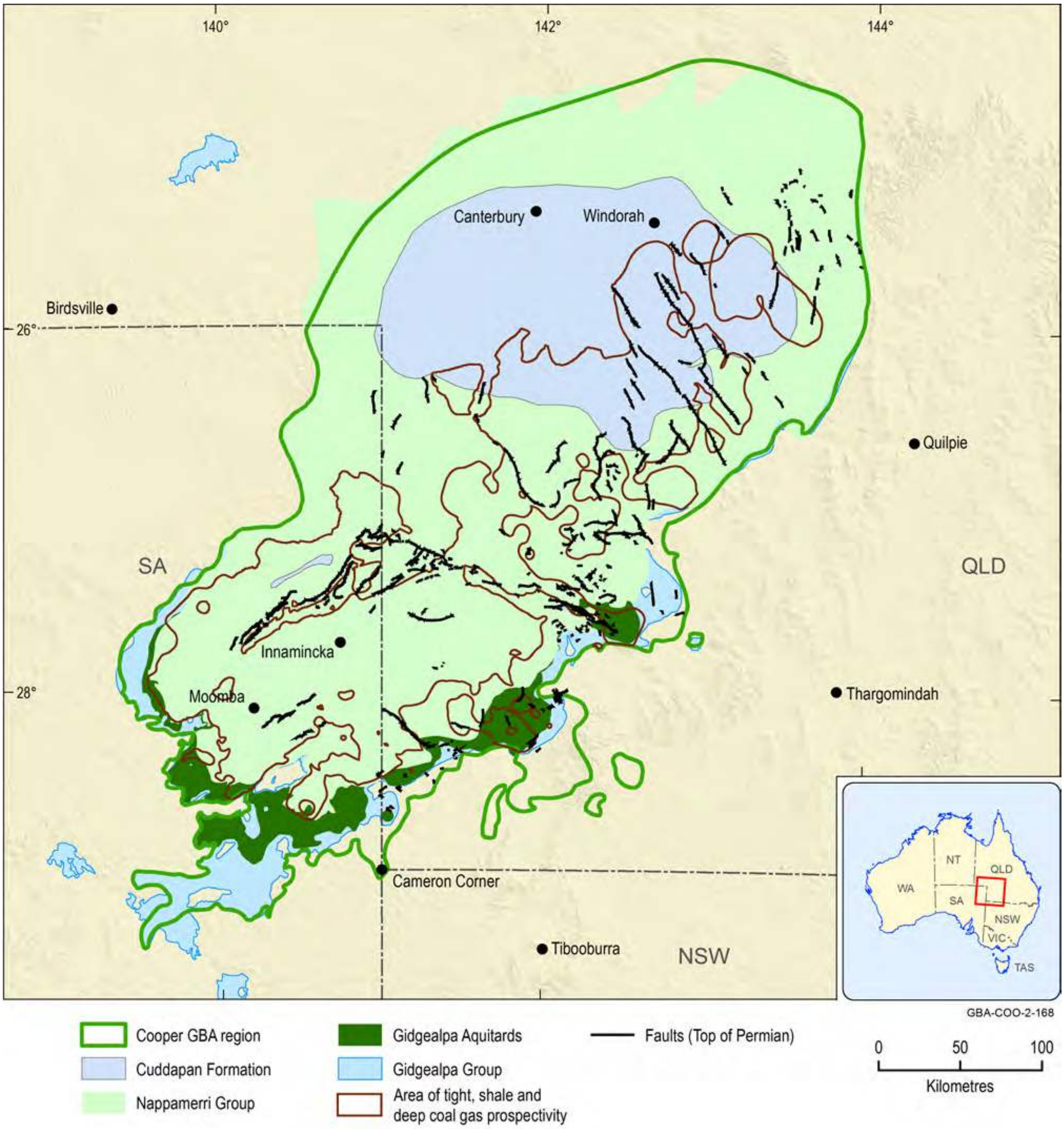

Figure 7.1 **Potential Connectivity across the Cooper Basin – Eromanga Basin (Evans et al. 2020)**

Table 7.1 Hydraulic Parameters for Hydrostratigraphic Units in the Vicinity of the Project Area

Basin	Formation	Hydraulic Conductivity (m/d)		Porosity (%)
		Min	Max	
Eromanga Basin	Hooray Sandstone	4.3×10^{-4}	4.3×10^{-1}	
	Westbourne Formation, Adori Sandstone and Birkhead Formation	8.0×10^{-7} [2]	2.5×10^{-4} [2]	0.2 [2]
	Hutton Sandstone	3.5×10^{-1}	9.8×10^{-3}	
	Poolowanna Formation	1.0×10^{-7} [2]	3.7×10^{-3} [2]	0.18 [2]
Cooper Basin	Toolachee Formation	2.0×10^{-3} [1]	4.3×10^{-3}	0.15 [1] 0.08 to 0.12[3]
	Patchawarra Formation	3.3×10^{-4} [1]	3.5×10^{-3} [1]	0.13 [1] 0.08 to 0.12[3]
[1] Gov. of South Australia, Primary Industries and Resources, SA. Petroleum and Geothermal in South Australia – Cooper Basin, 2009 (PIRSA 2009).				
[2] Alexander, E.M., Reservoirs and Seals of the Eromanga Basin (1996).				
[3] Santos.				

7.2 Registered Groundwater Bores

A total of 2,352 groundwater bores registered under the Water Act (‘registered water bores’) are identified within the Project area. The locations of these bores together with their facility type is presented in Figure 7.2.

Of the 2,352 registered groundwater bores:

- 523 bores identified as destroyed and abandoned;
- 368 bores identified as petroleum or gas exploration bores;
- 27 bores identified for monitoring use (CSG, GAB, and mine use);
- 270 water supply bores; and
- 1,164 bores with no facility role specified.

7.2.1 Groundwater Use and Purpose

Of the 2,352 registered bores in the Project, a total of 1,802 may be considered potential water supply bores (Figure 7.3).

This includes oil and gas exploration wells that may have been converted to water supply bores, and the remaining registered bores that do not have information regarding the facility role.

Groundwater abstraction within the Project area provides a water source for the pastoral industry, population centres, mining activities, and other extractive industries. Most bores target shallow aquifers in the Winton-Mackunda partial aquifer and Cenozoic aquifers, as these aquifers are relatively shallow when compared to the artesian GAB aquifers. However, the relatively small number of groundwater bores (often repurposed petroleum wells) tapping into artesian GAB aquifers provides higher flow rates and suitable water quality for stock watering.

The majority of current groundwater bores (90%) are less than 300 m deep and abstract groundwater from the Winton-Mackunda partial aquifer and Cenozoic aquifers of the Eromanga Basin. There is significant lateral and vertical separation between these shallow aquifers and host stratigraphy of the oil and gas resource. As mentioned, some oil and gas wells have been converted to water bores, providing some overlap of aquifers used for domestic and stock watering.

The hydrostratigraphic units of the Cooper Geological Basin are not used for groundwater supply (Evans et al. 2020).

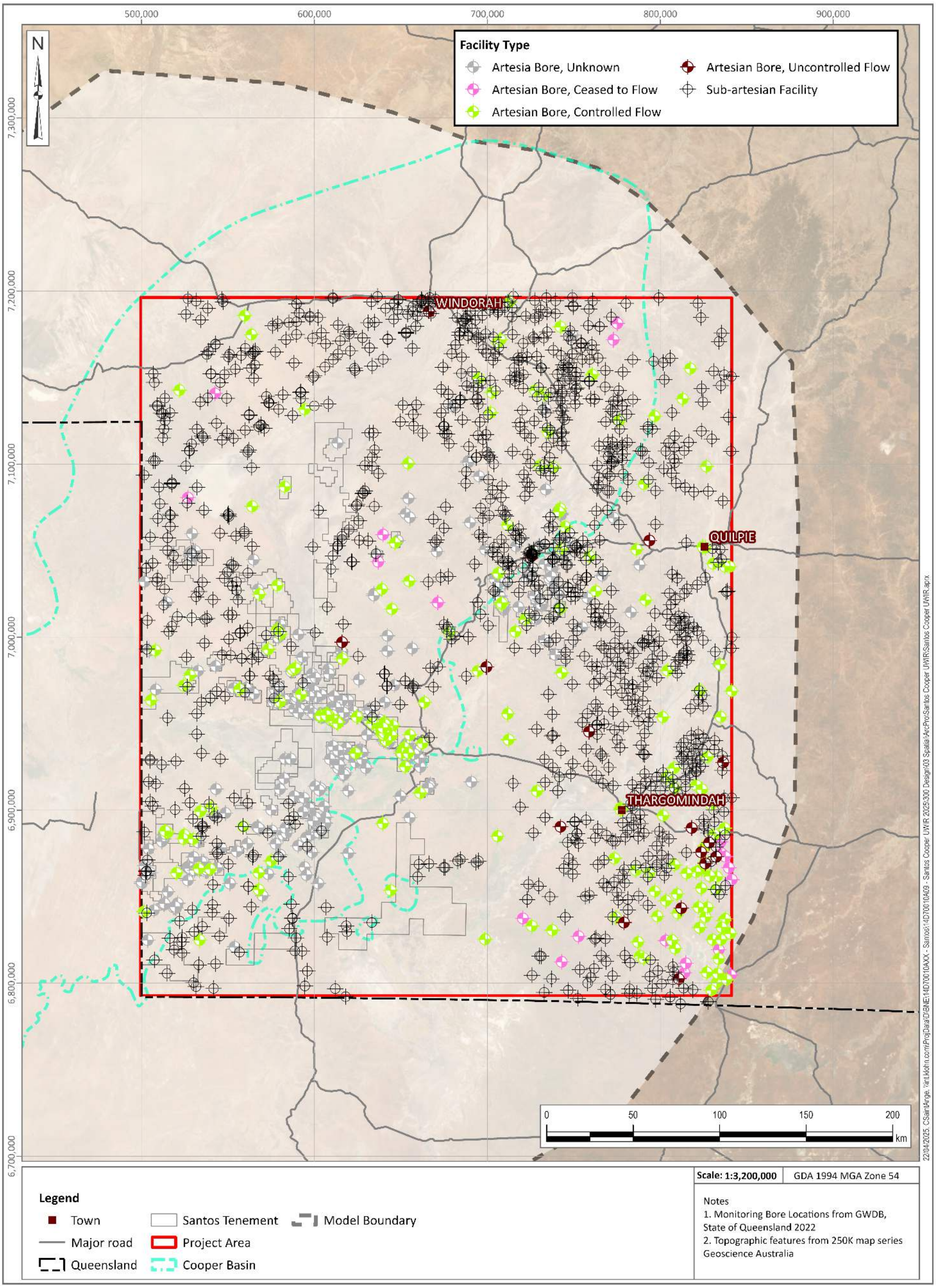

Figure 7.2 Registered Groundwater Bores by Facility Type within the Project Area

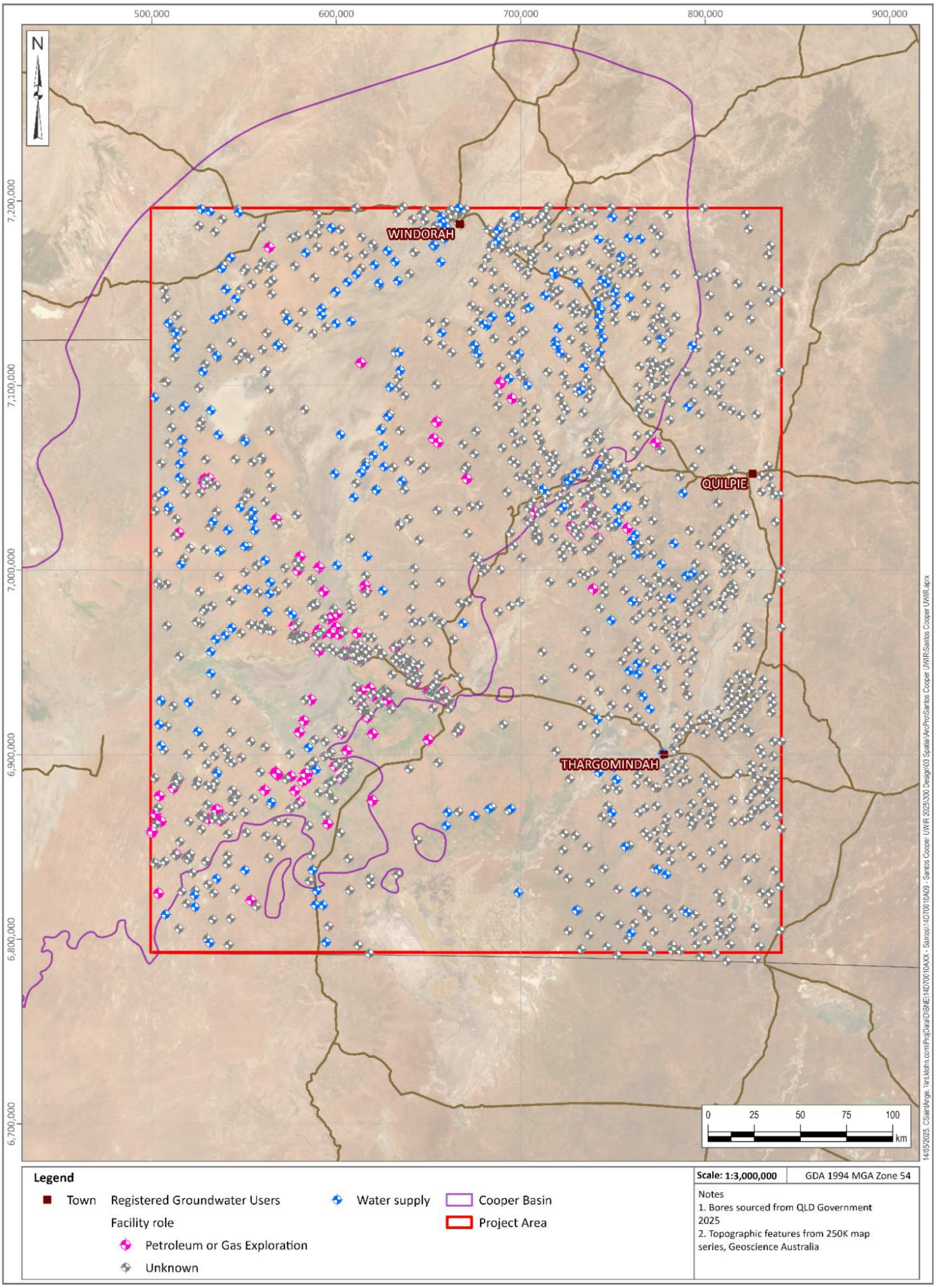

Figure 7.3 Potential Water Supply Bores within the Project Area

7.3 Groundwater Levels, Flow, Recharge, and Discharge

7.3.1 Regional GAB

Primary recharge of the GAB aquifers occurs through uptake at the Eromanga boundary of the system and do not form part of this Project area. Regional groundwater flow is from the east to southwest across the Cooper Region, with potentiometric sinks occurring in South Australia, over the Nappamerri and Patchawarra Troughs. Hydraulic head is highest in the east (greater than 300 mAHD) dropping to 50 to 100 m in western parts of GAB hydrostratigraphic units forming part of the Cooper Region.

While there are broad trends in potentiometric pressures, there is considerable variability across the Cooper Basin, including potentiometric sinks (with sub-artesian hydraulic head pressures) near petroleum fields on the South Western flank of the Cooper Basin. Very high hydraulic heads could be due to the presence of petroleum / hydrocarbons, or to some broader hydrodynamic change such as aquifer compartmentalisation or changes to transmissivity. Overall, the broadly spaced contours suggest sluggish groundwater flow and presence of a groundwater sink, particularly around western portion of the Cooper Basin in South Australia (Evans et al. 2020).

The Rolling Downs aquitard is likely to be acting as a competent aquitard, in part due to the lack of artesian GAB springs and artesian pressures in the Winton-Mackunda partial aquifer (Evans et al. 2020).

7.3.2 Local Eromanga Basin

The Department of Regional Development, Manufacturing and Water (DRDMW) and Santos have undertaken groundwater monitoring within the Eromanga Basin. Relevant monitoring bores are presented in Table 7.2 and Figure 7.4.

Eight (8) historic DRDMW groundwater GAB monitoring locations are located within the Project area, which target Eromanga Basin aquifers (Table 7.2). Water level data is available from 1974 to 2011, but records are limited, and the quality of the data is uncertain.

Santos currently collects water level data from nine (9) monitoring bore locations (Table 7.2), including two historic DRDMW GAB monitoring bores that Santos has assumed responsibility for, as indicated in Table 7.2.

Hydrographs for the representative bores are presented in Figure 7.5 to Figure 7.9 and have been selected based on their proximity to Santos' tenements and the number of data points available for review. It is important to note that except for the Surlow 1 Water Bore, all bores display artesian conditions. Changes in the frequency of water use from these bores over the years, as well as the time elapsed since shut-in, will have an effect on the individual water level readings and trends. Artesian heads from these bores were converted to groundwater elevations (in mAHD) for the hydrographs.

Table 7.2 GAB Monitoring Network - Target Aquifers

RN	Owner	Easting1	Northing1	Formation
358	DRDMW	726181	7048168	Hooray Sandstone
16768	DRDMW	505678	6963605	Hutton Sandstone
22946	DRDMW	521920	7142708	Hooray Sandstone
23233	DRDMW	760843	7151644	Cadna-Owie/Hooray
23059	DRDMW	661145	6909983	Wallumbilla - Hooray Sandstone
23093	DRDMW	756058	7208663	Cadna-Owie /Adori
PPL Coothero 1: 23569	DRDMW / Santos	654269	6932959	Hooray Sandstone
PPL Balooma 1 23372	DRDMW / Santos	737660	7034142	Hooray Sandstone
Challum Spine Road Bore No. 2^	Santos	566004	6968840	Winton-Mackunda
Irtalie 1: 23570	Santos	623669	6932913	Hutton Sandstone
Gordan's Bore: 23361	Santos	727308	7016801	Namur Sandstone
Surlow 1 Water Bore	Santos	595450	6975888	Winton-Mackunda
Supply 1: 23923	Santos	595451	6975889	Rolling Downs Group*
Apollosa 1	Santos	662602	6938778	Namur Sandstone
Ballera West 2	Santos	584523	6893653	Nappamerri Group*

*Target formation either provided/ or inferred from the Queensland Government Open Data Portal.
[1]Datum – GDA94, Zone 54
^unable to measure water level due to sealed headworks

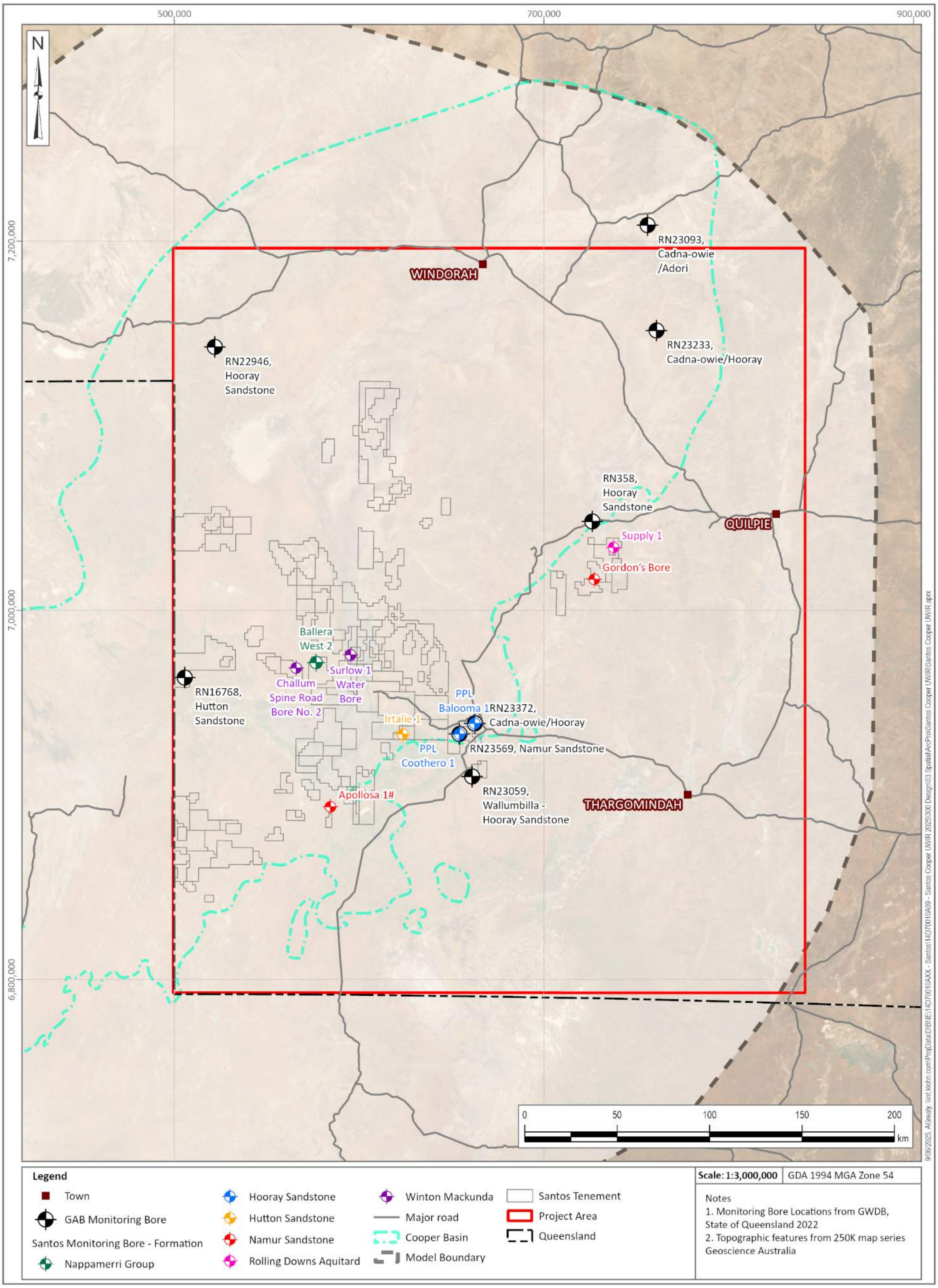

Figure 7.4 Location of Monitoring Bores (GAB and UWIR)

7.3.2.1 Groundwater Levels over the Reporting Period

Groundwater elevation hydrographs for the UWIR monitoring network and the GAB monitoring network from youngest to oldest units are presented in Figure 7.5 to Figure 7.9. The following were observed:

- **Winton-Mackunda Formation**: Water levels in the shallow aquifers are expected to be influenced by the local topography. Overall, regional southwesterly flow towards topographic low points is expected. Monitoring in this partial aquifer is limited and does not indicate a connection between climatic trends. Figure 7.5 shows groundwater levels for the sub-artesian bore Surlow 1 remained stable throughout the monitored period (2014 to 2024), with a total decline of 0.6 m since the start of monitoring in 2014.
- **Rolling Downs Aquitard**: The available data in Figure 7.6 shows a 112 m decline between 1988 to 2002 at RN23059 (an artesian bore with controlled flow), before increasing in 2005 and remaining stable until monitoring ceased in 2012. Piezometric levels at supply 1 appear to reflect the influence of climatic trends. Despite notable variations in the piezometric level during the monitoring period, clear trends are not identified.
- **Main GAB Aquifers:** Figure 7.7 and Figure 7.8 shows the hydrographs for bores screened in the main GAB aquifers. These aquifers reflect notable variations in water levels since 1970.
  - **Cadna-Owrie Formation, Hooray Sandstone, Namur Sandstone:**
    - RN358 displayed increasing piezometeric heads based on five measurements between 1998 until the end of the monitoring period in 2010.
    - PPL Coothero 1 (RN23569) shows a 29 m decline between 2010 to 2014, while PPL Balooma 1 (RN23372) recorded a 38 m increase between 2010 and when Santos commenced monitoring in 2017. Both monitoring bores are controlled flow artesian bores and are currently used as water supply to roadworks and livestock. Piezometric heads have been relatively stable at these two bores over the current reporting period (2022 to 2024) with a slight general decreasing trend noted at PPL Coothero 1.
    - Apollosa 1 shows increasing piezometric heads with an 18 m increase recorded between 2020 and 2024.
  - **Hutton Sandstone:**
    - Figure 7.8 shows a fluctuating but general rising piezometric level in Irtalie 1 since the start of monitoring in 2014. A review of the well pressure measurements indicated the presence of outliers (< 100 mAHD) were recorded when the well pressures were measured while the bore was flowing. Stable groundwater levels were recorded in RN16768 for three monitoring rounds from 2006 to 2012.
- **Nappamerri Group:** Figure 7.9 shows generally stable piezometric heads at Ballera West 2 over the current reporting period (2022 to 2024). Outliers were noted in 2020 and 2021 when the well pressures were measured while the bore was flowing.

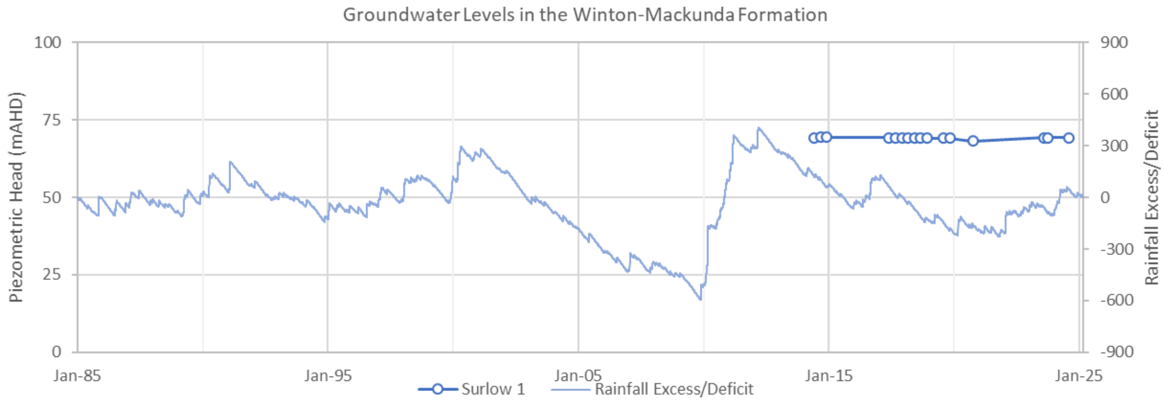

Figure 7.5 Groundwater Elevation Hydrograph – Winton-Mackunda Formation

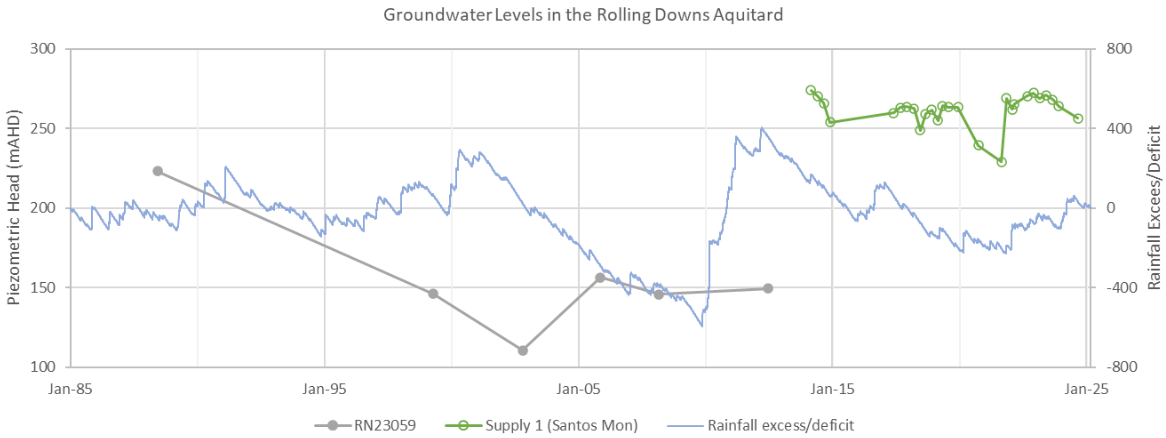

Figure 7.6 Groundwater Elevation Hydrograph – Rolling Downs Aquitard

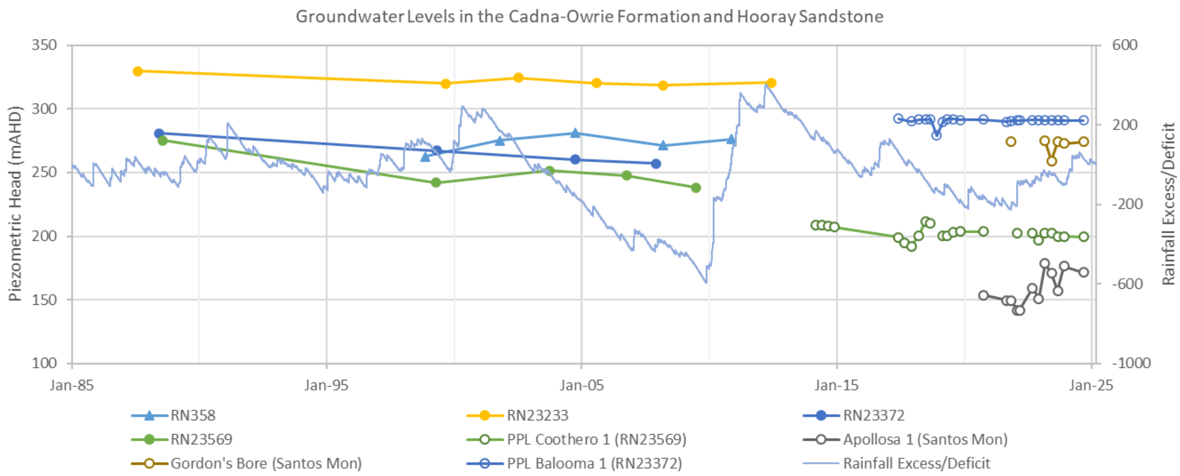

Figure 7.7 Groundwater Elevation Hydrograph – Cadna-Owie Formation and Hooray Sandstone

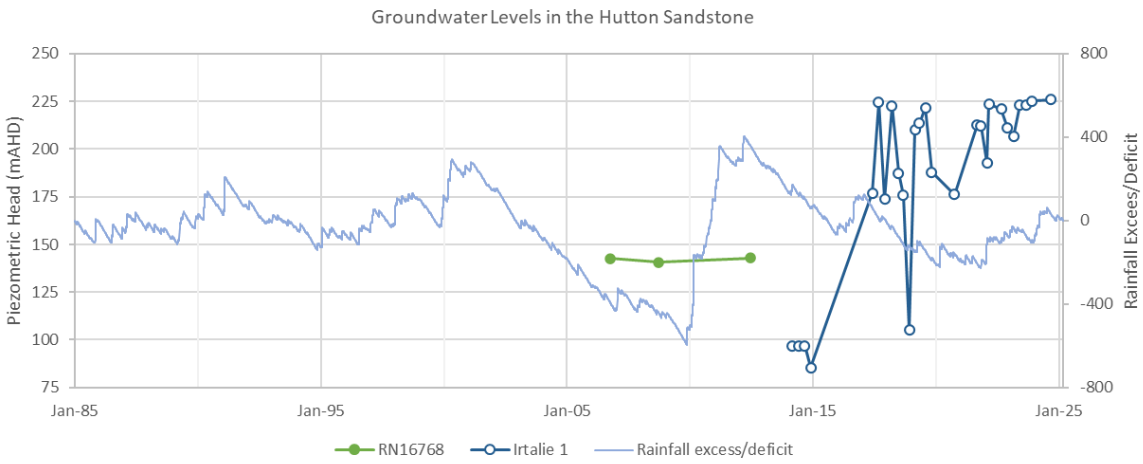

Figure 7.8 Groundwater Elevation Hydrograph – Hutton Sandstone

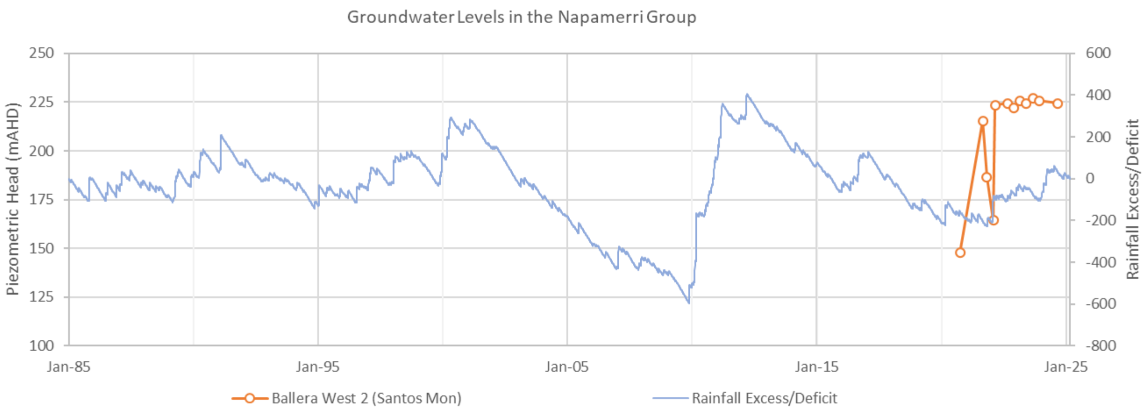

Figure 7.9 Groundwater Elevation Hydrograph – Nappamerri Group

7.3.3 Cooper Basin

There are no available groundwater monitoring data for the Cooper Basin. Final shut-in pressures[3] from petroleum wells for the Santos Cooper operations recorded over a 30-year period (1982 to 2011) (Figure 7.10) demonstrate that pressures in the underlying Toolachee and Patchawarra Formations (Cooper Basin) have higher hydrostatic pressures compared to the Hooray Formation (Eromanga Basin). Final shut-in pressures from formation tests in the Cooper Basin mostly shows higher pressure (right of the line on Figure 7.10) probably due to the presence of petroleum / hydrocarbons (Webster et al. 2000). The low yielding wells (left of the lines on Figure 7.10) show depleted pressure. The data suggests that formation pressures do not vary significantly with time. The difference in pressures for each of the formations also suggest that the Cooper Basin formations are not connected vertically with the overlying Eromanga Basin in the areas where the Santos gas exploration are conducted.

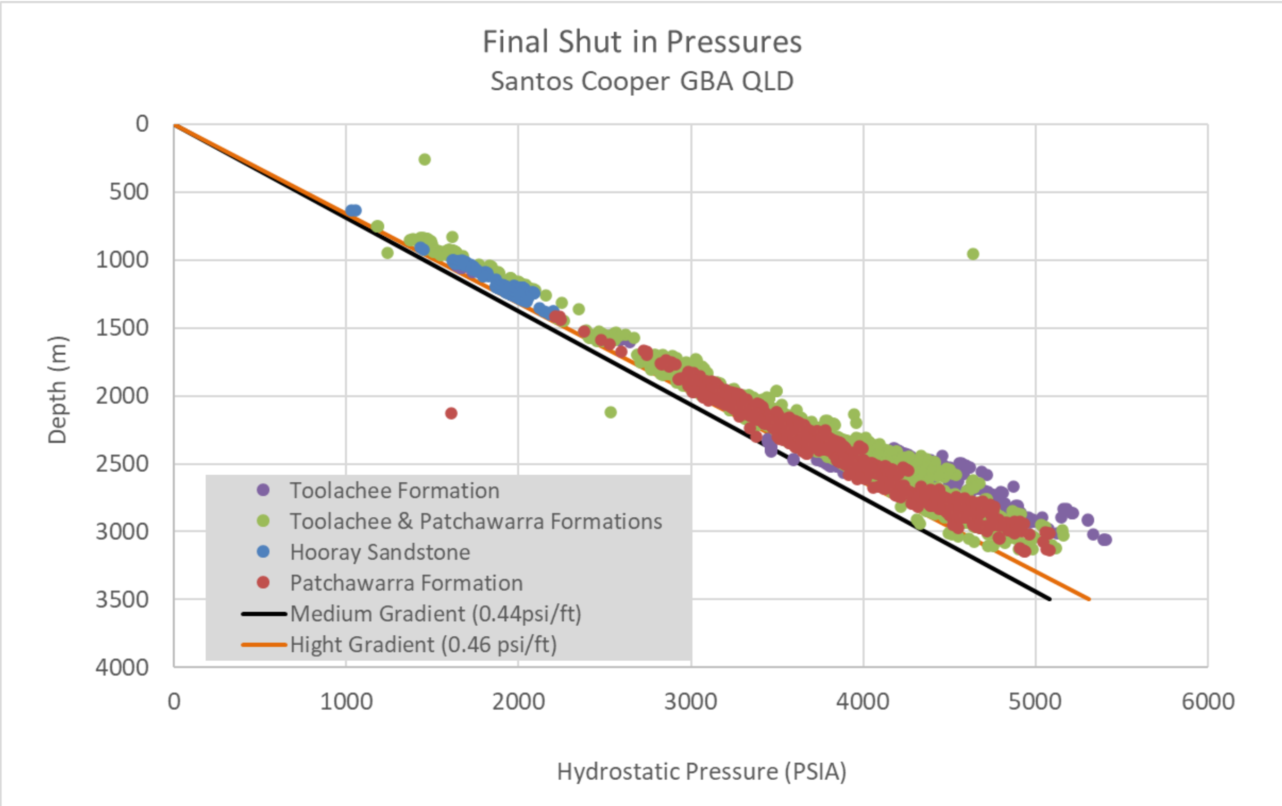

Figure 7.10 Final shut-in pressures from formation tests in Cooper Region

[3] Shut-in pressure is the pressure exerted by water in an artesian aquifer when confined (Santos 2019b).

7.4 Groundwater Chemistry

Evaluation of the major ionic and isotopic constituents of groundwater can provide an indication of the source of water (i.e. from which aquifer formation it comes) and the potential for interaction between different hydrostratigraphic units (i.e. communication or mixing of waters due to recharge or discharge).

Piper diagrams provide a graphical representation of the ionic proportions of water and allows for classification based on the relative major ion composition. The dominant ions in groundwater collected from the Project area are sodium, bicarbonate and chloride. The corresponding water types can be described as either sodium-bicarbonate or sodium-bicarbonate-chloride (Figure 7.11).

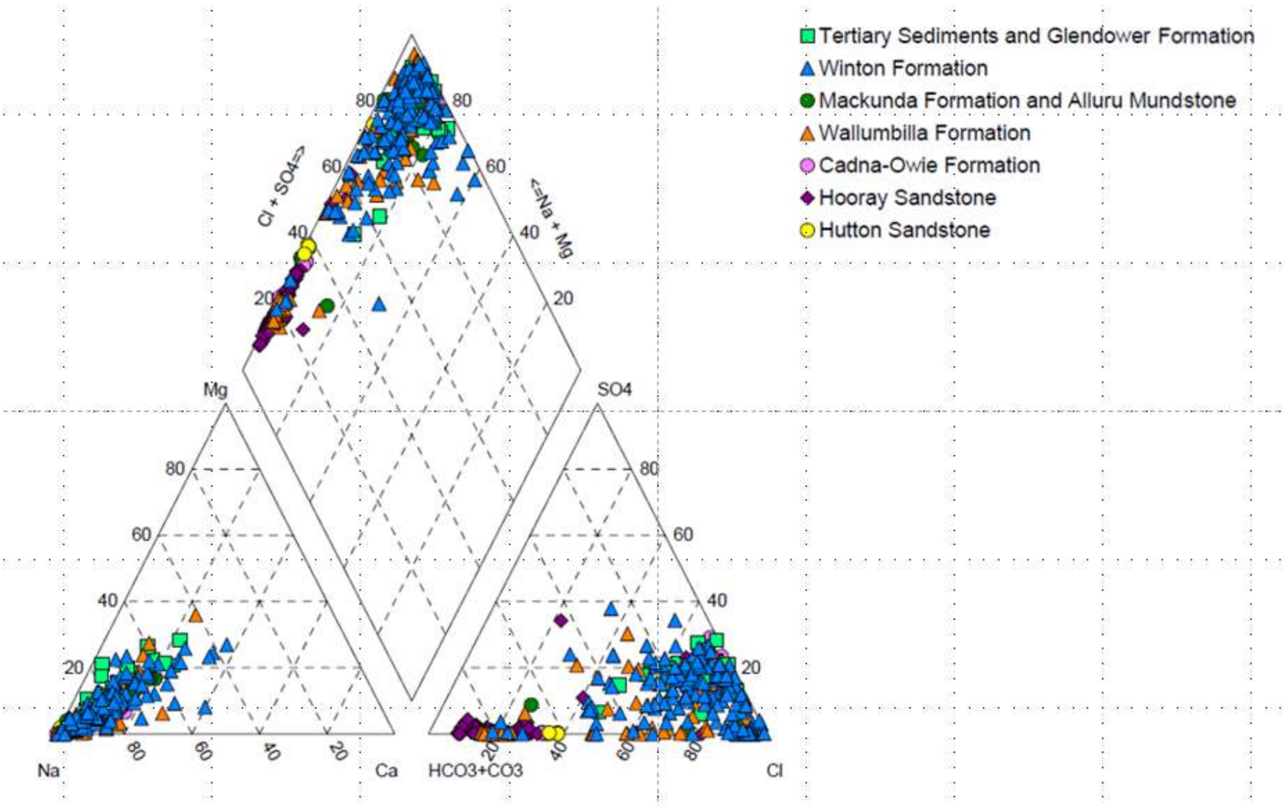

Figure 7.11 Piper Diagram of Groundwater Collected within the Project Area

The shallow Cenozoic aquifer shares some similarities in groundwater type with some groundwater in the Winton-Mackunda partial aquifer and the Winton Formation. The Piper diagram also shows that Cenozoic groundwater hydrochemistry is distinct from the artesian GAB aquifers. An apparent trend from the Na+K vertex towards the centre of the cation subplot, and anions dominated by chloride (Cl) with highly variable contents very little sulfate (SO_4), results in a cluster near the top right of the central diamond.

Environmental tracers, such as chlorine-36 (^{36}Cl), have been used to characterise aquifer processes and estimate the age of groundwater in artesian GAB aquifers (Evans et al. 2020). High ^{36}Cl values are present in the major recharge zones of the artesian GAB aquifers, decreasing towards the central portions of the aquifer in the Cooper GBA region, (Ransley et al 2015) and with depth (Hasegawa et al. 2016).

The present artesian groundwater flow directions in the GAB have been in place for at least one million years based on ^{14}C, ^{36}Cl and noble gas studies (Ransley and Smerdon 2012). Near-stagnant groundwater flow in the central Eromanga Basin has been inferred from ^{36}Cl and ^{4}He data (Radke et al. 2000)(Ransley and Smerdon 2012), which suggests that the groundwater could be in excess of 1 million years old. Vertical leakage or cross-formational flow occurs at undetermined rates but is presumed to be significant over timescales of thousands to millions of years (Evans et al. 2020).

7.4.1 Groundwater Quality over the Reporting Period

Groundwater sampling and analysis were conducted quarterly and reported annually for the UWIR monitoring network with locations presented in Figure 7.4.

The water quality analysis results are detailed in the annual groundwater monitoring reports (LBWco 2023; 2024; 2025), and observations for key analytes are summarised in Table 7.3.

Temporal plots of available monitoring data are presented in Appendix I.

Table 7.3 Summary of Water Quality Results (2022-2024)

Screened Unit	pH	Electrical Conductivity	TDS	Major Ions	Dissolved Metals
Winton-Mackunda Formation	Neutral to slightly alkaline	Slight increasing trend in Surlow 1 (32,000 to 35,000 mg/L) from Q3 2023 to Q3 2024); Stable in Challum Spine Bore 2	Slight increasing trend in Surlow 1 (>20,000 mg/L)	Slight increasing trend in Cl, Mg, and Na in Surlow 1 since 2023	Slight increase in Cu, Va in Surlow 1 since Q4 2023
Hooray Sandstone	Neutral to slightly alkaline	Fluctuating within historical limits	Fluctuating within historical limits	Fluctuating within historical limits	Stable; outliers recorded at PPL Coothero 1 for Cu in 2022 (0.4 to 0.6 mg/L)
Hutton Sandstone	Neutral to slightly alkaline	Stable	Fluctuating within historical limits	Fluctuating within historical limits	Slight increasing trend in Cu in 2024

LBWCo (2023; 2024; 2025) reported the following analysis of groundwater monitoring trends:

- Water pressure measurements in most artesian wells showed no evidence of consistent decline when compared to historical data. Apollosa 1 (Namur Sandstone) and Irtalie 1 (Hutton Sandstone) show rising water levels since the start of monitoring in 2014 with an approximately 30 m increase during the 2022 to 2024 monitoring period.
- Concentrations of key analytes, in both artesian and sub-artesian wells, showed no evidence of significant change from historical ranges (where data was available) except for copper. As discussed, elevated dissolved copper concentrations were attributed to the use of a copper cooling coil during sampling since 2020 and are not considered to represent the actual groundwater conditions.
- A review of available bore data indicates that artesian bores in the UWIR monitoring network are suspended petroleum bores that were converted into monitoring and groundwater supply bores (it is noted that no bore installation details are available for

Gordon's Bore). TRH is expected to be detected in converted petroleum bores and has been recorded at concentrations up to 27 mg/L (maximum TRH C10-C36 concentration recorded in Apollosa 1 in November 2021).

- Groundwater monitoring data does not indicate significant impacts to have occurred to the unconsolidated and consolidated aquifers.

7.5 Conceptual Model Summary

The Cooper GBA Program Stage 2 (Evans et al. 2020) considered various sources of data (including data from Santos) to compile an up-to-date conceptual model for the Cooper Basin incorporating the Cooper–Eromanga Basin hydrocarbon system. The conceptual model proposed by Evans et al. (2020) (Figure 7.12) is summarised below:

- The Cooper Basin contains gas reservoirs occurring at significant depths in depocentres such as the Patchawarra, Nappamerri and Windorah troughs. These gas reservoirs are separated from the Eromanga Basin aquifers (e.g. the Hutton Sandstone aquifer) by the Nappamerri Group.
- Due to the layered nature of the deposition environment, limited vertical flow of gas or water is expected near the conventional gas traps associated with the Santos exploration and development. There are potential for connectivity between the Eromanga and Cooper Basins where the Nappamerri Group do not cover the deeper formations completely towards the edges of the Cooper Basin.
- Primary recharge of the Eromanga Basin occurs on the boundary of the system and does not form part of this Project area. Regional groundwater flow is from the northeast to southwest across the Cooper GBA region towards regional topographic low points (e.g. Lake Blanche). The artesian Hutton aquifer, forming part of the Eromanga Basin, is one of the main target areas for oil development for Santos.
- The limited GAB water level data (1974 to 2009) shows no basin wide trends in the Cooper GBA region. Isotopic data suggests that these artesian pressures have been in place for at least a million years. The Rolling Downs aquitard prevents upward vertical leakage between the artesian Hutton aquifer, towards the sub-artesian Winton-Mackunda partial aquifer. Technical investigations suggest that there is no, or only a very limited connection between the GAB and the overlying (Quaternary, Tertiary and Cenozoic) aquifers. Groundwater from regional GAB aquifers is not conceptualised to notably contribute to surface water / GDE systems.
- GAB springs do not occur in the Cooper GBA region.
- Episodic flooding of losing streams in the parts of the Cooper Creek floodplain contributes recharge to shallow aquifers in the Cenozoic and Winton-Mackunda partial aquifer, forming freshwater lenses in the vicinity of some large near permanent waterholes. Groundwater from regional aquifers is not conceptualised to contribute to surface water.
- Most bores target shallow aquifers in the Winton-Mackunda partial aquifer as these aquifers are relatively shallow when compared to the artesian GAB aquifers.

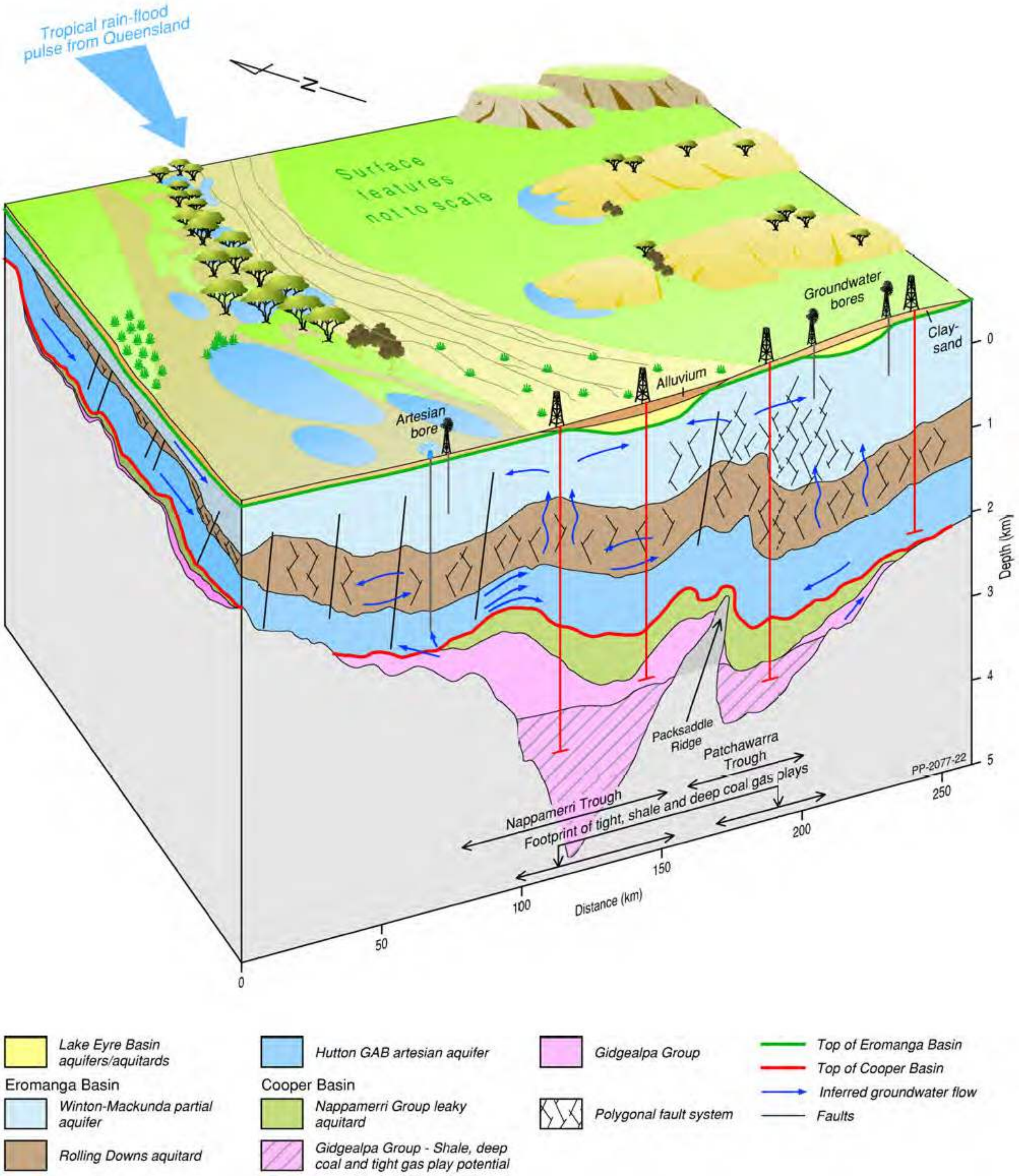

Figure 7.12 Conceptualisation of Cooper and Eromanga Basins (Evans et al. 2020)

8 PART C: PREDICTED WATER LEVEL DECLINES FOR AFFECTED AQUIFERS

8.1 Groundwater Model

8.1.1 Model Code Selection

Analytical groundwater modelling has been undertaken to provide estimates of the decline in groundwater level/pressures in response to the extraction of co-produced water as a result of the Project development. The modelling platform adopted for the prediction of groundwater level/pressure changes in this UWIR is the same platform adopted for the 2013, 2016, 2019 and 2022 UWIRs, which have been previously approved by the regulatory authorities. Improvements made in the 2022 model setup were retained for this UWIR.

The analytical modelling platform adopted for the Project is Analytical Aquifer Simulator (AnAqSim release 2024-2-3 January 2025) (Fitts Geosolutions 2025), a pre- and post-processing package that uses analytic elements for the simulation of groundwater flow. AnAqSim (Fitts Geosolutions, LLC) employs high-order line elements, spatially-variable area sinks, and specified time steps to allow simulation of multi-level aquifer systems and wide-ranging flow simulations.

In the analytical element method (AEM), boundaries of the domain are discretised, but the domain itself is not. The AEM is fundamentally different than numerical methods like finite elements and finite differences, where the domain is distributed into small blocks or elements with simple head distributions (e.g. linear) assumed within these blocks or elements.

AnAqSim employs the AEM, which superposes analytic solutions to yield a composite solution consisting of equations for head and discharge as functions of location and time. The AEM is described in detail in Strack (1989) and Haitjema (1995).

AnAqSim uses a variation of the AEM that allows the model domain to be divided into subdomains, each with its own definition of aquifer parameters. Each subdomain model is written in terms of two-dimensional functions, with three-dimensional flow simulated using multiple layers in a model. In multi-level models, the resistance to vertical flow is accounted for in the vertical leakage between levels. This subdomain approach allows for a high degree of flexibility with respect to a model's heterogeneity, anisotropy and layering.

Like any flow model, the flow equation in AnAqSim is based on Darcy's Law and conservation of mass (and volume, with constant density). The conservation equation, in its simplest form is:

$$-\nabla Q = \gamma = L_t + L_b + S\partial h/\partial t$$

where ∇Q is the divergence of the two-dimensional aquifer discharge vector field and γ is the net extraction per area (sink term, units of L/T). The sink term γ may have contributions from leakage out the top of the subdomain (L_t), leakage out the bottom of the subdomain (L_b), and transient discharge/area into storage ($S\partial h/\partial t$).

In many practical cases, the model needs spatially-variable extraction (γ varies with x, y) due to spatially-variable vertical leakage and/or spatially-variable storage changes. When that is the case, the model needs spatially-variable area (SVA) sinks to approximate the proper distribution of γ. The spatially-variable area sink functions in AnAqSim create a smooth, continuous and irregular γ surface within a subdomain.

8.1.2 Model Dimension

The groundwater model was developed in three-dimensions (3D) in order to simulate groundwater movement in both the horizontal and vertical planes. This is particularly important in the vicinity of the oil and gas wells where the co-produced water is expected to flow towards the well laterally, as well as potentially from the hydrostratigraphic units above and below the producing unit. Furthermore, the conceptual model identified that more than one overlying hydrostratigraphic unit above the producing unit, therefore, the incorporation of the horizontal flow of these individual units, and the vertical flow between adjoining units, is required for the model domain.

8.1.3 Time Discretisation

Calibration simulations were completed to steady state conditions. The available datasets do not provide useful time series data for a transient calibration. The calibration was therefore undertaken using a multiple steady state approach where the model parameters were tested against a series of basin development phases where data for calibration is available in a specific area of the basin.

This is regarded as conservative considering:

- Regional artesian pressures in the Eromanga Basin expected to be relatively consistent over large time scales, which is confirmed by the available time series data (Section 7.3.2).
- Artesian pressures in the Cooper Basin are reported to be present over time scales of thousands of years (Section 7.3.3).

Predictive simulations were simulated in steady state conditions, which is considered a conservative approach for predicting a maximum drawdown.

8.1.4 Model Layers

The compilation of the AEM using the AnAqSim graphic user interface facilitated the construction of the model domain, as well as vertical geometry provided for each of the 3D layers (Table 8.1). The AnAqSin platform allows for a 2D layer where mostly horizontal flow is expected, with the possibility to defining 3D areas where vertical flow might be important. For the Cooper GBA system both 2D and 3D aquifer units were defined in the model to represent the near horizontal flow in the regional GAB hydrostratigraphic units, and potentially vertical gradients in the Cooper GBA region respectively.

Layers 1, 2, 3 and 4 of the model interacts on its boundaries with the outer 2D layer (numbered as Layer 2), which is conceptually represented in Figure 8.1.

Table 8.1 Model Layers and Vertical Discretisation

Label	Level	Domain Type	Top Elevation (mAHD)	Bottom Elevation (mAHD)
Eromanga Ecological Inner 3D	1	confined/unconfined	170	-300
Eromanga 2D Boundary	2	confined/unconfined	170	-2300
Eromanga Inner 3D	2	confined	-300	-1000
Eromanga Rolling Downs Aquitard	3	confined	-1000	-1800
Eromanga GAB Aquifers and Oil Extraction	4	confined	-1800	-2300
Cooper Nappamerri Aquitard	5	confined	-2300	-2800
Cooper Gas Extraction	6	confined	-2800	-3300
Deep Cooper Below Gas	7	confined	-3300	-4500

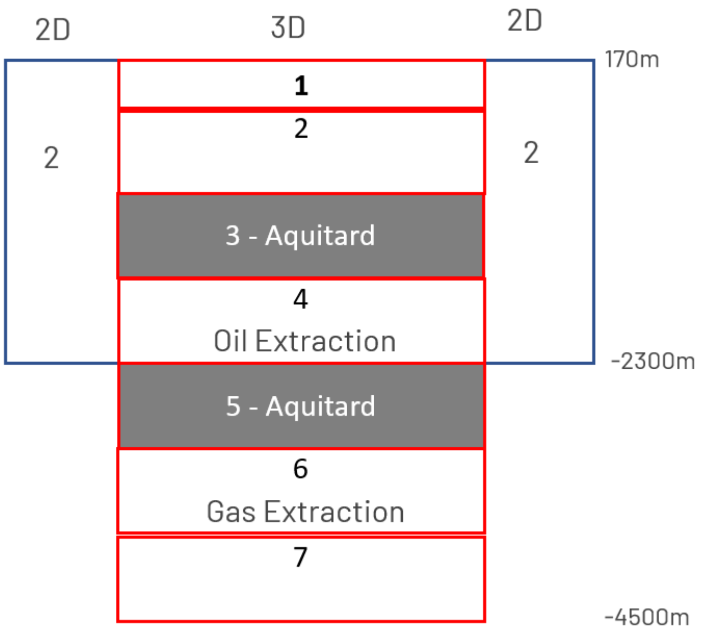

Figure 8.1 Conceptual Representation of Groundwater Model Layers

The layered stratigraphy of the two basins overlying each other allows for this simplified numerical simulation to represent the system's key behaviour and assessing the potential impacts of the deep oil and gas development on the shallow aquifers. The regional GAB hydrostratigraphic units are represented by the 2D outer layer. The model interaction with the regional GAB flow field is achieved via specified head and specified flux boundaries. These boundaries are presented in Figure 8.2.

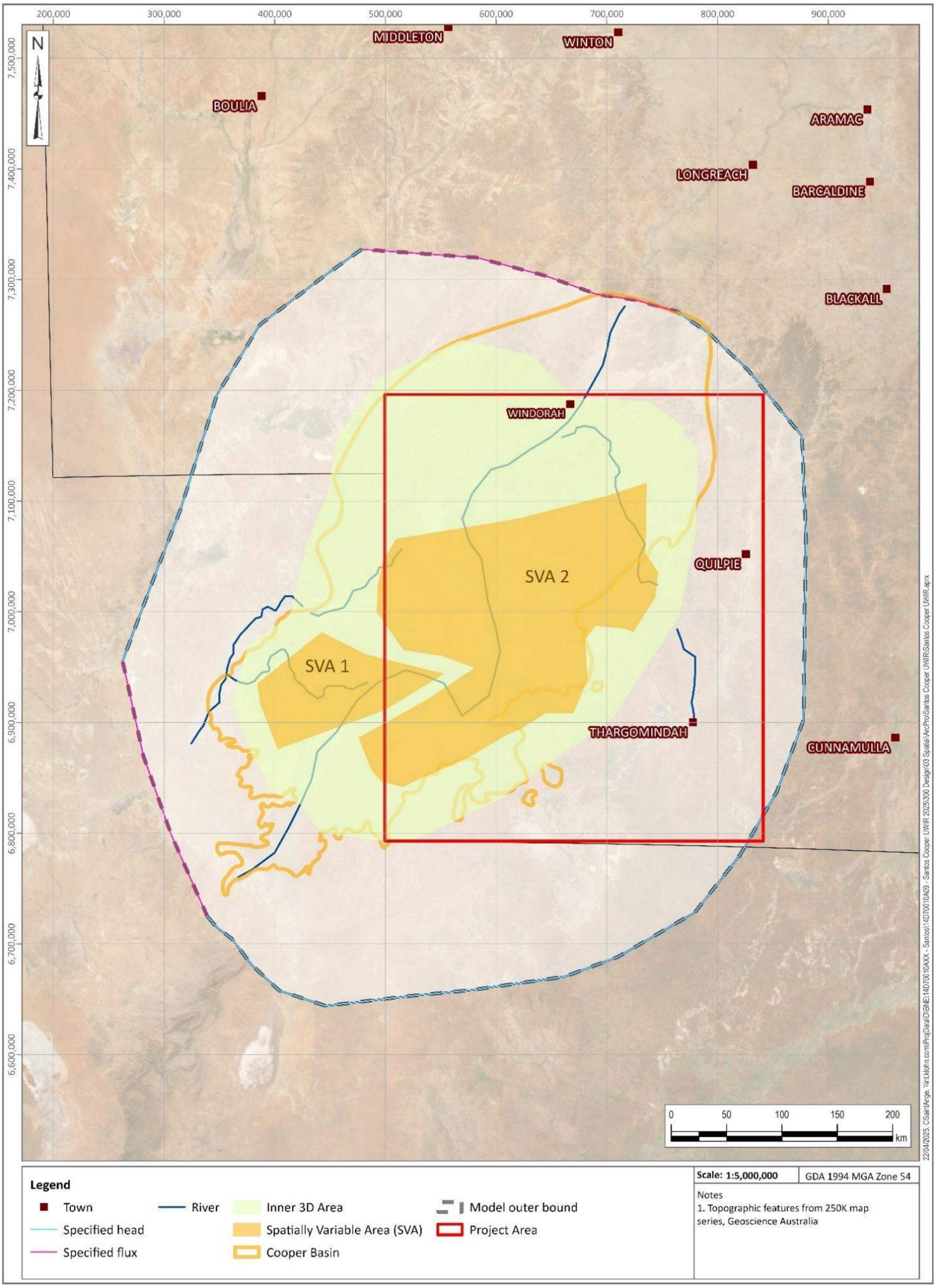

Figure 8.2 Groundwater Model Boundary Conditions and SVA Vertical Flow Computation Areas

8.1.5 Model Extent and Boundary Conditions

A suitably larger model domain was selected in order to mitigate any influence that the boundary conditions may have on the modelling outcomes. For the purpose of this assessment, the boundary conditions were selected to represent the regional processes in the Eromanga and Cooper Basin as realistic as possible, while allowing for the current and future oil and gas well placements of the SWQ operations at the appropriate target depths. Only the SWQ component of the Santos operations are assessed in this model. The predictions of the potential impacts of the current and proposed operations will therefore only be applicable to the SWQ area. Predicted impacts on the Cooper Basin within South Australia is not expected to change the impacts predicted in Queensland due to the reported compartmentalisation and limited vertical connectivity expected between the deep oil and gas resources and the shallow aquifer systems.

Boundary conditions represent the hydrogeological setting of a model domain by establishing flux conditions along the boundary and the associated hydraulic head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions. Boundary condition options in AnAqSim can be specified either as:

- Specified head or Dirichlet; or
- Specified flux or Neumann boundary conditions.

Conceptually, it was essential to meet three criteria as part of the modelling process:

1. Define the appropriate model boundaries for both the Eromanga and Cooper Basins by natural geological and hydrogeological boundary conditions;
2. Allow for correct vertical flow solution (3D flow equations) in areas where oil and gas wells are operational; and
3. Allow for correct horizontal flow solution (2D flow equations) in the model where the horizontal flow in the regional Eromanga Basin dominates the flow.

Boundaries were delineated on the basis of the potential radius of influence, hydrogeological units, landscape/topography, and surface water bodies such as streams. In AnAqSim these boundaries are implemented with lines and polygons, rather than defining properties for individual cells. For the 3D model domain areas it is possible to define vertical flow boundaries over the defined area. The SVA areas provide the opportunity to define a different boundary conditions over the defined subsections.

The model boundaries are shown in Figure 8.2 together with the 2D and 3D model domain areas, as well as the SVA areas. Table 8.2 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

Table 8.2 Correlation of Real-World Boundaries with Adopted Model Boundary Conditions

Boundary	Boundary Description	Boundary Condition
2D outer model area	Shallow groundwater interacts with streams	River Lines representing rivers or streams Zero flux from top and bottom
Northeast	Regional GAB heads in Northeast	Specified Head Line (220 mAHD to 300 mAHD)
Southeast	Regional GAB heads in Southeast	Specified Head Line (50 mAHD to 220 mAHD)
South	GAB Outflow to South	Specified Head Line (50mAHD to 100 mAHD)
Southwest	Flow parallel to the boundary towards Lake Blanche	Specified Flux Line Zero Flux
Northwest	GAB inflow from Northwest	Specified Head Line (185 mAHD to 60 mAHD)
North	No known GAB flow from North	Specified Head (220 mAHD to 220 m AHD)
Inner 3D Area	Oil and gas extraction area where vertical flow important (Node Spacing 10km)	Specified Flux from bottom over entire area (200 mAHD)
SVA 1	Higher density SVA points (Node Spacing 5km) Cooper Basin gas overpressure area (Webster et al. 2000)	Specified Flux from bottom over SVA 1 (400 mAHD)
SVA 2	Higher density SVA points (Node Spacing 5km) Cooper Basin gas overpressure area (Webster et al. 2000)	Specified Flux from bottom over SVA 2 (300 mAHD)

8.1.6 Calibrated Hydraulic Parameters

The hydraulic conductivity for each of the model layers in AnAqSim represent bulk hydrostratigraphic unit properties and do not represent small scale variations within the model layers. The steady state model comprises of seven layers which holistically represents the main aquifers and hydrostratigraphic units relevant to the proposed oil and gas development. The final horizontal and vertical hydraulic conductivities and transmissivity values for each model layer are listed in Table 6.2. These hydraulic conductivity values are similar to the values used in the modelling assessment used in the 2013 UWIR (Golder Associates 2013) and its subsequent revisions.

Table 8.3 Calibrated Horizontal and Vertical Hydraulic Conductivities

Label	Level	Domain Type	Top Elevation (mAHD)	Bottom Elevation (mAHD)	K Horizontal (m/d)	K Vertical (m/d)
Eromanga 2D Outer	2	confined/ unconfined	170	-2300	0.3	1.00E-07
Ecological Inner 3D	1	confined/ unconfined	170	-300	0.55	1.00E-06
Eromanga Inner 3D	2	confined	-300	-1000	0.5	1.00E-04
Rolling Downs Aquitard	3	confined	-1000	-1800	0.001	1.00E-06
Hutton	4	confined	-1800	-2300	0.25	1.00E-04
Cooper Nappamerri Aquitard	5	confined	-2300	-2800	0.001	1.00E-07
Deep Gas	6	confined	-2800	-3300	0.01	1.00E-04
Deep Cooper Below Gas	7	confined	-3300	-4500	0.001	1.00E-04

8.1.7 Model Calibration

A number of performance measures can be proposed to indicate when a model fits historical field measurements closely enough to be acceptable for use in future predictions. These may include Root mean squared error (RMS), Scaled mean sum of residuals (SRMS), Residual mean (RM), Absolute residual mean (ARM), Scaled absolute mean (SAM) and Scaled mean sum of residuals (SMSR).

The analytical model has been calibrated against various measured and published data sets providing detail of a specific hydrostratigraphic unit during the development of the oil and gas fields. The following data was used to guide the calibration of the model:

- **Pre-development Steady State**: Webster et al. (2000) published a paper with spatial trends of the pre-development pressures compiled from Santos deep oil and gas development. These spatial trends were used as a guide to establish the pre-development simulation without oil and gas extraction.
- **2011 Steady State:** A hydrocensus conducted by Golder in 2011 provided spatial measurements of accessible bores and wells, including water levels and pressure heads. The dataset primarily represents shallow aquifers, with limited data from oil and gas wells that were converted to water supply wells. Additionally, some water level data collected through GAB monitoring between 2009 and 2011 (refer to Section 7.3.2) are incorporated within this dataset.

The following numerical stability and calibration performance measurements were evaluated during the calibration of the Santos Cooper Basin model:

1. Model convergence: Model convergence was obtained during all model runs with the following settings:

   a) maximum change in heads of 1.0E-03 m.

   b) maximum water balance error along inter domain boundaries of 1.0E-3 m^3/d.

   c) maximum water balance error along the internal streams of 1.0E-4 (m^3/d)/m.

2. Quantitative measures: The steady state calibration was regarded as sufficient based on an average residual of 10.3 m, and a Scaled Root mean square error (Scaled-RMSE) of 9.9%. The graph provided in Figure 8.3 shows the correlation between measured and simulated heads from the steady state calibration. In case of absolute conformity, the points should create a 45-degree straight line (line of perfect fit). As it can be seen, the level of conformity is tolerable especially when the uncertainty in spatial variation of hydraulic properties is taken into account.
3. Qualitative measures: The regional "pre-development" steady state water level contours are illustrated in Figure 8.4. The pre-development steady state model results attempts to replicate the of broad trends in the Eromanga and Cooper Basins. In general, satisfactory trends could be reproduced showing the regional northeast to southwest flow within the Eromanga GAB Basin (Figure 8.4) (as reported by Webster et al. 2000) and the distribution of pressures in the Cooper Basin (Figure 8.4) (Webster et al. 2000). Small scale variations in hydraulic conductivity and the role of structural influences could not be reproduced in the simplified analytical model.

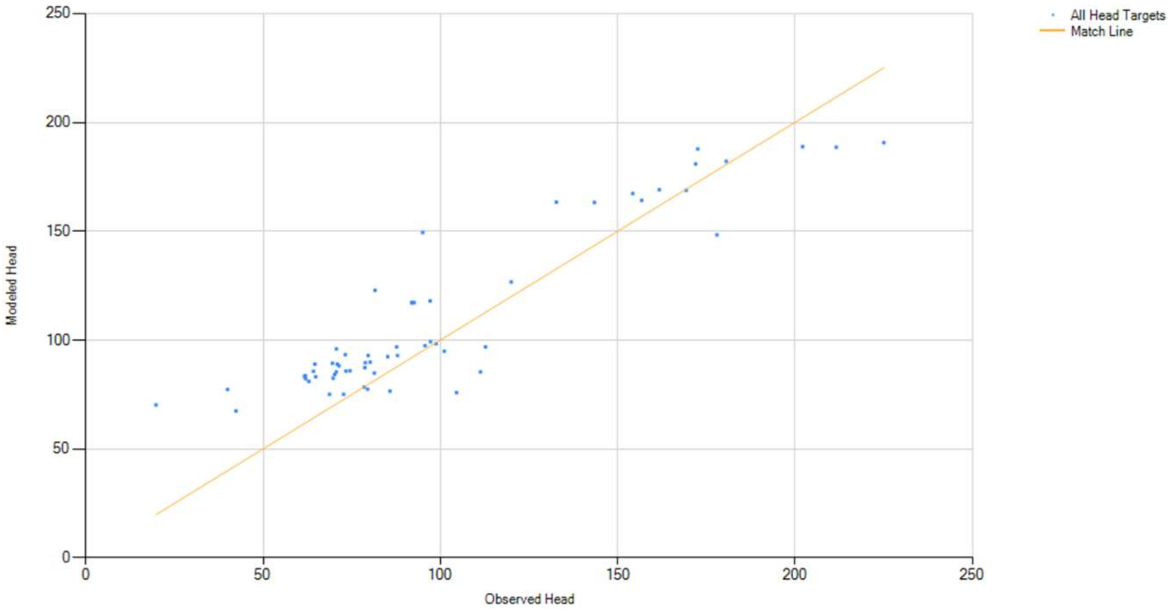

Figure 8.3 Correlation of Observed and Modelled Heads

Figure 8.4 Simulated Pre-development Pressures for Surface Layers (Layer1), the Hutton Sandstone Aquifer (Layer 4) and Cooper Gas Extraction (Layer6)

8.1.8 Model Confidence Level

The level of confidence in the model constructed and calibrated for the Santos Cooper Basin can be assessed based on criteria defined in the Australian Government National Water Commission groundwater modelling guidelines (Barnett et al. 2012). These guidelines classify model confidence according to three classes, where Class 3 is assigned the highest confidence and Class 1 the lowest. The model confidence classification provides an indication of the type of modelling applications for which the particular model is suitable for use.

The model confidence, for the model developed as part of this assessment, is regarded as above a Class 1 (with some reasonable calibration, regional data available for calibration, used to predict regional impacts, and numerical stability), but do not meet the criteria to qualify for a Class 2. According to the guidelines a Class 1 model is suitable for “developing coarse relationships between groundwater extraction locations and rates and associated impacts”. This is regarded as appropriate for estimating the drawdown impacts associated with the Santos Cooper operations in Queensland.

8.1.9 Model Assumptions and Limitations

Groundwater flow models are inherently simplified mathematical representations of complex aquifer systems. The simplification limits the accuracy with which groundwater systems can be simulated in general. There are numerous sources of error and uncertainty in groundwater flow models. Model error commonly stems from practical limitations of time discretisation, parameter structure, insufficient calibration data, and the effects of processes not simulated by the model. These factors, alongside unavoidable error in historic field observations and measurements, result in uncertainty in the model predictions. Additional spatial and time series monitoring data will be required for the various hydrostratigraphic units to improve these predictions.

As discussed, technical investigations undertaken as part of the Cooper GBA show that there is no, or only a very limited connection between the GAB and the overlying (Quaternary, Tertiary and Cenozoic) aquifers. Groundwater from regional GAB aquifers is not conceptualised to notably contribute to surface water / GDE systems (Commonwealth of Australia 2021). The model incorporates this conceptualisation.

The hydraulic conductivity estimates used in the model are selected based on the functioning of relatively thick and extensive model layers covering the Cooper Basin and even larger Eromanga Basin. These hydraulic conductivity properties are selected to simulate the broad hydrogeological processes described in conceptual model presented by Evans et al. (2020). Small scale variability in hydraulic properties within layers might result in model uncertainty, as it may not reflect the true complexity of the geology.

Limitations in the inherent analytical model numerical formulation include assumptions that the layers are horizontal, constant thickness and continuous over the model domain. This might not be entirely true for all the hydrostratigarphic units, especially the Nappamerri Aquitard that do not cover the entire Cooper Basin. The proposed Santos gas well locations below the Nappamerri are however not overlapping the areas where the Nappamerri Aquitard do not cover the Cooper Basin and might not play a significant influence in the predictions, especially with the low co-produced water estimates for the gas wells.

8.2 Predicted Water Level Declines

8.2.1 Scenario Results

Following calibration, the model can be used to simulate the proposed development scenario to predict potential impacts on the groundwater resource. Scenarios simulated for the Santos SWQ operations include:

- Immediate Affected Area (IAA) (current operations and proposed development for the next three years from 2025 to 2028); and
- Long-Term Affected Area (LTAA) (includes all current and proposed developments up to 2040).

The predicted drawdown for the Project development over the next three years (Figure 8.5 and Figure 8.6) and for the total Project development (Figure 8.7 and Figure 8.8) is calculated as the difference in groundwater levels/pressures from the baseline pre-development scenario. Existing registered bores screened in the assigned depth horizons are shown for each model layer. Locations where the maximum drawdown is predicted within a geological unit (not related to groundwater bores) is indicated with green dots on the indicated maps.

Key points from the model predictions include:

- Predictions are considered to be a conservative (worst-case) since the simulation was completed under steady state conditions.
- The predicted drawdown associated with the Project over the next three years (IAA) in the regional unconfined aquifers hosted by Cenozoic and Winton-Mackunda Formation and the Rolling Downs aquitard (layers 1,2 and 3) (<300 mAHD) is less than the trigger values 2 m (layers 1) and 5 m (layers 2 and 3) respectively. Therefore, the development of the Project in the Eromanga Basin is not expected to impact any registered bores within these aquifers.
- The predicted IAA drawdown in the GAB aquifers (layer 4), the Nappamerri Aquitard (layer 5) and the Cooper Basin gas extraction units (layer 6) exceed 5 m, however no bores are present within the IAA area.
- The predicted LTAA extent in the Eromanga Basin extends to include one registered bore (RN22691) which is attributed to the Hutton Sandstone (model Layer 4) as shown in Figure 8.8. A 6.1 m drawdown is predicted for RN22691 over the course of development until 2040. A review of available aerial imagery and bore reports from the Geological Survey of Queensland (GSQ) Open Data Portal indicates that RN22691 is a suspended petroleum exploration bore located in ATP 67. This bore, along with seven other registered bores (that are no longer triggered) were predicted to be triggered in the previous assessment undertaken in the 2022 UWIR. RN22691 was reportedly scouted by LBW Co in February 2025 – no evidence of a water bore was observed in the vicinity of the coordinates listed in the QLD Gov Bore Report (Santos 2025).
- The greatest drawdown for the LTAA and IAA is observed in the GAB aquifers and Napamerri Aquitard. A maximum drawdown of 12 and 9 m respectively is predicted in the LTAA.

There are no third-party water supply bores predicted to be triggered under both the IAA and LTAA development scenarios. This can be attributed to the following:

- Reduction in the number of producing wells when compared to the 2022 SWQ UWIR (Section 6.3)
- Decreasing water volumes as the project matures (Section 6.3)
- Decreasing number of proposed wells when compared to the 2022 SWQ UWIR. The number of newly proposed wells (oil and gas) in Appendix II is 120, compared to the 260 in the 2022 SWQ UWIR.

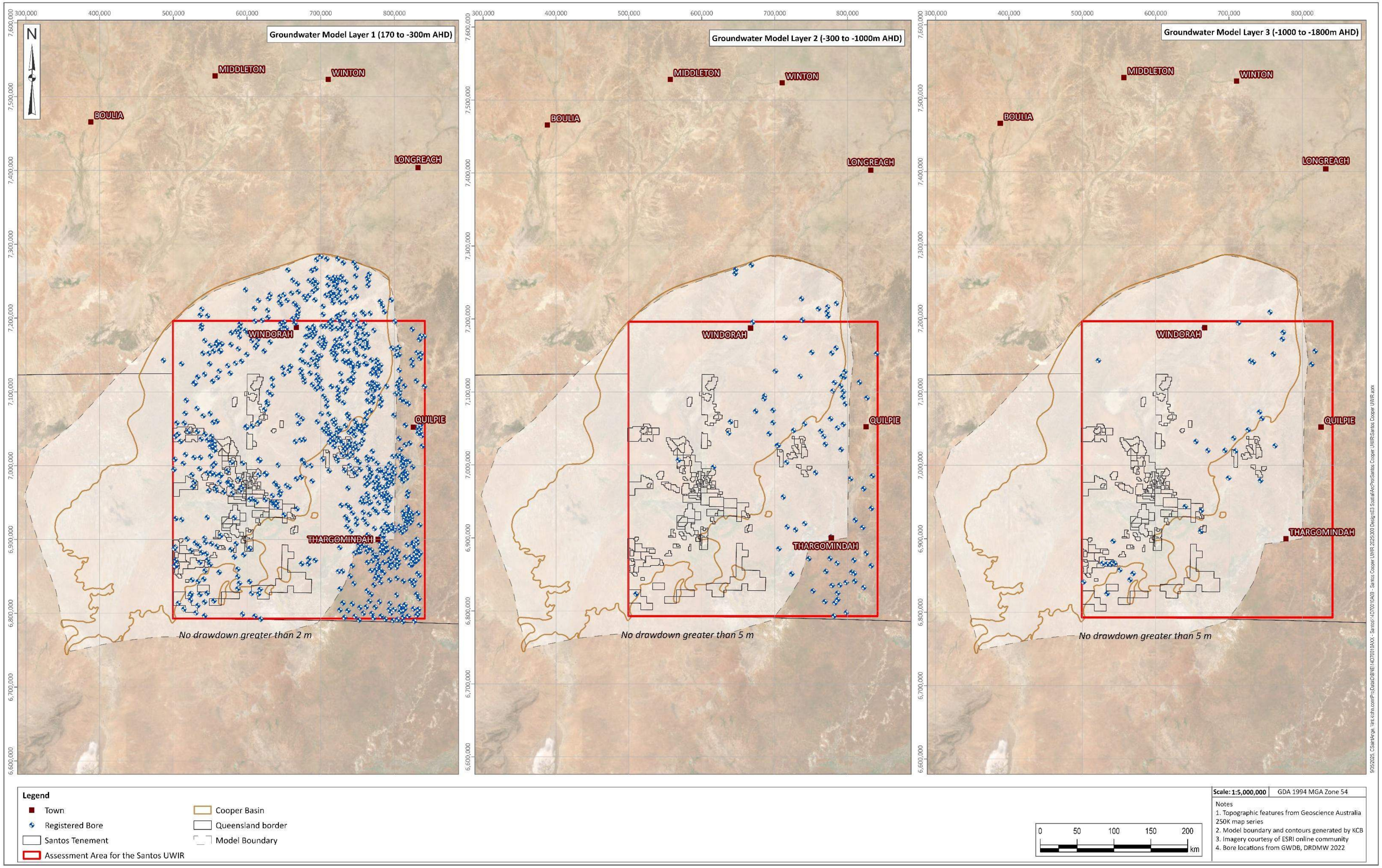

Figure 8.5 **Predicted IAA Drawdown for Layer 1 (170 to -300 mAHD), Layer 2 (-300 to -1000 mAHD) and Layer 3 (-1000 to -1800 mAHD)**

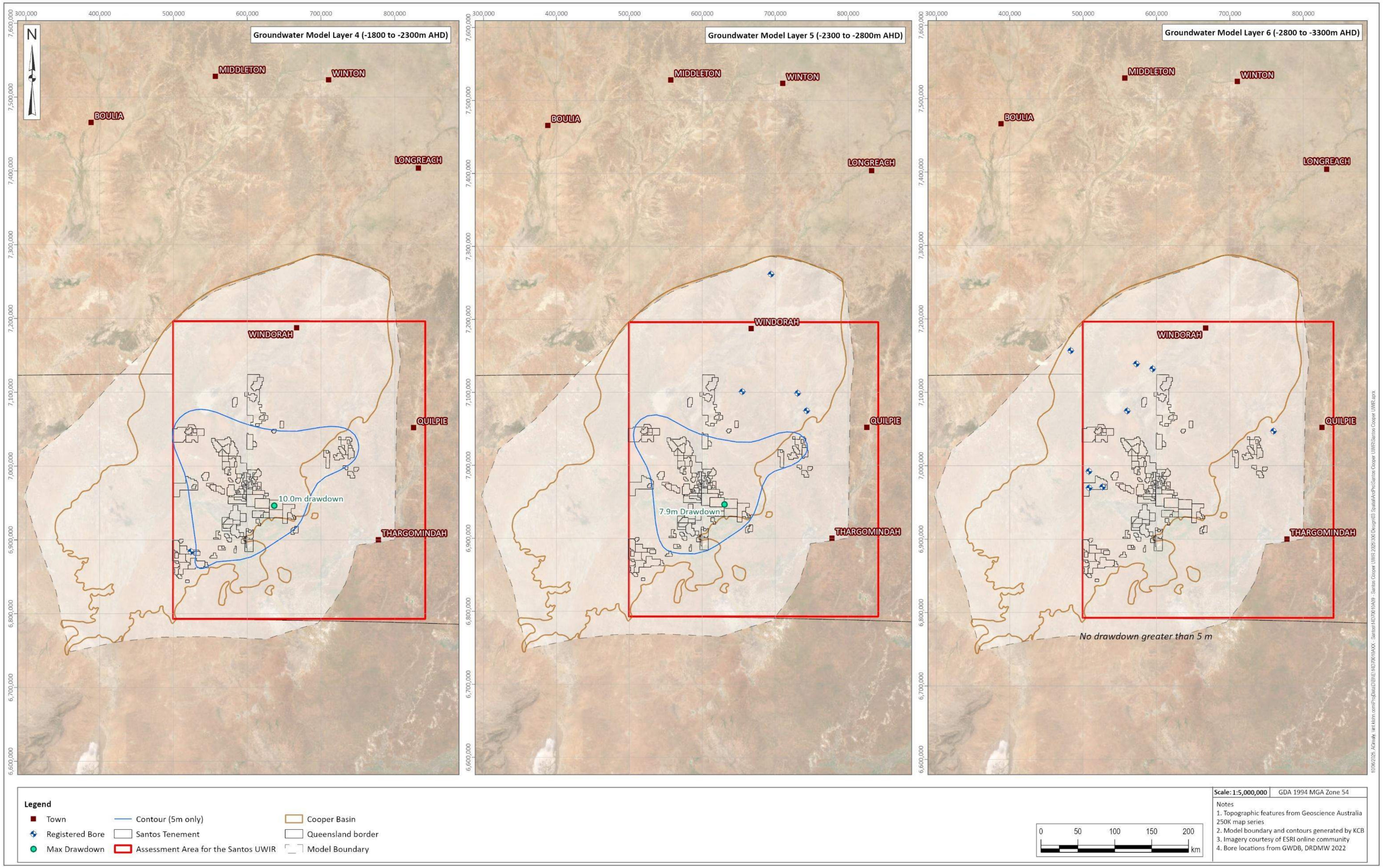

Figure 8.6 Predicted IAA Drawdown for Layer 4 (-1800 to -2300mAHD), Layer 5 (-2300 to -2800mAHD) and Layer 6 (-2800 to -3300mAHD)[4]

[4] Locations where the maximum drawdown is predicted within a geological unit are indicated with green dots. These locations are not associated with a specific bore location.

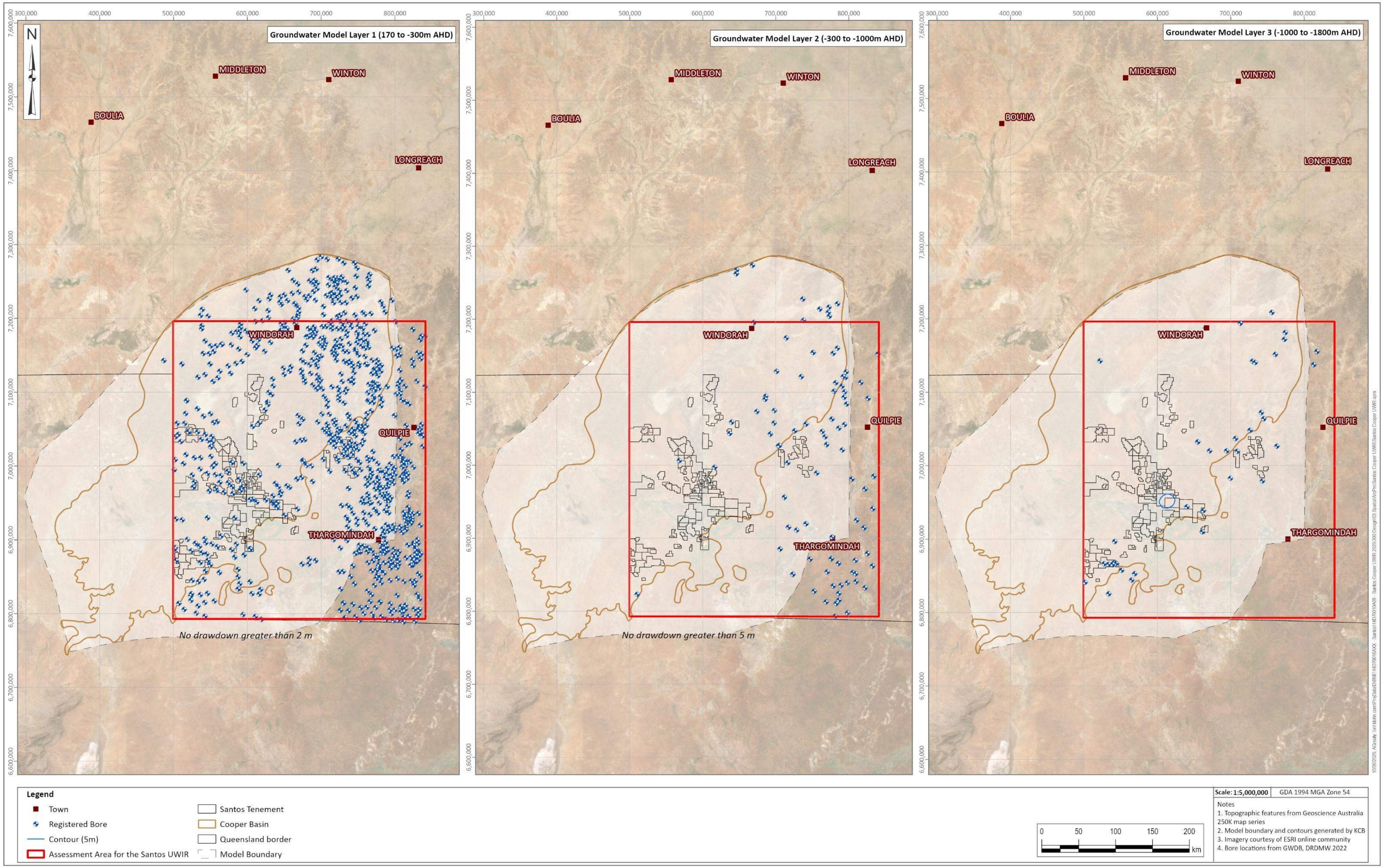

Figure 8.7 **Predicted LTAA Drawdown for Layer 1 (170 to-300mAHD), Layer 2 (-300 to -1000mAHD) and Layer 3 (-1000 to -1800mAHD)**

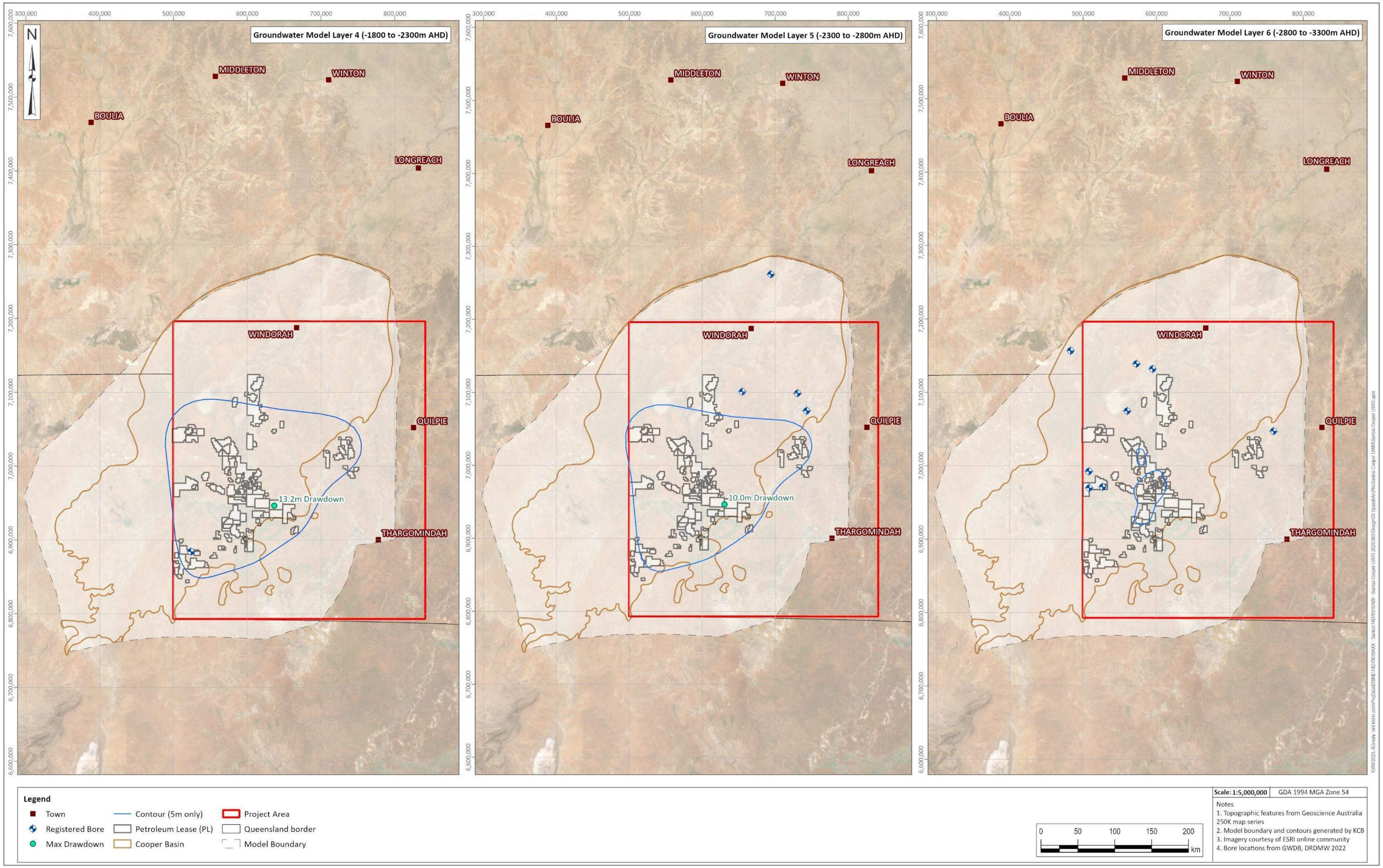

Figure 8.8 Predicted LTAA Drawdown for Layer 4 (-1800 to -2300mAHD), Layer 5 (-2300 to -2800mAHD) and Layer 6 (-2800 to -3300mAHD)[5]

[5] Locations where the maximum drawdown is predicted within a geological unit are indicated with green dots. These locations are not associated with a specific bore location.

8.2.2 Groundwater Depressurisation During the UWIR Period

The abstraction of groundwater as part of the Project development during the IAA Period (2024-2027) is not predicted to result in a basin wide depressurisation of the formations.

Heavily utilised (third-party groundwater abstraction) in the near surface aquifers (the Quaternary, Tertiary and Winton Formations) show no impacts exceeding the trigger levels defined under the Water Act (Figure 8.5). No third-party groundwater users are predicted to be affected by drawdown exceeding Water Act triggers.

Groundwater production from oil production will have limited impacts on the GAB aquifers (including the Hutton Sandstone; Layer 4 in model) within the Project area. The spatial extent of drawdown was limited to the vicinity of the production wells (Figure 8.6).

Groundwater extraction from gas production in the Cooper Basin will have a negligible impact on groundwater levels within Cooper Basin aquifers.

8.2.3 Groundwater Depressurisation Over the Project Life

The abstraction of groundwater as part of the Project development during the LTAA Period is not predicted to result in a basin wide depressurisation of the formations.

Heavily utilised groundwater aquifers near the surface (the Quaternary, Tertiary and Winton Formations), show no impact of exceeding the trigger levels defined under the Water Act (Figure 8.7). No third-party groundwater users are predicted to be affected by drawdown exceeding Water Act triggers.

Groundwater production associated with oil production will have limited impact on the GAB aquifers (including the Hutton Sandstone; Layer 4 in model) and the Cooper Nappamerri Aquitard (Layer 5 in model) within the Project area. The spatial extent of drawdown was limited to the vicinity of the production wells (Figure 8.8).

Groundwater extraction from gas production in the Cooper Basin remains to have a negligible impact on groundwater levels within Cooper Basin aquifers.

9 PART D: IMPACTS TO THE ENVIRONMENTAL VALUES

9.1 Identified Environmental Values

9.1.1 Groundwater and Surface Water Interactions

Permanent waterholes serve as critical habitats and refuges for flora and fauna during extended dry periods. Many of these waterholes also hold significant cultural value due to their customary, spiritual, and economic importance to Traditional Owners. The Cooper GBA program included analyses of groundwater levels, water chemistry, chemical tracers, and water balance estimations (Commonwealth of Australia 2021). Findings from chemistry and tracer data indicate that waterholes are primarily surface water-fed and may facilitate ephemeral groundwater recharge. Water balance assessments similarly showed no detectable groundwater inputs to these features. Technical investigations suggest minimal to no hydraulic connection between the GAB and the overlying Quaternary, Tertiary, and Cenozoic aquifers. Consequently, groundwater from regional GAB aquifers is not considered to make a significant contribution to surface water flows.

The investigation concluded that surface water is a source of periodic freshwater recharge of shallow systems which sustains fringing riparian vegetation, and that groundwater drawdown in the regional unconfined aquifers hosted by Cenozoic and Winton-Mackunda sediments will not impact on groundwater dependent vegetation growing on the floodplains of Cooper Creek.

Conceptualisation of shallow aquifer interactions after Evans et al. (2020), is represented in Figure 9.1. Episodic flooding of the Cooper Creek floodplain contributes local recharge to shallow aquifers, forming freshwater lenses in the vicinity of some large near permanent waterholes (Miles and Costelloe 2015)(Cendon et al. 2010). These freshwater lenses either lay on top of a more saline regional water-table or alternatively are perched above the water-table. Deep-rooted vegetation may utilise the fresher shallow groundwater near the Cooper Creek as a water source during dry periods (Cendon et al. 2010; Evans et al. 2020).

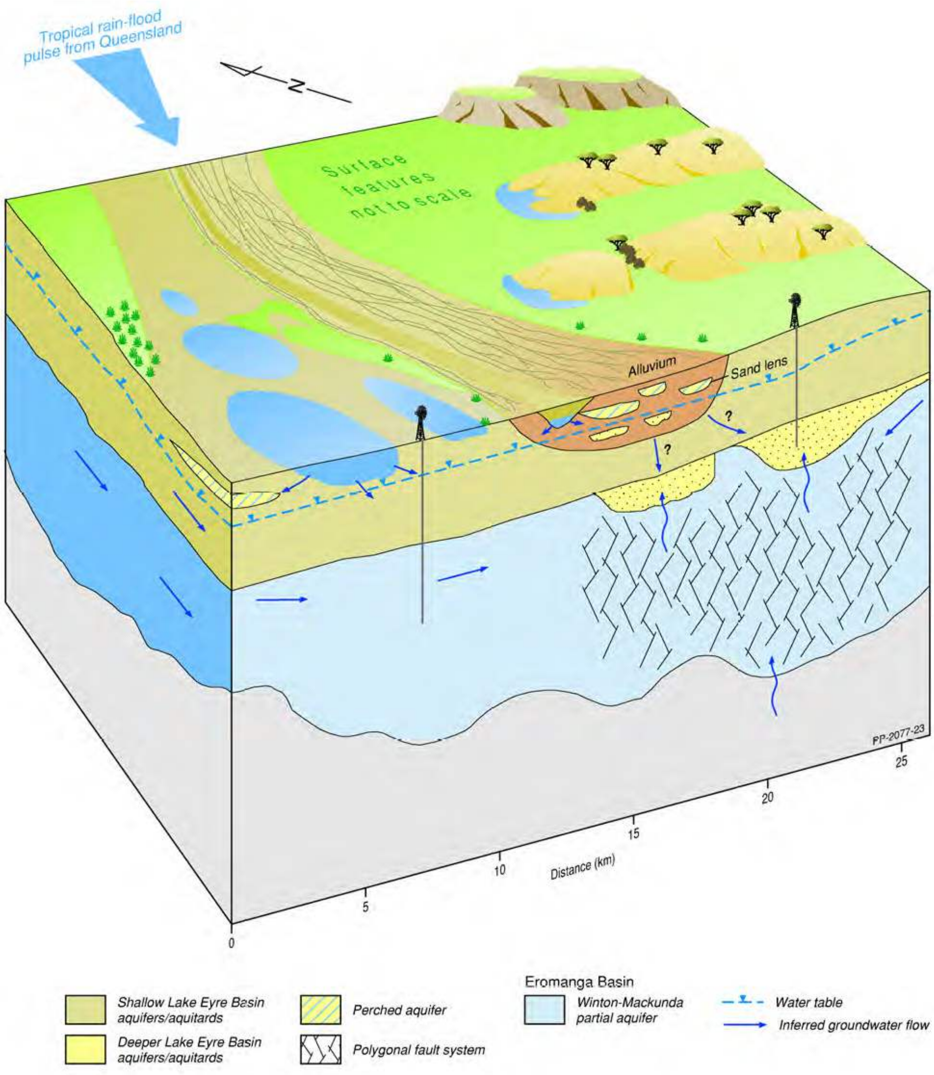

Figure 9.1 Shallow Aquifer Interactions with Surface Water Features (Evans et al. 2020)

9.1.2 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) can be defined as those ecosystems whose ecological processes and biodiversity are wholly or partially reliant on groundwater. The extent of GDE dependency on groundwater can range from being marginally or episodically dependent, to being entirely dependent on groundwater (SKM 2001).

Examples of GDEs include:

- Terrestrial vegetation supported by shallow groundwater.
- Aquatic ecosystems in rivers and streams that receive groundwater baseflow. Baseflow typically accounts for a significant portion of total flow volume in major rivers and streams.
- Baseflow can sustain streamflow volumes long after rainfall events, or throughout dry seasons, and is therefore critical to the maintenance of aquatic ecosystems in rivers and

streams in many Australian environments. Baseflow can occur as springs discharging into a river or stream, or as diffuse influx of groundwater through banks and bed sediments.

- Wetlands, which are often established in areas of groundwater discharge.
- Springs and associated aquatic ecosystems in spring pools.
- Aquifers and caves, where stygofauna (groundwater-inhabiting organisms) reside.

GDE mapping provided in Queensland Globe (State of Queensland 2025b) collates information from a number of sources into a central database, including published research and interpreted remote sensing data. Confidence levels are placed on the mapped extents of the GDEs and ground-truthing of the mapped areas is typically required to confirm presence of the GDEs. Potential low to moderate confidence GDEs are identified in the Project area as presented in Figure 9.2.

As outlined in Section 9.1.1 surface water is conceptualised as the primary source of periodic freshwater recharge sustaining potential GDEs on the floodplains. Groundwater drawdown within the regional unconfined aquifers hosted by the Cenozoic and Winton-Mackunda formations is not expected to impact groundwater dependent vegetation on the Cooper Creek floodplains.

9.1.2.1 Spring Complexes

Whilst outcrop of the artesian GAB aquifers is distant from the Cooper Region (> 90 km as shown in Figure 9.2 – GDE surface point), significant changes to recharge rates of the GAB aquifers are likely to have a bearing on the water balance of artesian GAB aquifers, potentially affecting the aquifer throughflow into and out of the Cooper Region. Aquifer throughflow in and out of the Project area is likely to be a significant component of the water balance due to the Eromanga Basin boundaries extending beyond the Cooper Region boundary.

The lack of springs that source groundwater from artesian GAB aquifers in the Cooper GBA region suggests that the Rolling Downs aquitard for the most part impedes connectivity between artesian GAB aquifers and Winton-Mackunda partial aquifer (Commonwealth of Australia 2021; Evans et al. 2020).

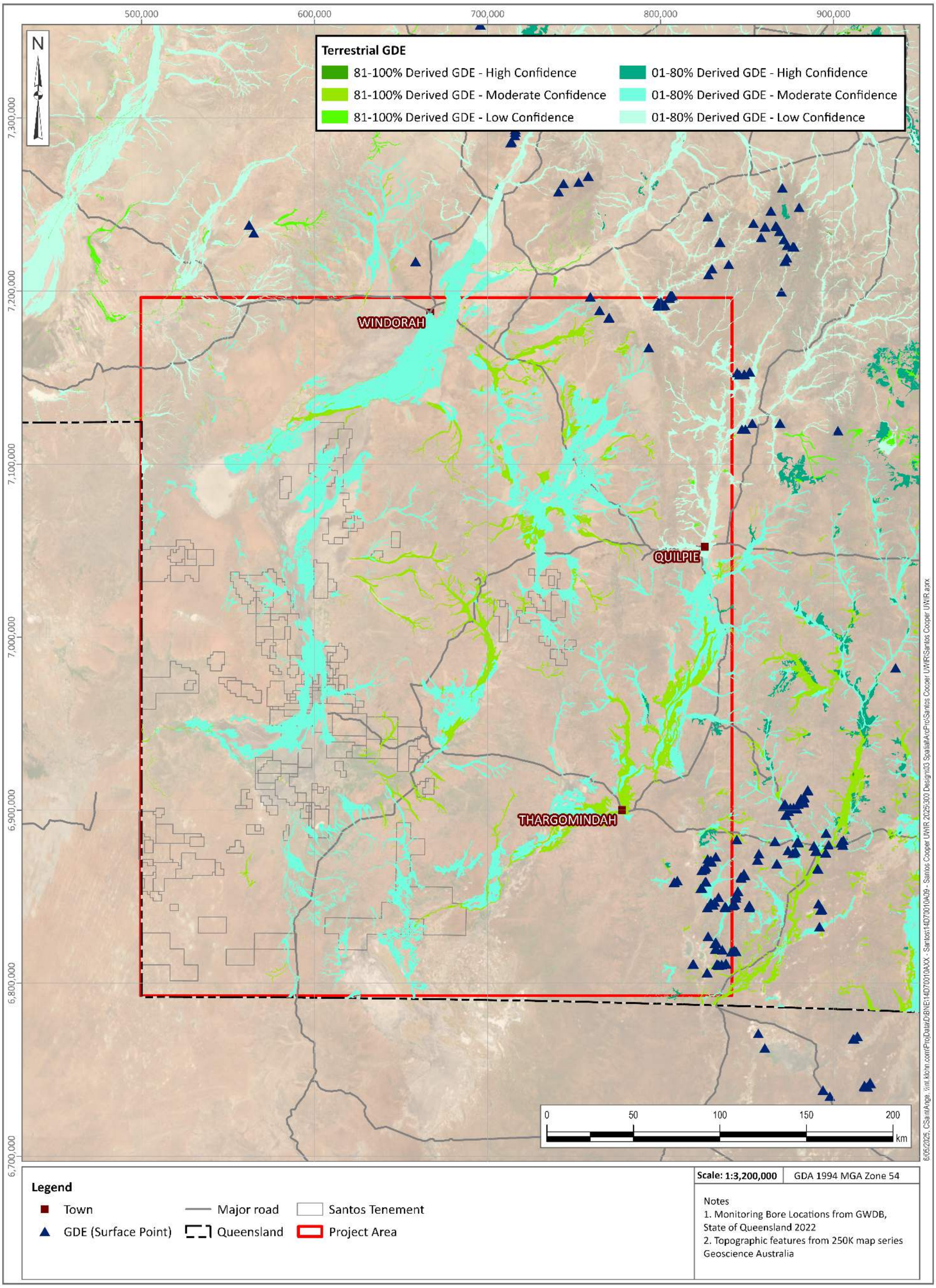

Figure 9.2 Mapped GDEs in the Vicinity of the Project Area

9.1.3 Third-Party Groundwater Use

Groundwater use and purpose including registered groundwater bores are presented in Section 7.2.

The majority of current groundwater bores (90%) are less than 300 m deep and abstract groundwater from the Winton-Mackunda partial aquifer and Cenozoic aquifers of the Eromanga Basin. Groundwater is used for a number of purposes in the Project area, including stock and domestic, town water supply, and monitoring for GAB, CSG, and mining. There are 1,802 bores that are considered potential water supply bores within the Project which include old oil and gas exploration bores that were converted to water supply bores, and all the other third-party bores with no information on the facility role.

9.1.3.1 Bore Baseline Assessment

A water baseline assessment program was undertaken in 2011 to 2013 (Golder Associates 2013a) to collect baseline information with regards to existence, construction, condition and accessibility of water bores, and where possible, aquifer data including water level, water quality, groundwater yield and use.

The initial program identified that the confirmed number of bores that exist within the area of interest is less than that indicated in the Queensland groundwater bore database. A total of 242 bores were assessed, of which 171 were identified and 117 were confirmed to be in use.

There have been two subsequent field visits for baseline assessments as follows (Santos 2025):

1. RN23227 and RN5092 were assessed in December 2024. Both bores were predicted to be impacted in the LTAA scenario in the 2022 UWIR but are no longer predicted to be triggered under the LTAA scenario in the 2025 model. These bores are currently in use and are > 1,000 m deep.
2. RN22691 and RN23102 were assessed in February 2025. Both bores were predicted to be impacted in the 2022 UWIR. RN22691 was found to not exist and RN23102 was found to be a capped oil borehole.

All registered groundwater bores were included in the bore impact assessment.

9.2 Impacts to Environmental Values

9.2.1 Impacts on Groundwater Resources

Potential impacts as a result of water production may include:

- Decline in groundwater level / pressure at water bores, reducing water availability (discussed in Section 9.2.2);
- Reduction in groundwater head resulting in degradation of groundwater discharge at spring complexes, potentially causing degradation of GDEs (discussed in Section 9.2.3and 9.2.4); and

- Reduction to baseflow to watercourses, potentially resulting in reduced availability of water to GDEs and reduced water availability to potential users downstream (discussed in Section 9.2.5).

Monitoring, management, and mitigation practices associated with the above activities are discussed further in Section 10. Consistent decreases in groundwater levels / pressures as a result of the Project have not been identified to date.

9.2.2 Impacts on Groundwater Users

Potential short term and long-term impacts to groundwater bores have been assessed against the *Water Act 2000* bore trigger threshold of 2 m for an unconsolidated aquifer (e.g. alluvium) and 5 m for a consolidated aquifer (e.g. Hooray Sandstone), using the drawdown predictions for the analytical model. The results indicate limited impacts to third-party groundwater users.

No third-party groundwater supply bores are identified within the IAA and LTAA. No known impacts to groundwater users have been identified to date.

Make good agreements are required to be established for bores in the identified IAA only. No requirements for additional make good agreements in this UWIR period are identified.

9.2.3 Impacts on Groundwater Dependent Ecosystems

Potential GDEs present within the Project area are conceptualised to be sustained by periodic surface water recharge of shallow systems (Commonwealth of Australia 2021). Groundwater from regional aquifers is not conceptualised to sustain GDEs. No known impacts related to the Project have been observed to date, nor are impacts to GDEs expected.

9.2.4 Impacts on Springs

No springs are located within Santos' SWQ tenements. The nearest springs are located more than 90 km beyond the tenement boundaries. No known impacts related to the Project have been observed to date, nor are impacts to springs expected.

9.2.5 Impacts on Surface Drainage

The Project does not include any planned discharge to, or abstraction from (including abstraction due to groundwater impacts), surface water systems.

Groundwater from regional aquifers is not conceptualised to materially contribute to surface water.

No known impacts related to the Project have been observed to date. No discernible impacts to the surface water system, or surface water users as a result of the Project development is anticipated.

9.2.6 Impacts from Subsidence

The potential for subsidence to occur is influenced by two primary factors (OGIA 2021):

- The magnitude of change in groundwater level; and
- The thickness and type of formations overlying the reservoir.

Minimal subsidence is expected as a result of the proposed development due to:

1. The predicted magnitude of change in groundwater levels is minimal and has been historically:
    a. Santos groundwater level monitoring over the past eight years (Section 7.3.2) identify that most of the bores display artesian conditions (except Surlow 1) and show limited changes in groundwater level. Surlow 1 shows almost no change in groundwater levels over the monitoring period (Figure 7.5), which does not suggest any risk of subsidence as a result of groundwater level changes.
    b. Groundwater modelling predictions indicate that depressurisation within the Cooper and Eromanga Basins is limited, with the extent of depressurisation not considered to result in subsidence or impacts to the integrity of the overlying formations.
2. The formations overlying the reservoirs are thick with some formations likely to act as 'bridges':
    a. The conventional oil and gas reservoirs in the SWQ study area are 1,000 to 4,500 mBGL, which provides over 1,000 m of vertical separation between the oil and gas reservoirs and the surface. The hydrocarbon reservoirs for the Santos SWQ operations generally occur in anticlines capped with thick, laterally extensive, low-permeability formations that isolate the reservoirs from overlying formations. Additionally, this is no requirement to remove formation water in order to facilitate gas flow for these operations.
    b. Consolidated sandstone formations, such as the Hutton Sandstone, are less likely to compact due to depressurisation. These formations often act as a 'bridge' should compaction be occurring in other clays, siltstones or minor coal seams, due to their effectiveness in managing increased vertical effective stress.

Subsidence associated impacts to EVs, including impacts to the structural integrity of overlying formations are not considered to be insignificant.

10 PART E: GROUNDWATER MONITORING PROGRAM

The following sections describe the monitoring and management measures for groundwater levels and quality and groundwater take. Each section provides an overview of the existing monitoring requirements and proposed monitoring and management measures to be implemented by Santos.

10.1 Groundwater Level and Quality Monitoring and Management

10.1.1 Rationale

The groundwater impact assessment suggests that the groundwater resource most likely to be affected by the Project are the Hooray and Hutton Sandstone aquifer, which are used in part, by the local community for domestic and municipal supply. The monitoring strategy focused on early detection and protection of these water resources.

A groundwater monitoring network was established through the 2013 UWIR development and the SWQ Water Bore Baseline Assessment. The network provides information on formation pressure, water levels and water quality in unconsolidated and consolidated aquifer formations. This network was revised in the 2019 and 2022 UWIRs to incorporate recommendations from the annual groundwater reporting. This change was intended to improve the overall quality of the monitoring strategy.

The monitoring strategy includes evaluation and assessment of the following:

- Changes in water level in shallow unconsolidated aquifers (>2 m); to evaluate potential to impact to third-party users.
- Changes in water level in consolidated aquifers i.e. Hooray Sandstone aquifer (>5 m) to evaluate potential impact to third-party users.
- Changes in water quality in unconsolidated aquifers and consolidated aquifers (i.e. Hooray Sandstone aquifer): evaluate the potential to impact third-party users.
- Results of previous water monitoring events/programs.

10.1.2 2022 - 2025 Groundwater Monitoring

Santos has undertaken annual monitoring of nine monitoring bores for the current UWIR period (2022 to 2025) as shown in Figure 7.4.

The current UWIR (KCB 2022) which was approved in July 2023 recommended reducing the monitoring from quarterly, to one annual monitoring event considering the limited observed changes to the water level and quality over the pervious reporting period. The annual monitoring period for 2023 overlaps with the 2019 UWIR in which the monitoring strategy included quarterly monitoring events.

The results for the groundwater level data for the Project bores and surrounding registered groundwater bores are discussed in Section 7.3.2. Water quality monitoring results are discussed in Section 7.4.1.

10.1.3 Proposed Monitoring and Management Measures

The proposed monitoring and sampling schedule for years 2025 to 2028 considers the limited observed changes to groundwater level and quality over the previous reporting period (i.e. no discernible change in water level, artesian pressures or quality). No changes to the monitoring program are proposed. All the monitoring points are existing and currently operational.

Monitoring will proceed as planned once the UWIR takes effect.

The groundwater monitoring network is presented in Table 10.1 and presented in Figure 7.4.

The network provides information on formation pressure, water levels and water quality in unconsolidated and consolidated aquifer formations. The intent of the monitoring program is to:

- Identify changes to water quality or levels to groundwater in shallow unconsolidated aquifers and consolidated aquifers which could be attributed to the Project;
- Undertake monitoring of groundwater conditions in accordance with the UWIR and Conditions of Approval; and
- Verify the modelled drawdown predicted by the groundwater modelling assessment throughout the life of the Project.

All bores are recommended to be sampled for the following analytes on an annual basis:

- pH
- TDS
- Major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate/bicarbonate)
- Dissolved heavy metals (including aluminium, arsenic, boron, barium, beryllium, cadmium, cobalt, chromium, copper, manganese, nickel, lead, selenium, vanadium, zinc, lithium, molybdenum, strontium, tin, uranium and iron).

A groundwater level is measured annually immediately prior to groundwater sampling.

Reporting Program

Santos is required to report to DETSI about the implementation of the monitoring strategy. Given that the bores are sampled on an annual basis, Santos will report to DES annually.

Santos will provide DES with the SWQ UWIR Annual Groundwater Monitoring report by May 1, each year. The monitoring section will form part of the annual UWIR review and reporting specified in Section 11.

Table 10.1 UWIR Monitoring Network

Bore Name	WBBA ID	Bore RN	Easting^	Northing^	Tenure	Monitoring Formation	Primary Use	Water Quality?	Water Level?	Water Level Measurement Method*	Comments
Challum Spine Road Bore No. 2	5018	-	566004	6968840	PL59	Winton-Mackunda	Roadwork and construction bore	Yes	No	Not feasible	Shallow (sub-artesian)
Irtalie 1	5028	23570	623669	6932913	PL36	Hutton Sandstone	Roadwork and construction	Yes	Yes	Pressure gauge	Hutton SS (artesian)
PPL Coothero 1	5033	23569	654269	6932959	PL33	Hooray Sandstone	Livestock and roadwork	Yes	Yes	Pressure gauge	Artesian
Gordon's Bore	-	23361	727308	7016801	PL170/ PL1029	Namur Sandstone	Roadwork and construction	Yes	Yes	Pressure gauge	Artesian
Surlow 1 Water Bore	5094	-	595451	6975889	PL205	Winton-Mackunda	Not in use	Yes	Yes	Manual dip reading	Shallow (sub-artesian)
Supply 1	5229	23923	595451	6975889	ATP636	Rolling Downs Aquitard#	Industrial	Yes	Yes	Pressure gauge	Artesian
PPL Balooma 1	-	23372	737660	7034142	-	Hooray Sandstone	Livestock	Yes	Yes	Pressure gauge	Artesian
Apollosa 1@	-	-	662602	6938778	-	Namur Sandstone	Livestock	Yes	Yes	Pressure gauge	Artesian
Ballera West 2	5015	-	584523	6893653	PL61/1073	Nappamerri Group#	Livestock	Yes	Yes	Pressure gauge	Artesian

WBBA – Water Bore Baseline Assessment (Golder Associates, 2013)
*If current condition of bore headwork allows
^ Datum - GDA94 / MGA Zone 54
# Aquifer attribution inferred based on bore depth
@Ownership of this bore was transferred to another landholder on 21 December 2018 and primary use is now for livestock water supply.

10.2 Production Monitoring and Management

10.2.1 Regulatory Requirements

As per the requirements outlined in the P&G Act*,* the volume of produced water will be monitored, recorded and provided to the relevant authority as required.

10.2.2 Proposed Monitoring and Management Measures

In accordance with the requirements of the P&G Act*,* Santos will continue to assess actual groundwater abstraction using the acceptable methods. The method used will be reviewed annually and reviewed, as necessary.

Produced Water Monitoring - Gas

The volume of water co-produced as part of Santos' gas operations is estimated based on the average water content of the gas produced. There is some uncertainty in the volume of water produced, however gas production accounts for ~3.5% of the total volume of water produced from the Project. Small variations in estimated versus actual produced volumes will not have a material impact on drawdown predictions.

Produced Water Monitoring - Oil

The methodology for monitoring water produced as a result of oil operations includes:

- Individual well water-cut meters (Red-eye or DNOC).
- Wellhead water-cut samples.
- Tank dips.

Monthly allocation to any given well is based on:

- Estimation of the theoretical monthly oil and water production by well (using latest individual well test rates multiplied by the number of days the well was producing (i.e. uptime)).
- Summing the theoretical volume of a well or wells that collect into some fixed, known gathering point to give the monthly total theoretical oil and water volumes.
- Comparing theoretical volumes to actual monthly oil and water production at a fixed, known gathering point (where the monthly actual oil and water production is based on measurement of trucked oil loads, or oil piped through a fiscal metering point).
- Allocating (pro-rating) the total theoretical volumes to the individual wells based on the ratio of "actual total"/ "theoretical total".

As mentioned, Santos' monitoring methodology for produced water (i.e. the approximately 4 GL/annum abstracted through oil production) is considered a reasonable approximation of actual volumes based on the premise that the total volume for each well is recorded at 2 points i.e. a known gathering point and a fiscal metering point.

11 UWIR UPDATES AND REVIEW

In accordance with the Water Act, a review period of no greater than three years will be undertaken. Site data including the following, will be reviewed annually:

- Groundwater level and quality data from the water monitoring plan.
- Santos extraction volumes.
- Santos pressure data.

An annual review of the accuracy of the prepared IAA and LTAA predictions will be undertaken. The Chief Executive will be provided with a summary of the outcomes of the annual review, including a statement as to whether a material change in the information or predictions used to prepare the maps has occurred.

It is the intention that data will be reviewed and compared to the assumptions made in the UWIR. A comparison of observed groundwater level data versus model predictions will also be undertaken. Significant discrepancies between the assumptions in this UWIR and the monitoring data will trigger a review of the UWIR.

The review cycle will be incorporated into the water monitoring plan. In addition to the review schedule, reporting to the regulator will be undertaken as required.

12 CONCLUSIONS

The impacts to groundwater from Santos' oil and gas operations in the Cooper Region of SWQ have been assessed in this UWIR, and are based on:

- A description of the geological settings of the gas and oil fields and the development of a conceptual geological cross section and geological contour maps for the top of, and thicknesses of, key formations.
- A review of the hydrogeological settings of the gas and oil fields and the development of a hydrogeological conceptual model and hydrogeological maps.
- An identification of environmental values related to the groundwater system, and in particular groundwater dependent ecosystem including GAB artesian discharge springs.
- Characterisation of produced water volumes.
- An assessment of impacts from groundwater extraction on the target petroleum reservoir, surrounding formations and on potential groundwater users.

The key conclusions of this UWIR are:

- The oil development will result in localised depressurisation of the GAB aquifers and associated oil target areas forming part of the Eromanga Basin.
- The Project will not impact surface waters, GDEs or spring complexes:
  - The Rolling Downs Aquitard limits propagation of drawdown from the petroleum targets to the surficial deposits. Technical investigations indicate that groundwater from regional GAB aquifers do not to contribute materially to surface water or GDEs.
  - No springs are located within Santos' SWQ tenements. The nearest springs are located more than 90 km beyond the tenement boundaries.
- Drawdown/depressurisation greater than the 2 m trigger threshold for unconsolidated aquifers, and 5 m for consolidated aquifers (under Section 362 of the Water Act) are not expected to affect any water supply bores.

This groundwater report demonstrates that impacts to GAB aquifers as a result of the Project is limited. Some depressurisation of the Eromanga layers used for petroleum production can be expected, with limited propagation to the layers immediately above it. It is considered that Santos' current SWQ activities pose little risk to the Cooper GBA region surface water, shallow groundwater systems and associated ecosystems.

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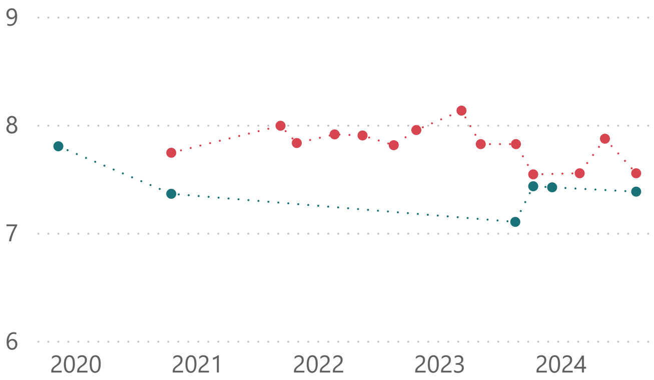
APPENDIX I

Groundwater Chemistry Plots

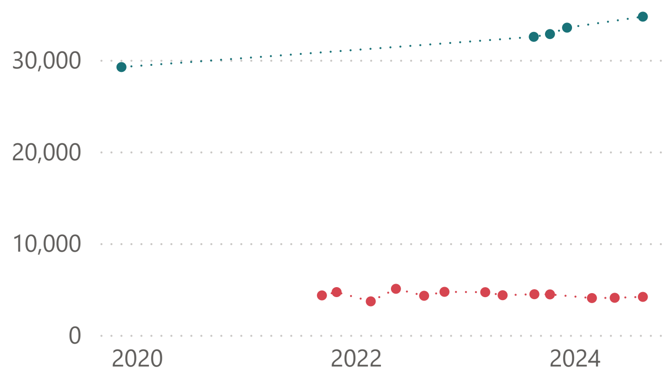
Winton Mackunda

● Challum Spine Road Bore No 2 ● Surlow 1

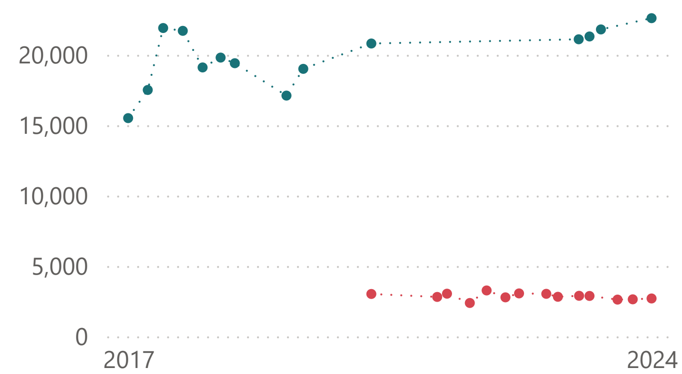
pH (Lab)



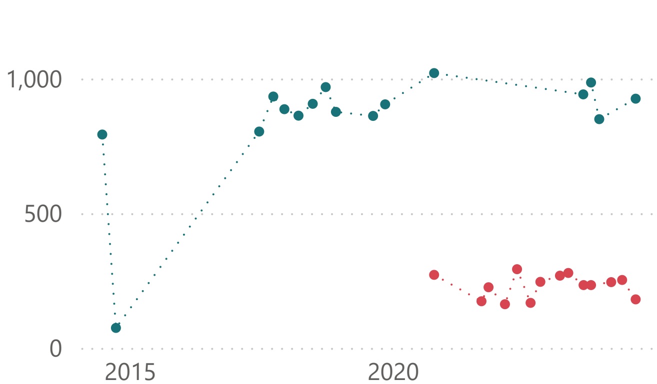
Electrical Conductivity (uS/cm)



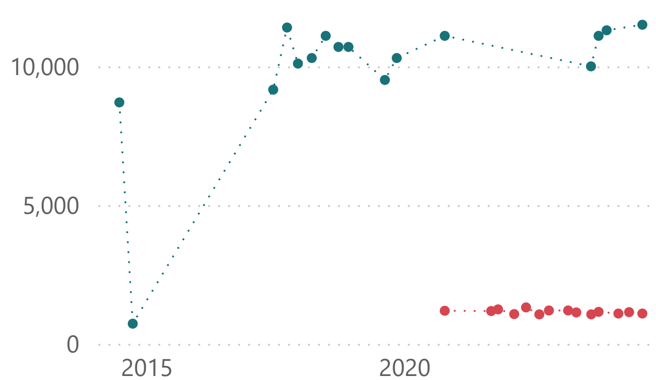
Total Dissolved Solids (Calc.) (mg/L)



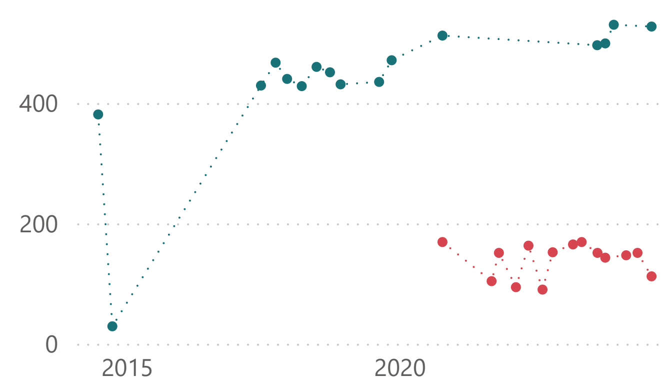
Calcium (filtered) (mg/L)



Chloride (mg/L)



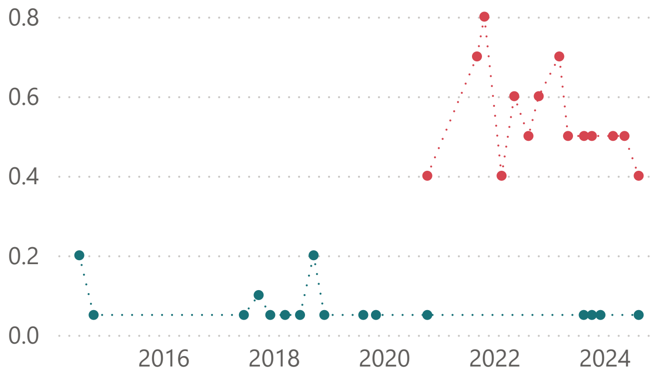
Magnesium (filtered) (mg/L)



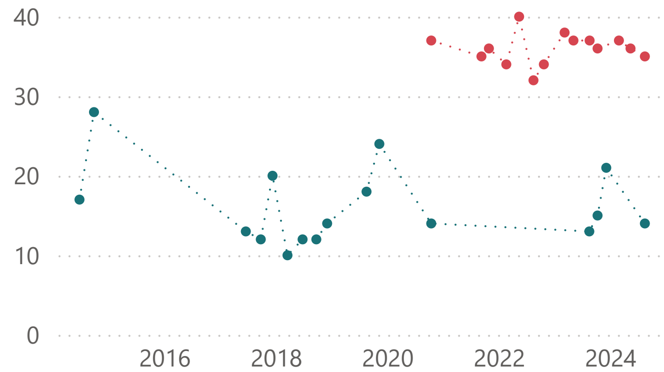
Winton Mackunda

Challum Spine Road Bore No 2 ● Surlow 1

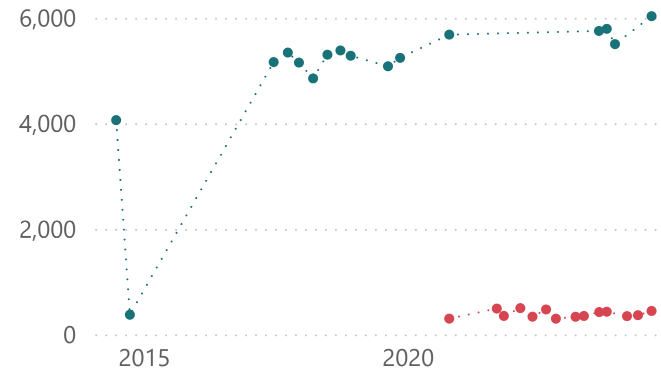
Fluoride (mg/L)



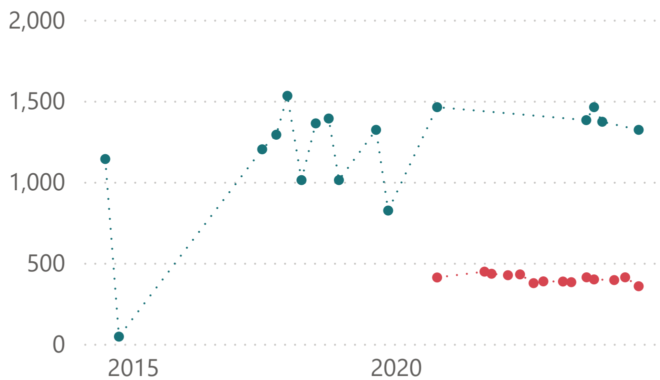
Potassium (filtered) (mg/L)



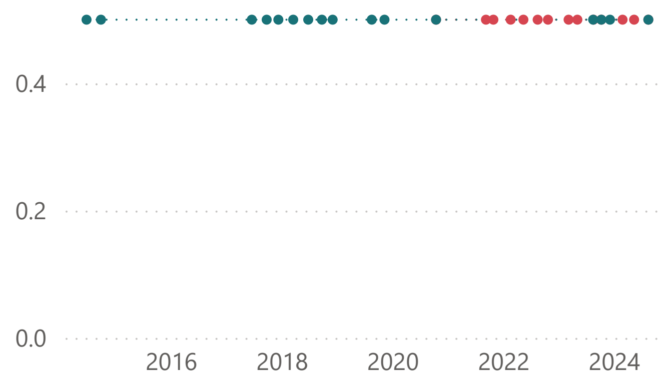
Sodium (filtered) (mg/L)



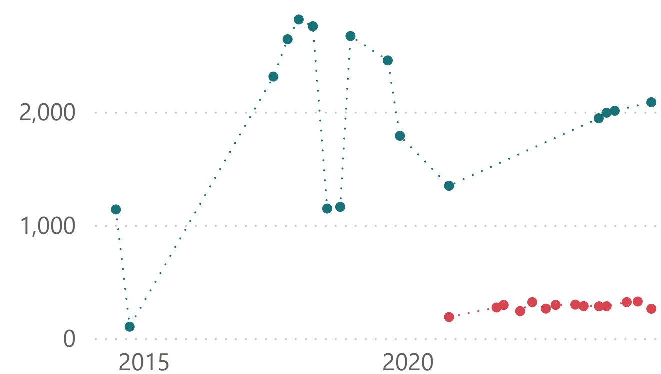
Sulphate as SO4 (mg/L)



Alkalinity (Carbonate as CaCO3) (mg/L)



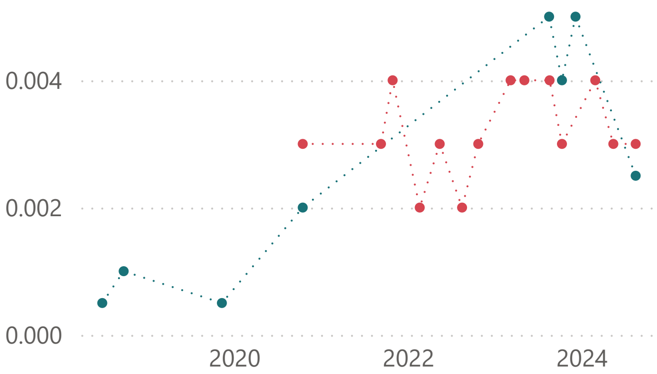
Alkalinity (Bicarbonate as CaCO3) (mg/L)



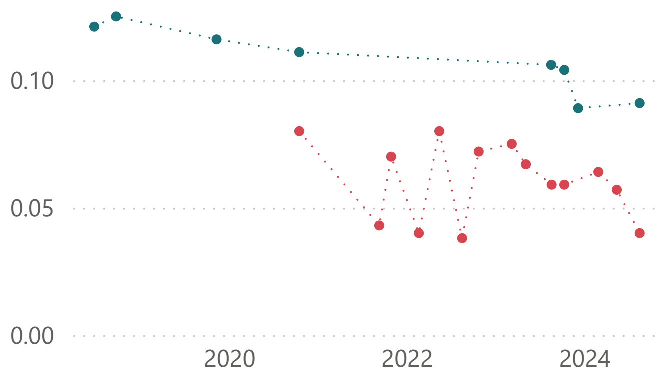
Winton Mackunda

Challum Spine Road Bore No 2 Surlow 1

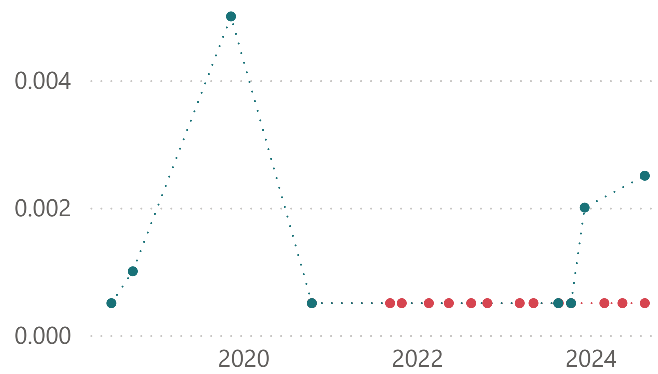
Arsenic (filtered) (mg/L)



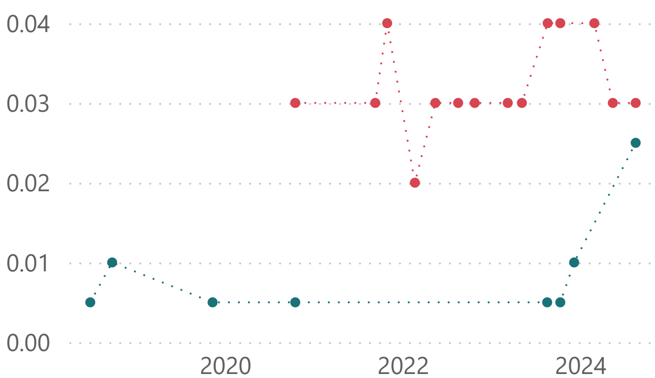
Barium (filtered) (mg/L)



Copper (filtered) (mg/L)



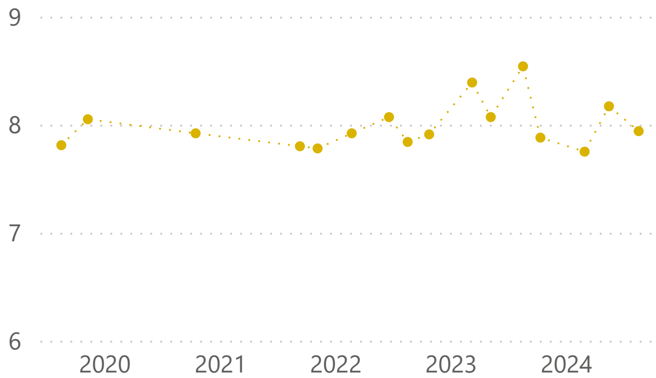
Vanadium (filtered) (mg/L)



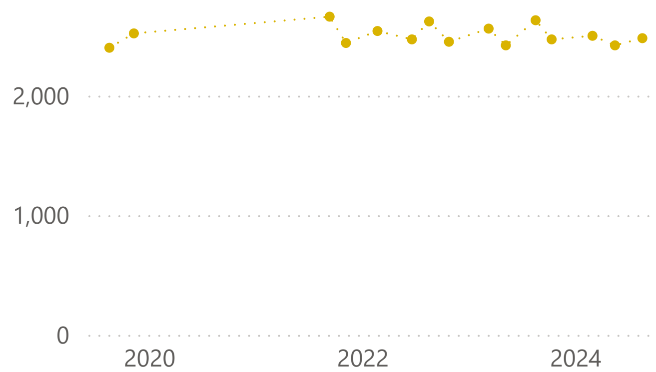
Rolling Downs Aquitard

Supply 1

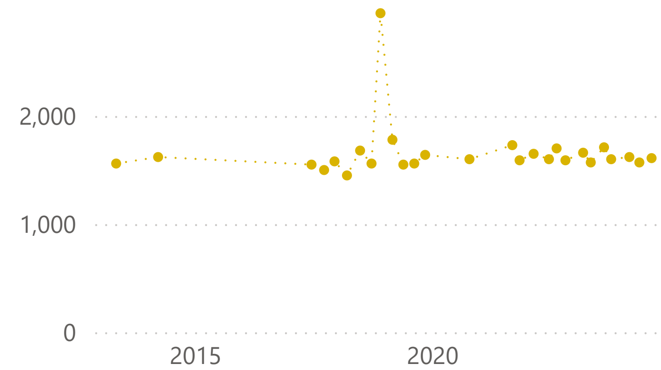
pH (Lab)



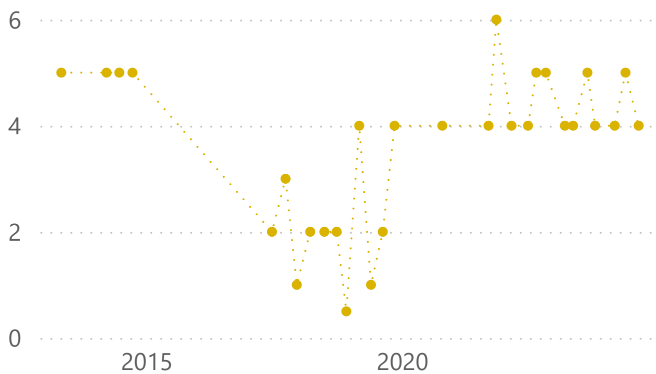
Electrical Conductivity (uS/cm)



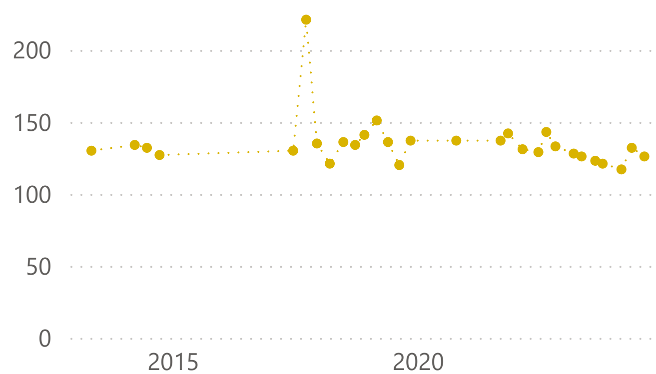
Total Dissolved Solids (Calc.) (mg/L)



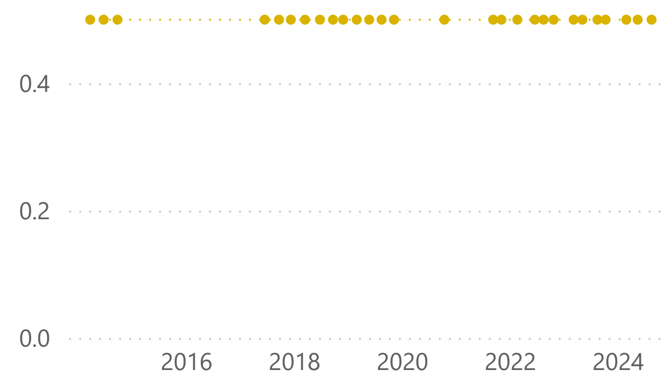
Calcium (filtered) (mg/L)



Chloride (mg/L)



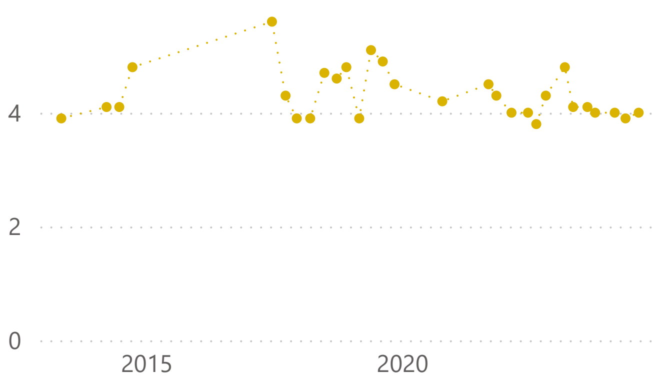
Magnesium (filtered) (mg/L)



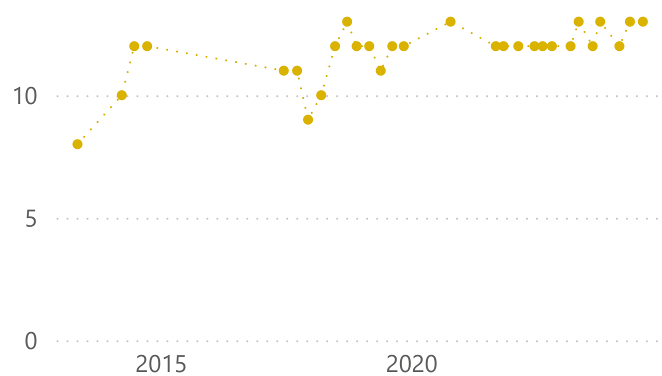
Rolling Downs Aquitard

Supply 1

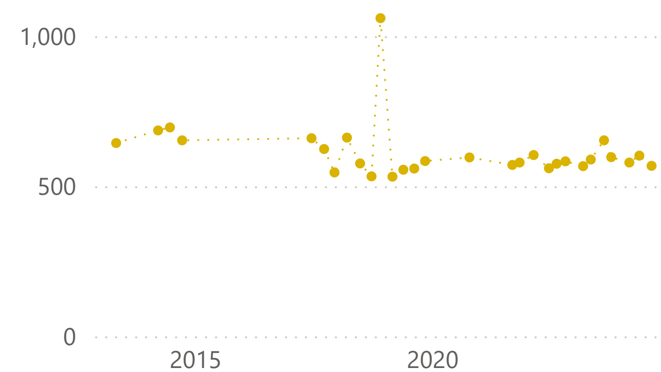
Fluoride (mg/L)



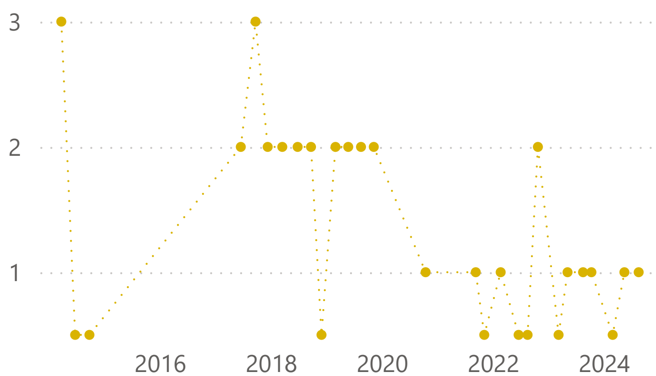
Potassium (filtered) (mg/L)



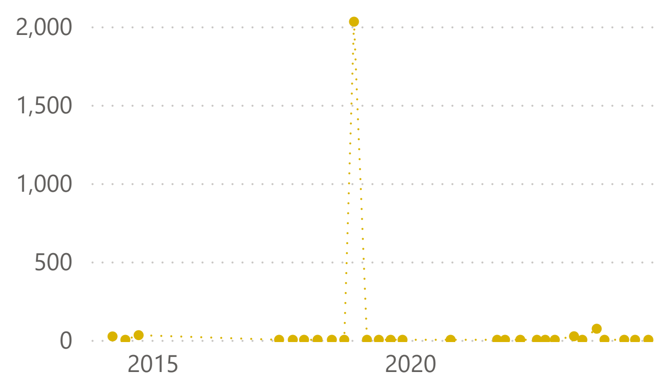
Sodium (filtered) (mg/L)



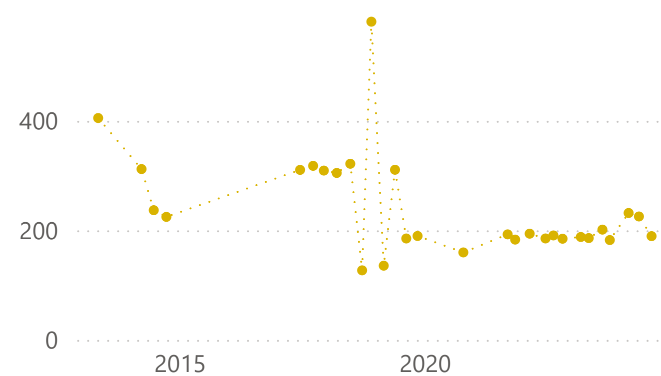
Sulphate as SO4 (mg/L)



Alkalinity (Carbonate as CaCO3) (mg/L)

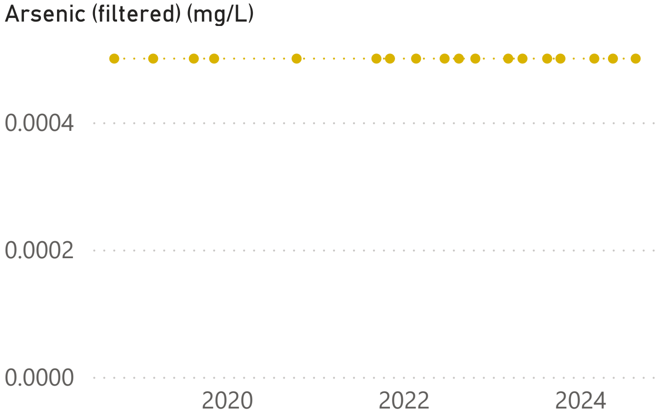


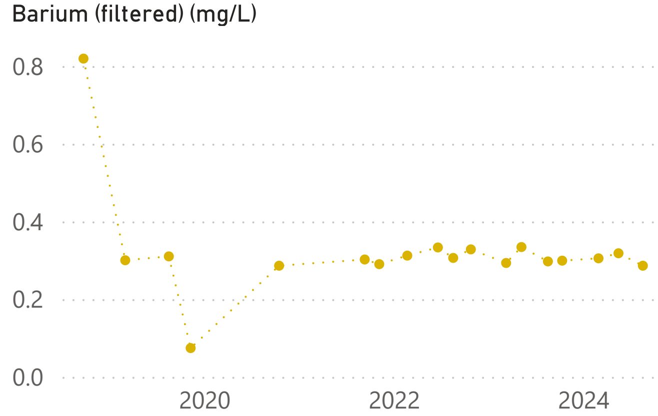
Alkalinity (Bicarbonate as CaCO3) (mg/L)

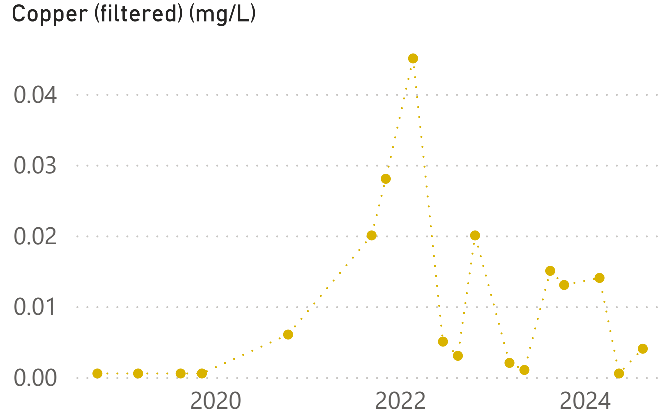


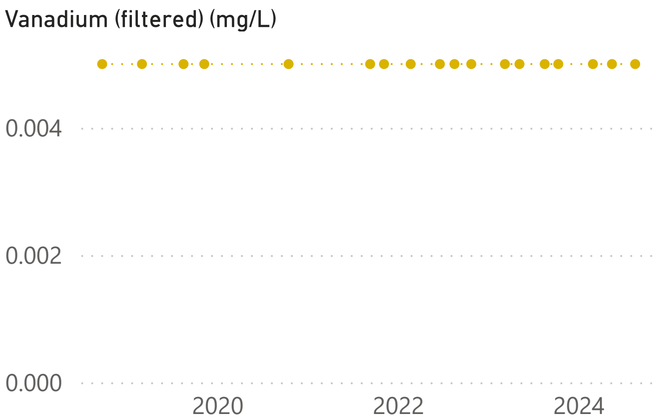
Rolling Downs Aquitard

Supply 1





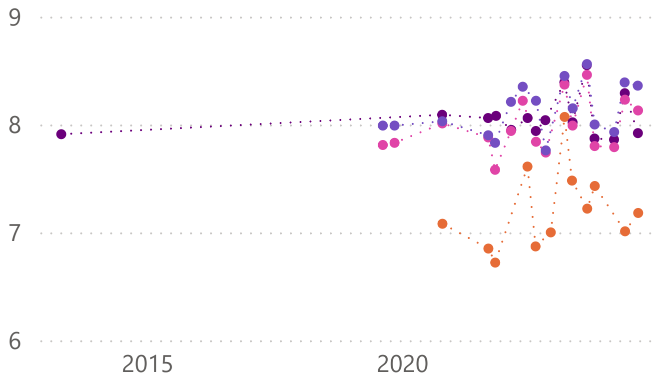




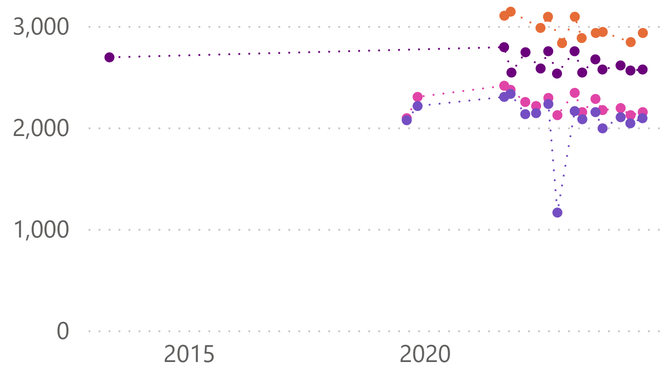
Hooray Sandstone

Apollosa 1 Gordons Bore PPL Balooma 1 PPL Coothero 1

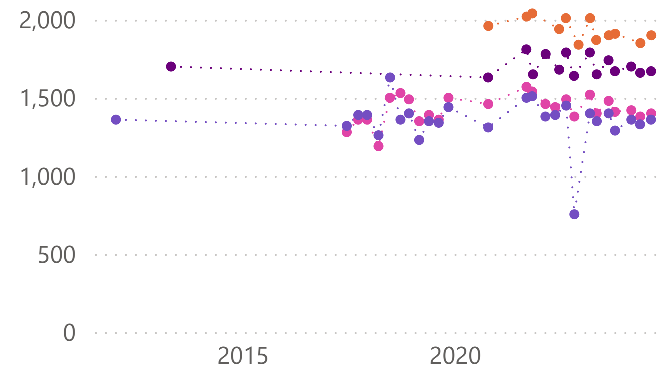
pH (Lab)



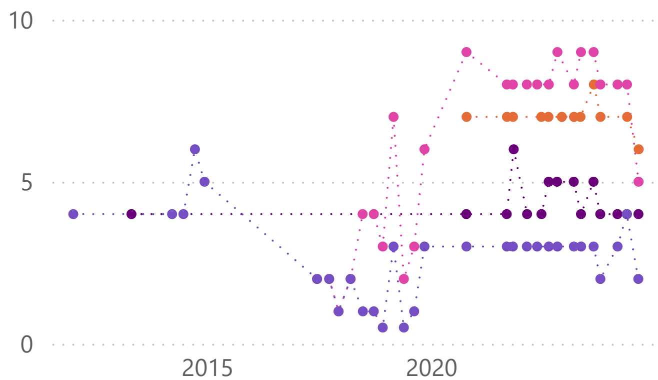
Electrical Conductivity (uS/cm)



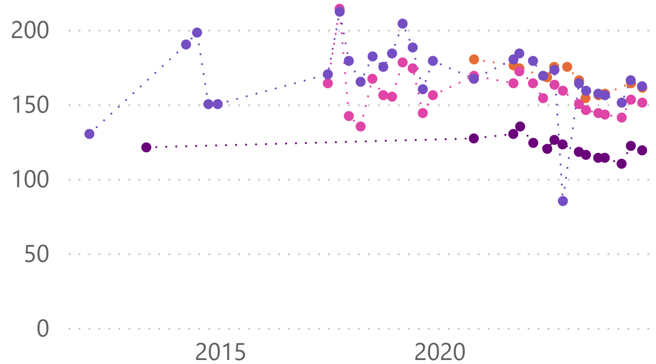
Total Dissolved Solids (Calc.) (mg/L)



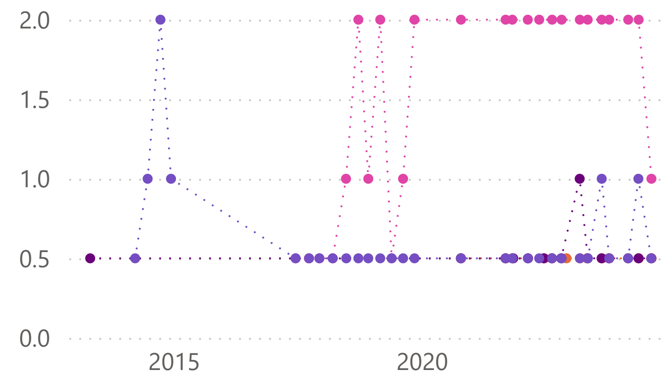
Calcium (filtered) (mg/L)



Chloride (mg/L)



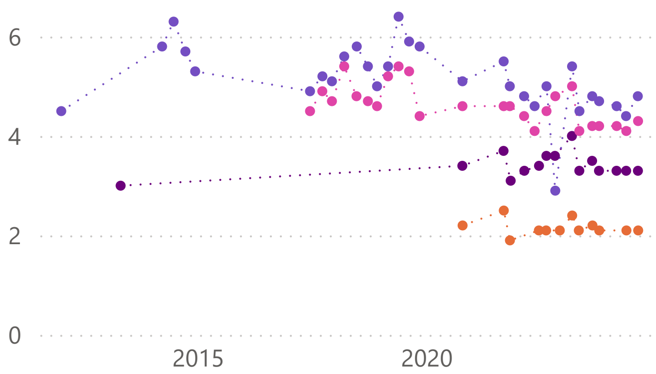
Magnesium (filtered) (mg/L)



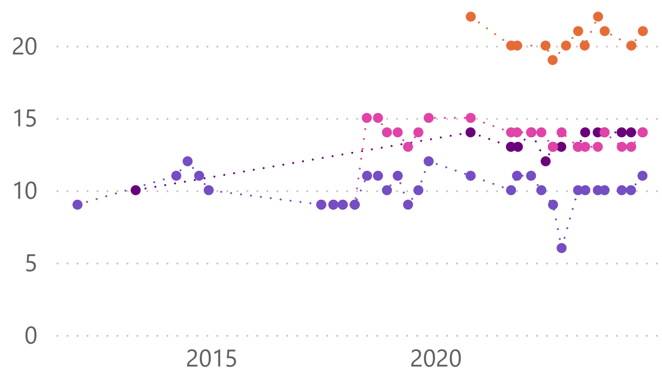
Hooray Sandstone

Apollosa 1 Gordons Bore PPL Baloom...

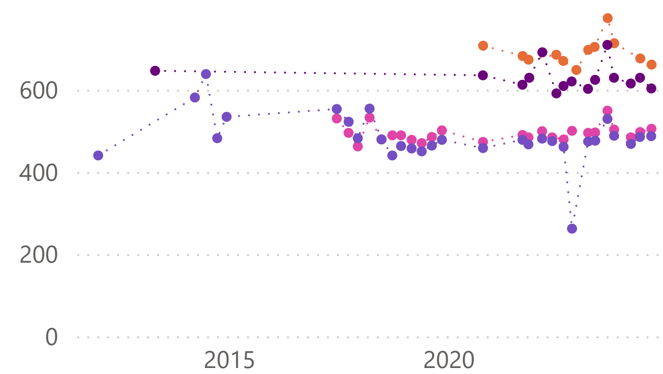
Fluoride (mg/L)



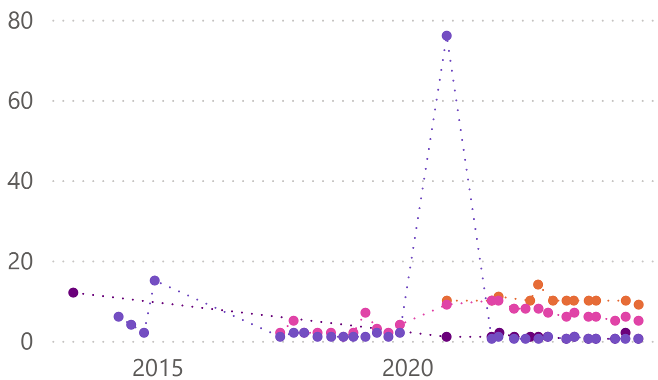
Potassium (filtered) (mg/L)



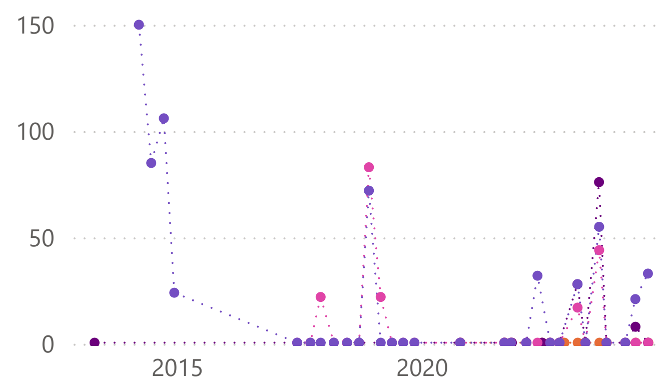
Sodium (filtered) (mg/L)



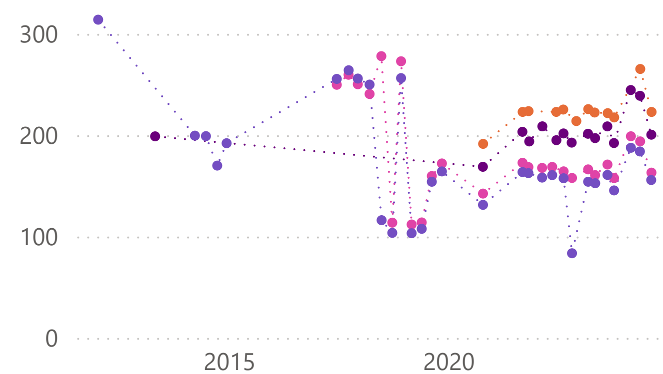
Sulphate as SO4 (mg/L)



Alkalinity (Carbonate as CaCO3) (mg/L)



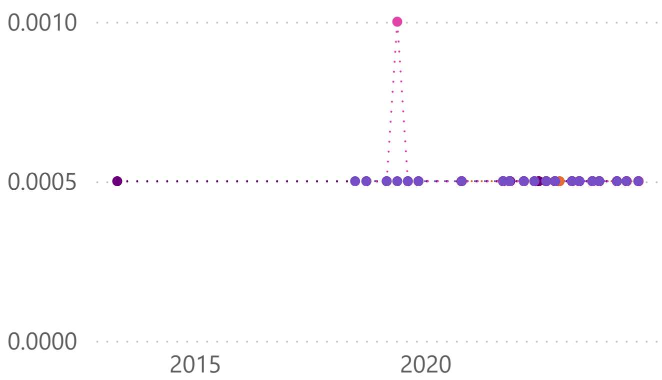
Alkalinity (Bicarbonate as CaCO3) (mg/L)



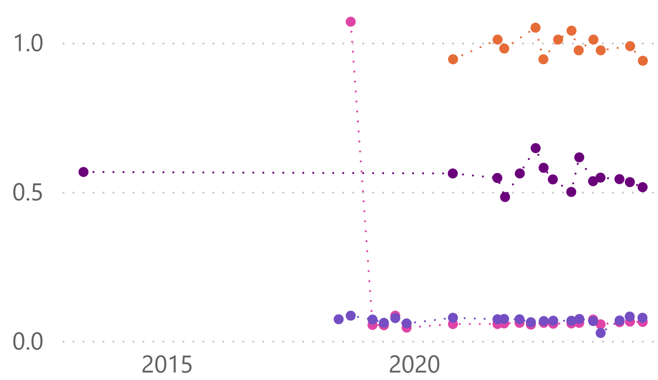
Hooray Sandstone

Apollosa 1 · Gordons Bore · PPL Balooma 1 · PPL Coothero 1

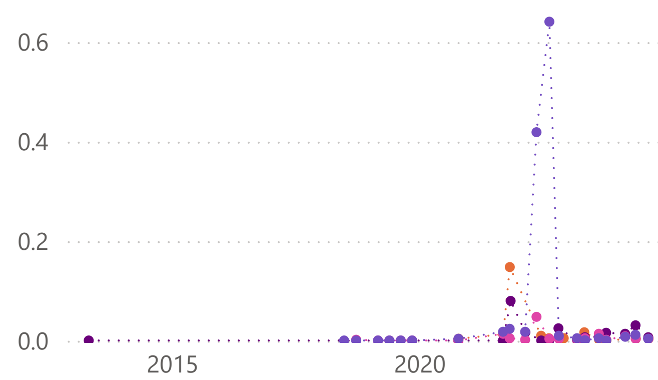
Arsenic (filtered) (mg/L)



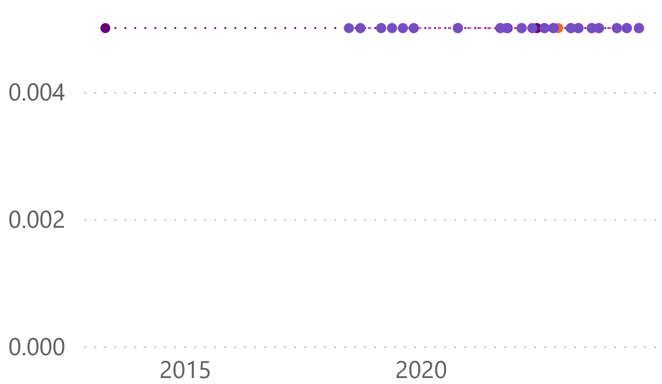
Barium (filtered) (mg/L)



Copper (filtered) (mg/L)



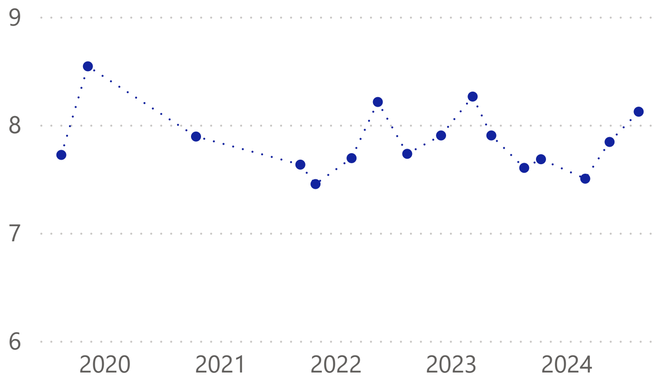
Vanadium (filtered) (mg/L)



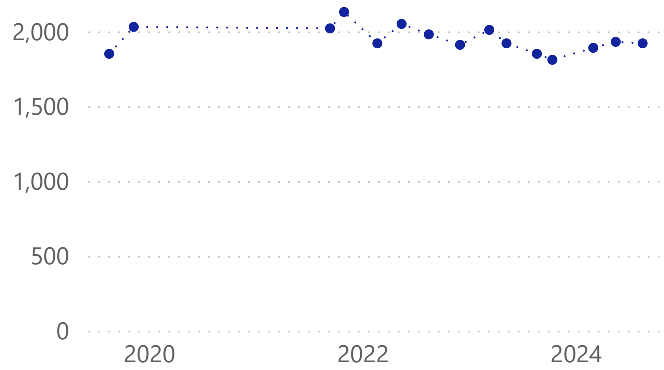
Hutton Sandstone

Irtalie 1

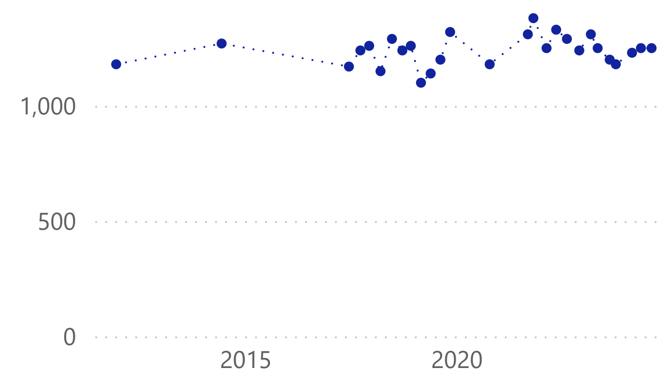
pH (Lab)



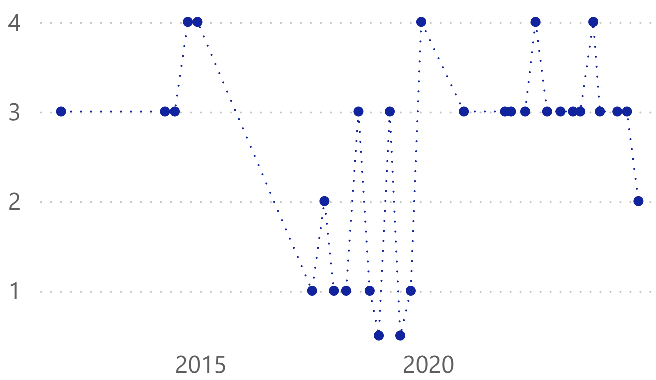
Electrical Conductivity (uS/cm)



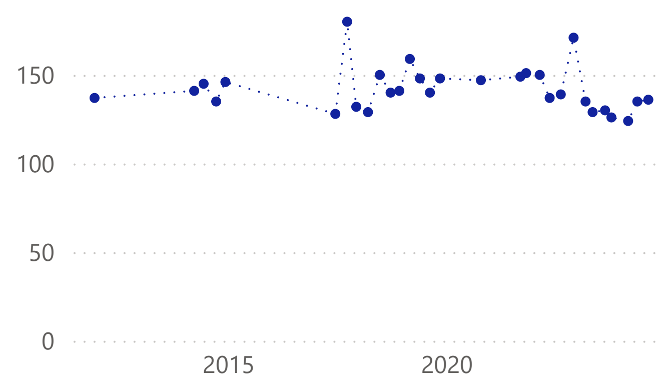
Total Dissolved Solids (Calc.) (mg/L)



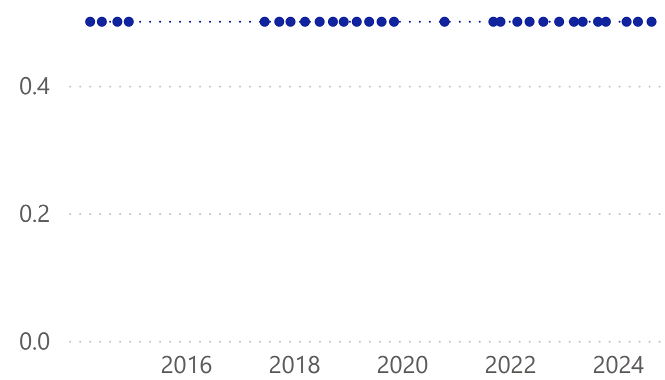
Calcium (filtered) (mg/L)



Chloride (mg/L)



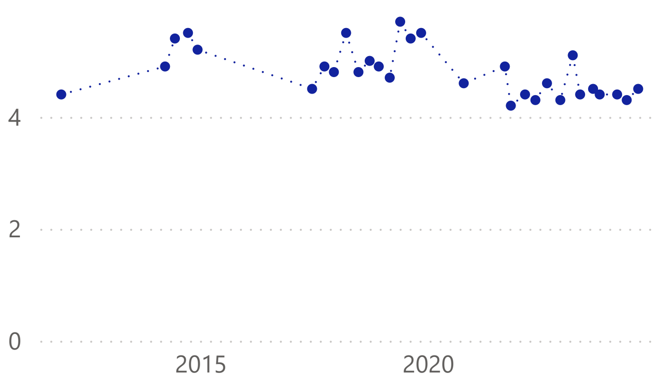
Magnesium (filtered) (mg/L)



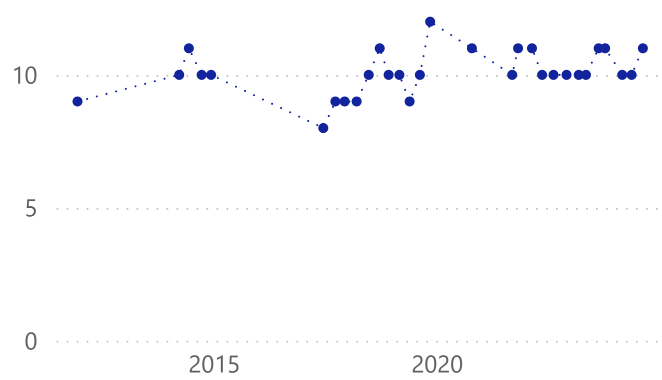
Hutton Sandstone

Irtalie 1

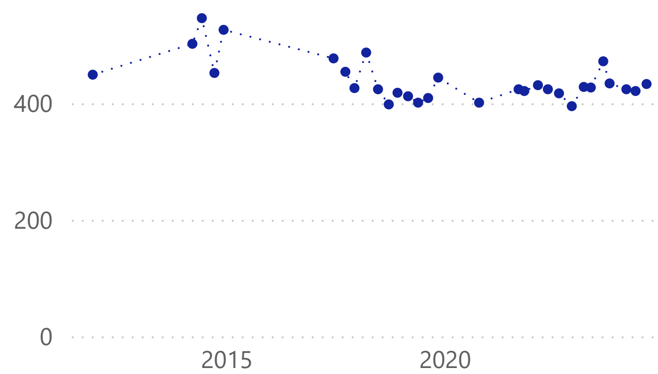
Fluoride (mg/L)



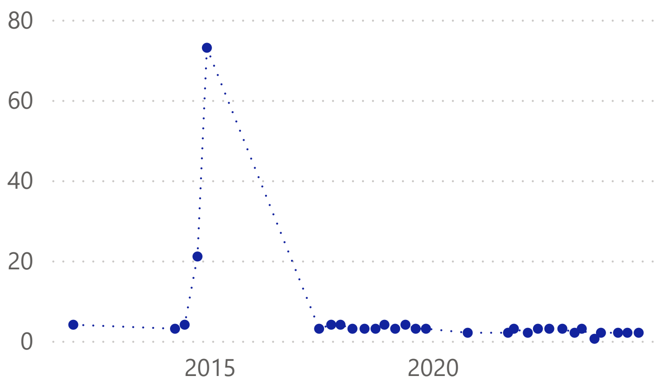
Potassium (filtered) (mg/L)



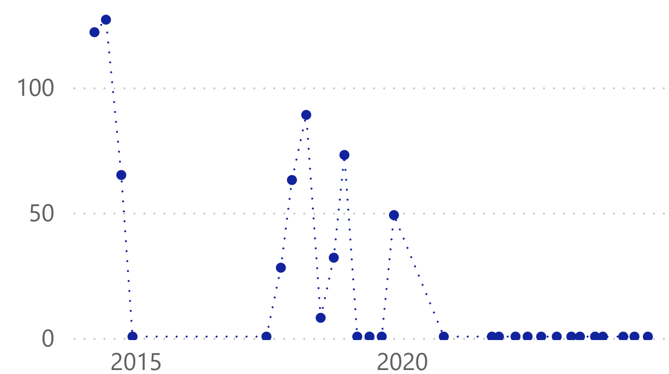
Sodium (filtered) (mg/L)



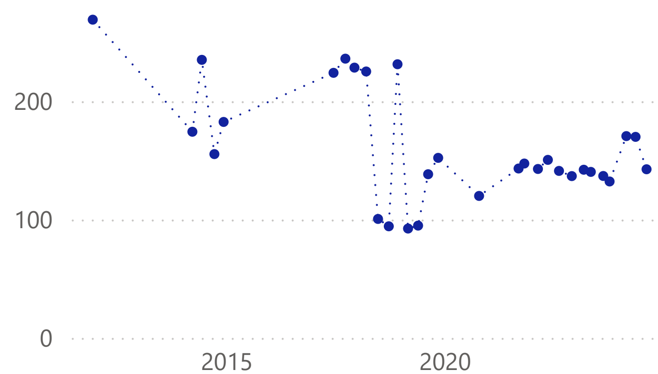
Sulphate as SO4 (mg/L)



Alkalinity (Carbonate as CaCO3) (mg/L)



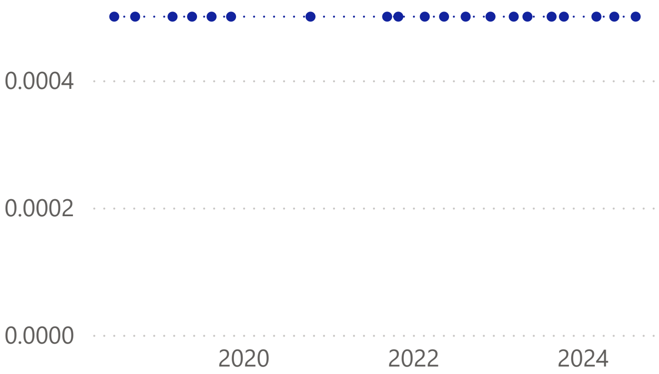
Alkalinity (Bicarbonate as CaCO3) (mg/L)



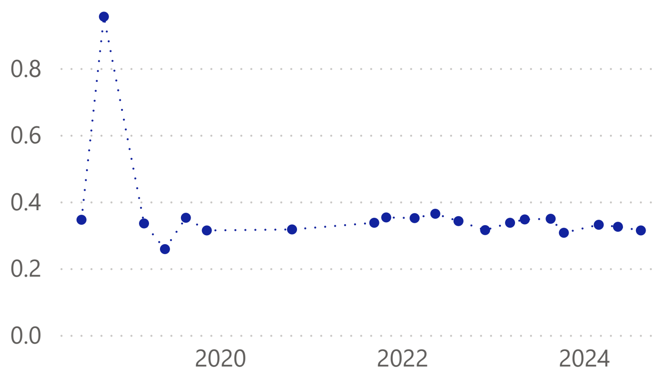
Hutton Sandstone

Irtalie 1

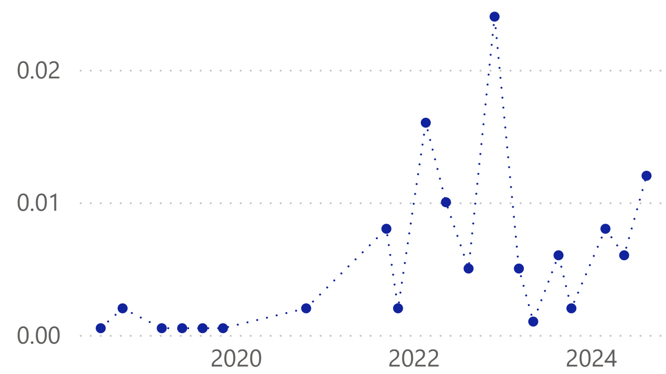
Arsenic (filtered) (mg/L)



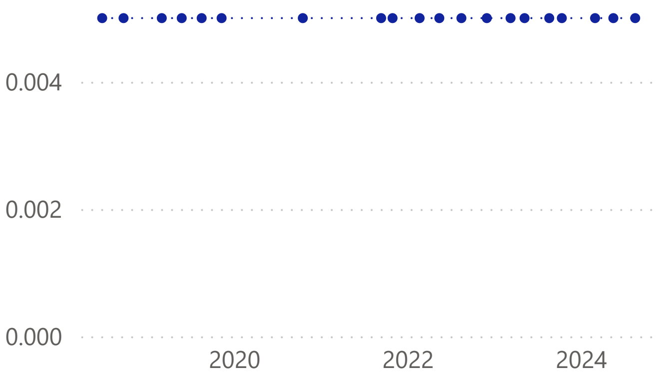
Barium (filtered) (mg/L)



Copper (filtered) (mg/L)



Vanadium (filtered) (mg/L)



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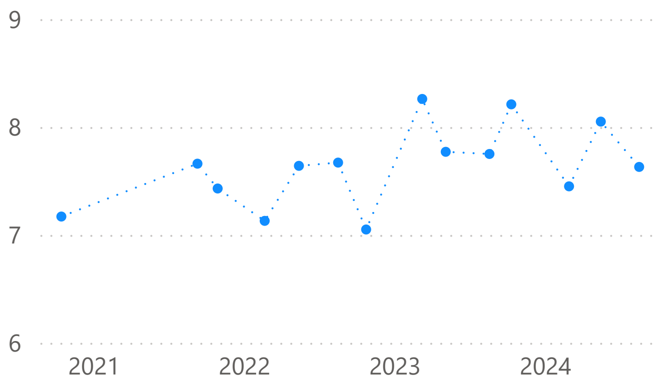
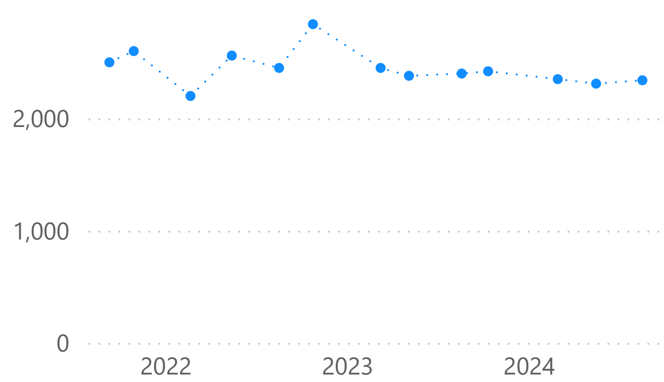
Ballera West 2

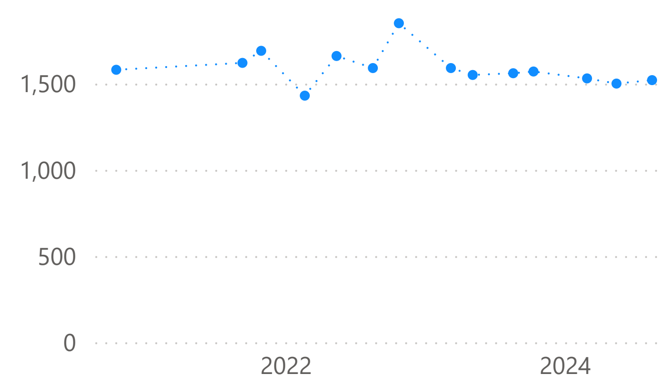
pH (Lab)



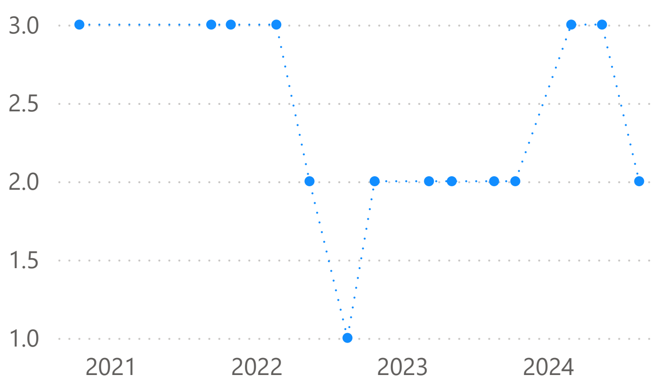
Electrical Conductivity (uS/cm)



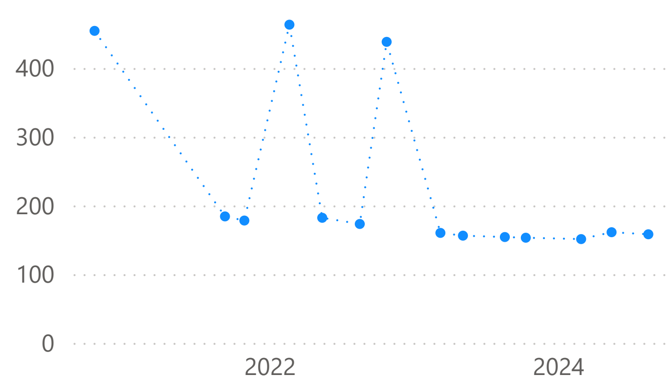
Total Dissolved Solids (Calc.) (mg/L)



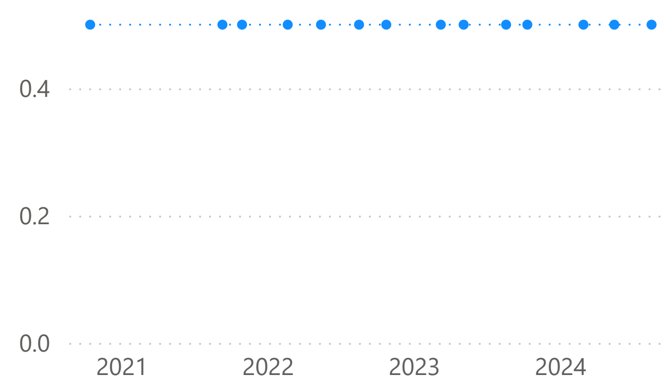
Calcium (filtered) (mg/L)



Chloride (mg/L)



Magnesium (filtered) (mg/L)



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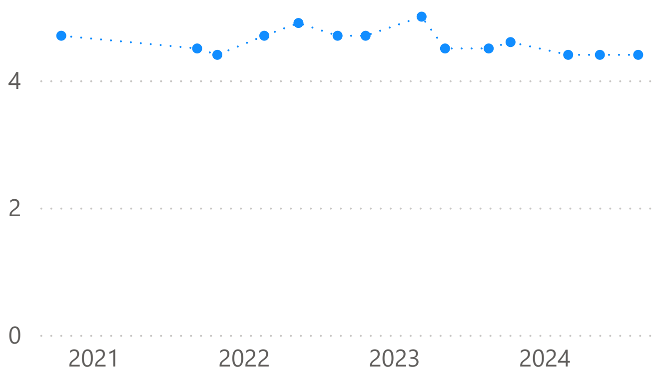
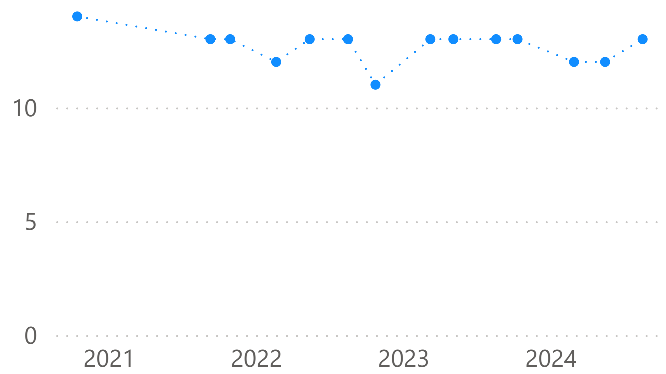
Ballera West 2

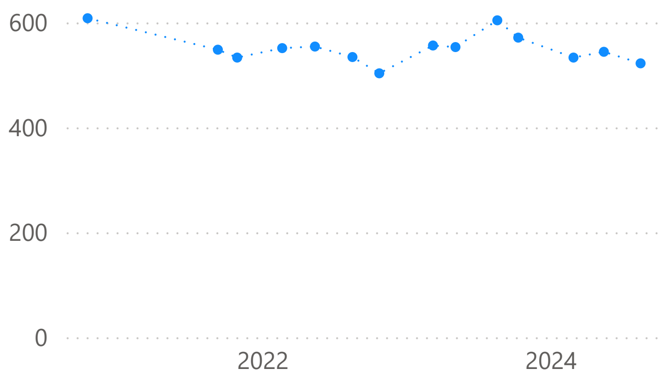
Fluoride (mg/L)



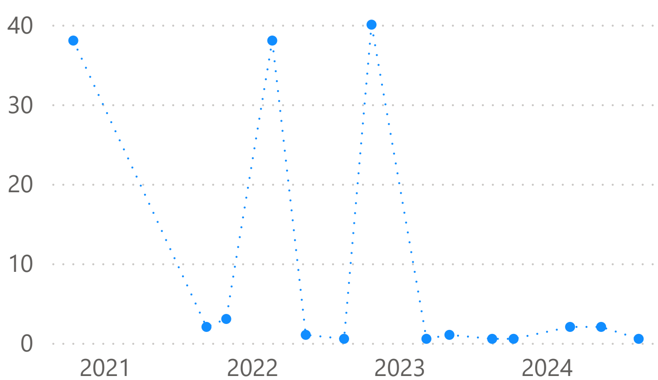
Potassium (filtered) (mg/L)



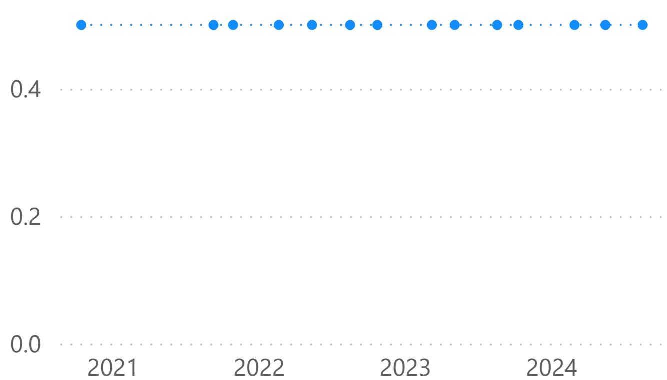
Sodium (filtered) (mg/L)



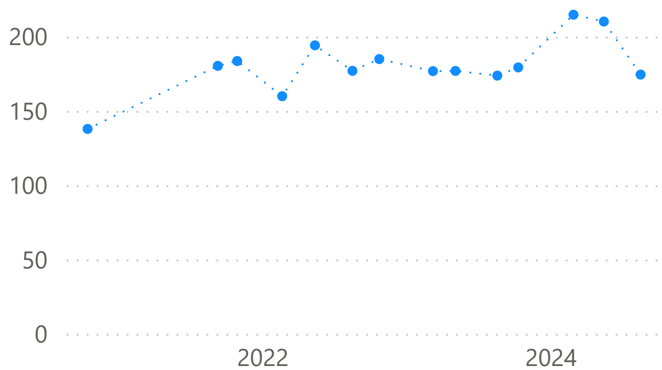
Sulphate as SO4 (mg/L)



Alkalinity (Carbonate as CaCO3) (mg/L)



Alkalinity (Bicarbonate as CaCO3) (mg/L)



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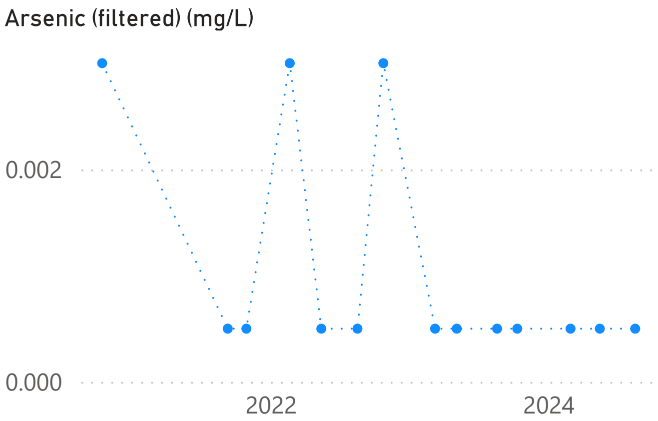
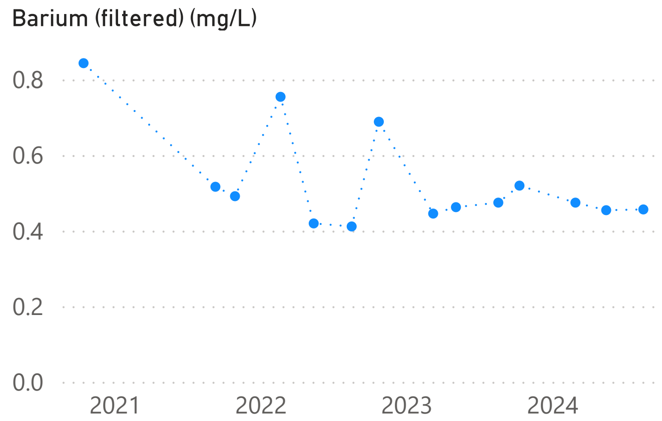
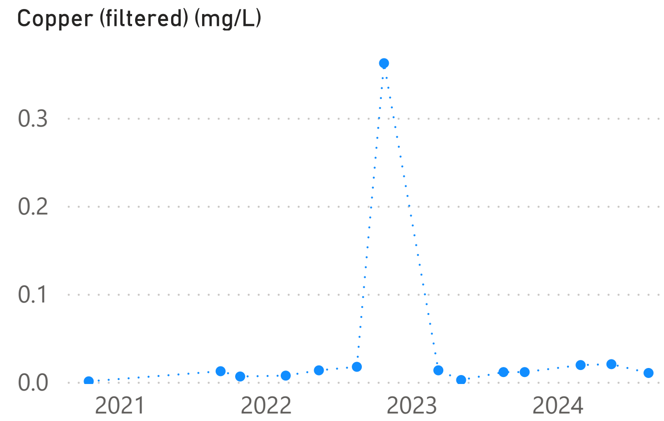
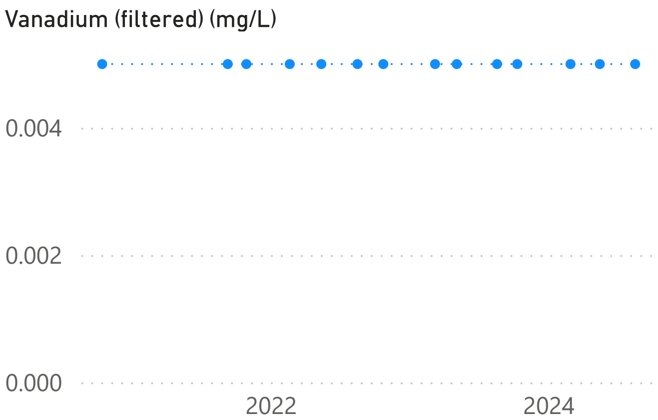
Ballera West 2









APPENDIX II

Oil and Gas Wells Included in The Model Predictions

Santos Acreage	IAA Gas Wells (Count)	IAA Oil Wells (Count)	LTAA Wells Gas (Count)	LTAA Wells Oil (Count)
ATP 1189	19	1	23	1
PCA 272	2		2	
PCA 281	0		1	
PL 1013	6		6	
PL 1016	1		1	
PL 1027				1
PL 1029				7
PL 1046	2	5	2	5
PL 1047	1		2	
PL 1051	0		1	
PL 1054	1		1	
PL 1055	4		4	
PL 1058	5		5	
PL 1060		6		8
PL 1073				2
PL 1105	1		2	
PL 1117				1
PL 112	13		15	
PL 1186	1		1	
PL 131	27		33	
PL 134	2		3	
PL 140	2		2	
PL 144				1
PL 145	4		4	
PL 146	3		9	
PL 147			2	
PL 148	4		4	
PL 150	12		13	
PL 151	4		8	
PL 153			3	
PL 155	7		11	
PL 169		2		2
PL 170		6		6
PL 175	1		1	
PL 177	6		7	
PL 187	1		1	
PL 23		29		36
PL 24		3	1	4
PL 25		1	2	2
PL 254	3		3	
PL 26	1	2	5	2

Santos Acreage	IAA Gas Wells (Count)	IAA Oil Wells (Count)	LTAA Wells Gas (Count)	LTAA Wells Oil (Count)
PL 287	3		3	
PL 288	1		1	
PL 29		3		3
PL 295		6		11
PL 301		15		15
PL 302			1	
PL 303		30		33
PL 33				2
PL 34		22		36
PL 35		5		8
PL 36		9		12
PL 37	1		1	
PL 38		5		5
PL 39		34		35
PL 495	1		1	
PL 50		3		4
PL 502		7		8
PL 508		5		5
PL 509		15		19
PL 51		10		11
PL 52		15		19
PL 57		19		19
PL 58	6		7	
PL 59	5		5	
PL 60	2		2	
PL 61	7	7	7	7
PL 62	2		2	
PL 63	2		2	
PL 68		1		1
PL 75		3		4
PL 76		2		3
PL 77		5		5
PL 80	13		13	
PL 81	3		3	
PL 84	6		6	
PL 86	1		1	
PPL 12	1		1	
PPL 13	1		1	
PL 1087	9		9	
PL 1119	4		4	
PL 1077	8		8	

Santos Acreage	IAA Gas Wells (Count)	IAA Oil Wells (Count)	LTAA Wells Gas (Count)	LTAA Wells Oil (Count)
PL 1093	5		5	
PL 1143	4		4	
PL 1138	8		8	
PL 1140	4		4	
PL 1139	4		4	
PL 1141		3		3