WESTERN GAS PRELIMINARY REGIONAL ISSUES ASSESSMENT

Bancannia, Pondie Range, Neckarboo and Yathong-Ivanhoe Troughs

Advice to the Advisory Body for Strategic Release

May 2021

Published by NSW Department of Planning, Industry and Environment

dpie.nsw.gov.au

Title: Western Gas PRELIMINARY REGIONAL ISSUES ASSESSMENT- Bancannia, Pondie Range, Neckarboo and Yathong-Ivanhoe Troughs

Subtitle: Advice to the Advisory Body for Strategic Release

Cover image: Landscape within the Pondie Range Trough

Executive Summary

Background and Purpose

The NSW Government is considering whether to release four areas located in western NSW, known as the Bancannia Trough, Pondie Range Trough, Neckarboo Trough, and Yathong-Ivanhoe Trough, for conventional and tight gas exploration. These four areas collectively cover an area of approximately 36,710 square kilometres, or approximately 4.5% of the State.

Under the Strategic Release Framework for Coal and Petroleum Exploration, the Minister with responsibility for the *Mining Act 1992* (the Deputy Premier) must obtain advice from the Advisory Body for Strategic Release (Advisory Body) on whether the areas should be released (either wholly or in part) for exploration. In giving this advice, the Advisory Body must consider the strategic and economic importance of the potential gas resource and relevant social, environmental and economic matters associated with the potential release of the four areas for exploration and/or production.

The Advisory Body has asked the Department of Planning, Industry and Environment (the Department) to prepare a Preliminary Regional Issues Assessment (PRIA) to assist with the consideration of these matters.

In preparing this PRIA, the Department has visited the area, consulted with the community and key stakeholders, and reviewed existing Government data sources. This PRIA updates and expands upon the PRIA originally commenced by the Department in 2018.

The underexplored nature and scale of the four potential release areas means that it is difficult to predict with any certainty what future gas exploration and/or production activities could occur, and the full extent of any potential gas development. Nevertheless, this PRIA has considered general development scenarios that could flow from the release of the four areas for conventional and tight gas exploration, and identified the key issues associated with these scenarios at a regional scale.

Notwithstanding the general nature of these scenarios, the Department is confident that any future gas development would be restricted to small portions of the potential release areas, and that there would be considerable flexibility for siting and designing any development to avoid any significant impacts.

Engagement Outcomes

The Department has examined the issues raised during engagement carefully. Key stakeholders were notified of the PRIA process and provided with an opportunity to provide feedback. Feedback was obtained through a variety of methods, including meetings, emails, phone conversations and completion of an online feedback form.

The Department received feedback from a total of 382 community members, community and industry groups, and local Councils. This included 188 responses to the Department's online form, 218 people in attendance at a community meeting in Ivanhoe, 19 by way of letter or emails and 7 by way of phone conversations or video meetings. Some members of the community provided feedback by multiple avenues.

The large majority of feedback is opposed to any gas exploration in the areas. Local community opposition was based on a broad range of environmental, social and economic concerns. The most commonly raised concerns were:

- potential impacts on groundwater resources, particularly the quality and availability of shallower groundwater resources relied upon by landholders and for town water supply;
- potential impacts on surface water, particularly the health and sustainability of the Darling River;
- potential impacts on Aboriginal values, connection to Country and the community;

- potential interactions with existing agricultural activities;
- ensuring suitable rehabilitation of any disturbance caused by exploration activities;
- potential for social impacts on local communities; and
- greenhouse gas emissions associated with gas extraction and use (and associated potential climate change impacts).

Notwithstanding, some stakeholders recognised the potential employment, economic and infrastructure development opportunities that might result from the release of the areas for gas exploration. There was a recognised need for diversification of industry to reinvigorate the region and maintain the population.

Relevant Findings

While gas exploration and/or production activities would undoubtedly result in some impacts to these areas, the Department has concluded that the existing regulatory and planning framework is sufficiently robust to protect areas that are valuable, and to ensure that any impacts associated with gas exploration and/or production comply with Government policies, guidelines and standards and are appropriately minimised and managed.

The Department has not identified any fundamental environmental, social or economic constraints that would preclude the release of the residual areas for conventional and tight gas exploration and/or development. In this regard the Department notes that:

- The potential release areas are generally sparsely populated, and any gas exploration and production could be sited to avoid and minimise impacts.
- Any future gas production is likely to have socio-economic benefits for the region, households and the State as a whole.
- The gas resource is strategically significant and could support local and export markets.
- Extensive work by the NSW Government and the Australian Energy Market Operator (AEMO) has shown any greenhouse gas emissions are likely to occur irrespective of whether the area is released for exploration as there will continue to be domestic demand for gas for household needs and developing needs for electricity firming capacity. With that said, the Department notes that Scope 3 emissions can be a significant contributor to anthropological climate change, and any future production project would need to include an assessment of the potential impacts to climate change in NSW.
- Although agricultural land uses are important drivers of the regional economy, the land is not highly productive and is used mainly for grazing purposes.
- While the area contains productive aquifers that are associated with the Great Artesian Basin, Darling River, and Lachlan River, independent expert advice from Mr George Gates suggests that there is unlikely to be any measurable impact on these water resources given the depth at which the gas is likely to occur and the many intervening impermeable sedimentary layers between the resource and aquifers.

With that said, the Department notes that parts of the potential release areas are more constrained than others.

In this regard, the Department notes that the Yathong-Ivanhoe Trough and Neckarboo Trough have much higher land and soil capability than the Bancannia Trough and Pondie Range Trough. The southern extent of the Yathong-Ivanhoe Trough and the western extent of the Neckarboo Trough have the highest land and soil capability. The Yathong-Ivanhoe Trough is also the most densely populated of all the potential release areas, the large majority of which is concentrated in Ivanhoe and the associated rural residential land uses. The Yathong-Ivanhoe Trough is also located adjacent to the Willandra Lakes Region World Heritage Area.

The Department heard strong concerns about potential gas exploration from the community, particularly in the Ivanhoe area and from members of the Yathong-Ivanhoe Neckarboo Aquifer Alliance. Given the Yathong-Ivanhoe Trough potential release area is the most densely populated of all prospective areas, this has led to concerns about the impacts of any production on a range of matters including water quality and quantity, conflicts with agricultural land uses, impacts on infrastructure, impacts on health and wellbeing and more. This community feels that they are unlikely to benefit from any gas exploration as it is relatively isolated from other centres and does not have an existing employment base in the resources sector.

While all four troughs have suitable geological features to suggest prospectivity for conventional and tight gas resources, they are underexplored and further exploration would be required to determine whether these areas host economic resources.

This means that there is no certainty about whether further exploration in these areas would lead to commercial gas production. The Department recognises that this has the potential to create uncertainty for the community that would continue for the 6 years or more of exploration and will make it difficult to anticipate or plan for the implications of any future development should the areas be released.

Recommendations

Given the large volume of land being considered for release in this instance, the Department considers that there is an opportunity to balance some of these issues, and to prioritise the release of some areas to avoid some of the constraints and avoid unnecessarily prolonging community uncertainty in particular areas.

The Department recommends that the Bancannia Trough and Pondie Range Trough potential release areas could be prioritised and released in whole and that the Yathong-Ivanhoe Trough and Neckarboo Trough potential release areas could be released in part (**Figure 1**).

The Department considers that the southern extent of the Yathong-Ivanhoe Trough and the western extent of the Neckarboo Trough should form the lowest priority for any release given the considerations outlined above. These portions of the release areas could be reassessed for release at a later date informed by the outcomes of exploration data and environmental and social performance of activities in the other areas proposed for release.

Areas in the northern extent of the Yathong-Ivanhoe Trough (north of the Yathong-Ivanhoe Nature Reserve) and in the eastern extent of the Neckarboo Trough are more strategically significant due to proximity to the Moomba Sydney Gas Pipeline and the town of Cobar, and could be considered a higher priority than other parts of these troughs. The Department considers that the Cobar local government area is more likely to benefit from the development of any gas resource in the future than Ivanhoe noting that it has a greater population, greater rental capacity, and an existing employment base in the resource sector.

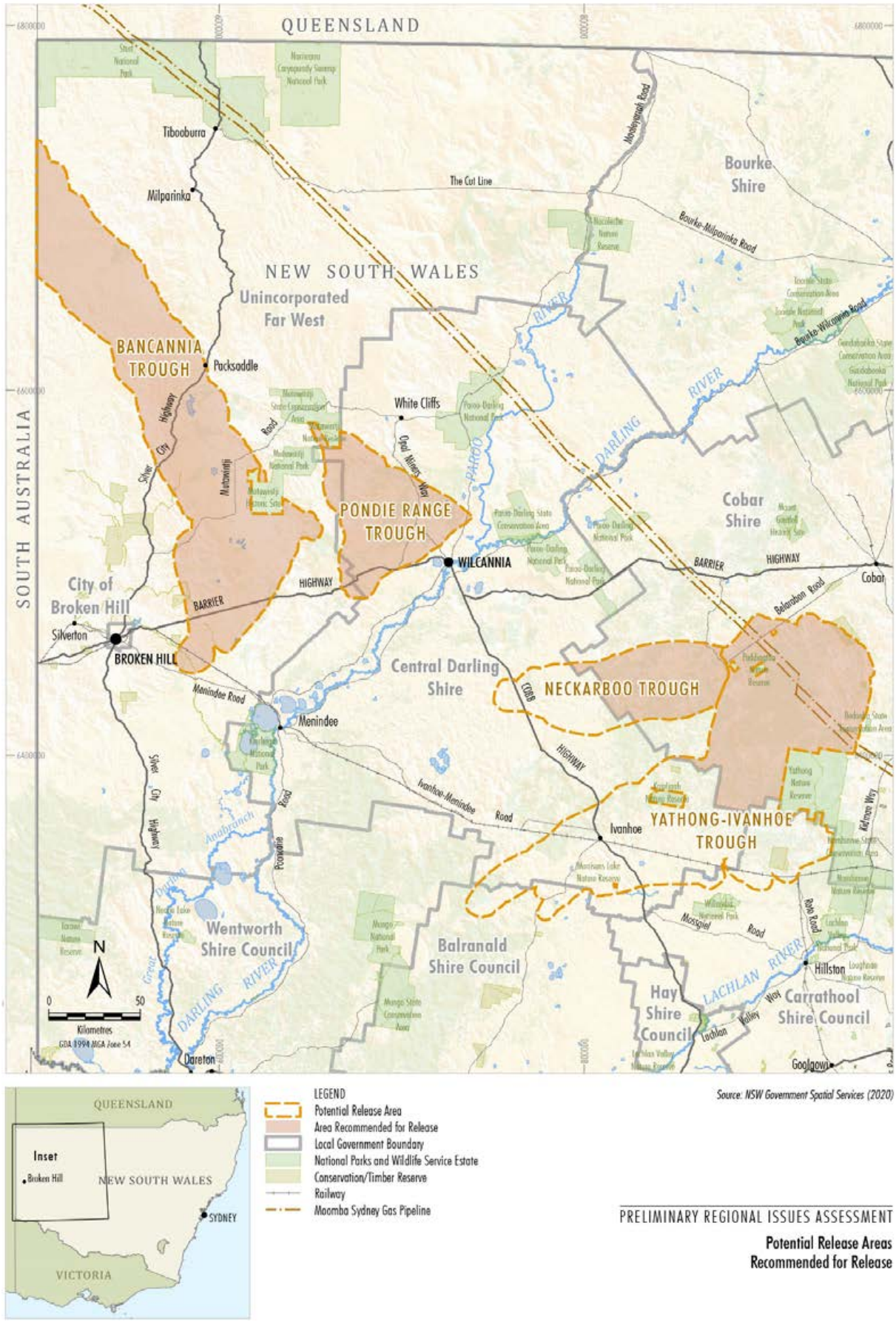


Figure 1: Potential Release Areas Recommended for Release

The Department has also identified several issues that should be considered in any future exploration or development assessment process if the four areas are released for gas exploration and production.

These issues include:

- the implementation of a transparent plan for consultation with the Aboriginal community about proposed activities and potential opportunities;
- the need to minimise impacts on Class 3 and 4 agricultural land where possible;
- the need to avoid conflicts with areas of conservation value, including land voluntarily protected (or to be protected) under a Conservation Agreement or Biodiversity Stewardship Site Agreement;
- the need to continue strict regulation of hydraulic fracturing activities, including continued enforcement of the ban on harmful chemicals known as BTEX and the requirement for stringent testing and reporting protocols; and
- the collection of suitable groundwater data to improve knowledge of the area and provide a sound basis for any future environmental assessment.

In the event that the southern extent of the Yathong-Ivanhoe Trough is released in the future, the Department recommends:

- a 2km buffer zone from any land zoned or identified as Residential (R1, R2, R3, R4, R5), Rural Village (RU5) and/or future growth areas in an environmental planning instrument be excised from the Yathong-Ivanhoe Trough release area to avoid amenity impacts including noise, dust and visual impacts on the town of Ivanhoe;
- an appropriate buffer is provided between any exploration or development and the Willandra Lakes Region World Heritage Area to avoid impacts to the curtilage and significance of this heritage item; and
- potential conflicts with the Mawonga Indigenous Protected Area are avoided or managed.

Contents

1.0 Background

1.1 Strategic Release Framework for Coal and Petroleum Exploration

The New South Wales (NSW) Government's Strategic Release Framework for Coal and Petroleum Exploration (the Strategic Release Framework) allows for controlled strategic release and competitive allocation of resource exploration titles in NSW for coal and petroleum (including gas). This framework sets out the process for conducting a Preliminary Regional Issues Assessment (PRIA).

The NSW Government introduced the Strategic Release Framework to provide greater clarity and transparency in decisions about where resource exploration activities may take place. Legislation implementing the Strategic Release Framework was passed by the NSW Government in October 2015.

The key steps and the various NSW Government authorities involved in the Strategic Release Framework are shown in **Figure 2** and **Table 1**.

The NSW Government is considering whether to release the Bancannia Trough, Pondie Range Trough, Neckarboo Trough, and Yathong-Ivanhoe Trough for conventional and tight gas exploration.

Under the Strategic Release Framework, the Advisory Body for Strategic Release (ABSR) will make a recommendation to the Minister with responsibility of the *Mining Act 1992* (the Deputy Premier) on whether the areas should be released (either wholly or in part). In making this recommendation, the ABSR will consider initial Resource Assessments prepared by the Geological Survey of NSW and this PRIA.

1.2 Preliminary Regional Issues Assessment

This Preliminary Regional Issues Assessment (PRIA) has been prepared for the Bancannia Trough, Pondie Range Trough, Neckarboo Trough, and Yathong-Ivanhoe Trough areas located in western NSW.

This PRIA outlines the advice of the Department of Planning, Industry and Environment (the Department) to the ABSR under the Strategic Release Framework on social, environmental and economic opportunities and constraints associated with releasing these areas for conventional and tight gas exploration and/or production.

In 2018, the Department commenced the preparation of a PRIA for the potential release of conventional gas resources within the Bancannia Trough and Pondie Range Trough. This was placed on hold and never finalised. This PRIA expands on the 2018 work to identify any new issues associated with both conventional and tight gas exploration and production in the Bancannia Trough and Pondie Range Troughs, as well as the Neckarboo Trough and Yathong-Ivanhoe Trough.

The PRIA relies on available data obtained from relevant local, State and Commonwealth Government agencies and has been developed based on engagement with interested and potentially impacted stakeholders (see **Section 4.0**).

The development of this PRIA focused on:

- engaging with the community to gain knowledge on matters of interest and concern;
- collecting relevant data to identify key issues, opportunities and constraints associated with releasing the areas; and
- examining the potential issues identified to inform the decision-makers on whether or not to release the areas for exploration, and the terms of any release.

If the Deputy Premier (and subsequently the NSW Cabinet) elect to proceed with inviting applications for exploration licences in the potential release areas, any exploration licences, if granted, would be issued under the *Petroleum (Onshore) Act 1991*.

Any future proposed gas production would also be subject to a comprehensive triple-bottom-line merit assessment under the *Environmental Planning and Assessment Act 1979* (EP&A Act), including extensive consultation with the community and government agencies and detailed technical environmental assessment (see **Section 3.6**).

The PRIA is an issues identification process, and does not pre-empt the assessment or determination of any future applications for conventional or tight gas exploration activities and/or production.

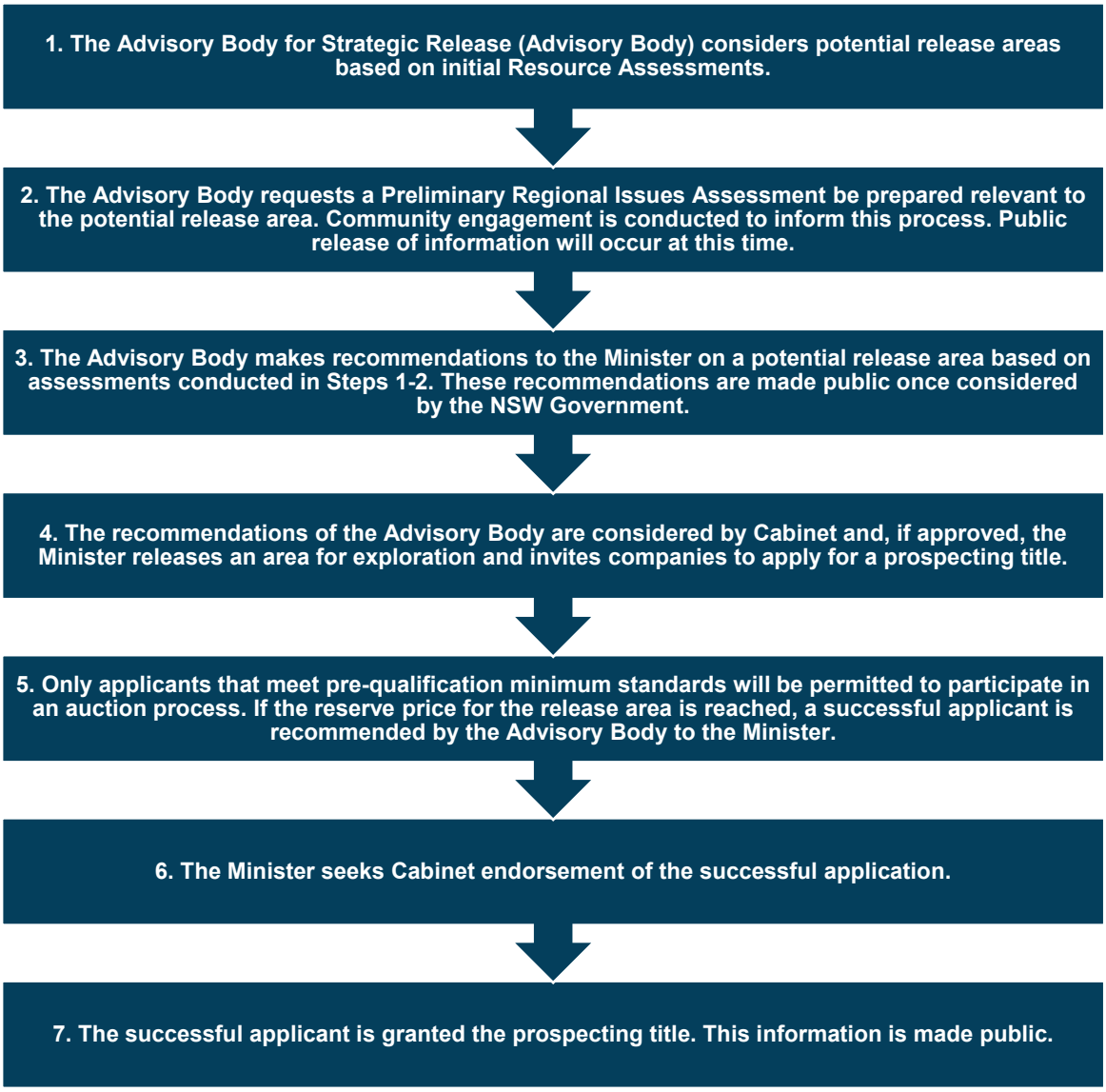


Figure 2: Steps in the Strategic Release Framework

Table 1: Key Authorities Involved in the Strategic Release Framework

Authority	Role
Advisory Body for Strategic Release (An interagency group with an independent Chair)	Recommends to the Minister where, when and how coal and petroleum resources should be released for exploration, based on whole-of-Government advice and assessments.
Department of Planning, Industry and Environment – Planning and Assessment	Undertakes the PRIA to inform the Advisory Body about environmental, economic and social matters.
Department of Regional NSW – Mining, Exploration and Geoscience	Prepares initial resource assessments identifying prospective areas for gas or coal. Oversees the Strategic Release Framework and the granting of exploration licences.
Minister with responsibility of the *Mining Act 1992* (the Deputy Premier)	Recommends to Cabinet the areas for consideration based on the advice of the Advisory Body for Strategic Release.
Cabinet	Reviews Ministerial recommendations for granting of exploration licences and provides endorsement where appropriate.

1.3 Potential Release Areas

The potential release areas are located in far Western NSW and collectively cover an area of approximately 36,710 square kilometres (km^2). The potential release areas are:

- **Bancannia Trough** - located approximately 75 km east of Broken Hill extending northwest, over an area of approximately 13,160 km^2 that is 40 km wide by 230 km long;
- **Pondie Range Trough** - located approximately 5 km northwest of Wilcannia extending west, over an area of approximately 4,000 km^2 that is 40 km wide by 80 km long;
- **Neckarboo Trough** - located approximately 80 km north of Ivanhoe and 150 km southwest of Cobar, over an area of approximately 4,380 km^2 that is 30 km wide by 125 km long; and
- **Yathong-Ivanhoe Trough** - located south of Cobar, extending southwest to the west of Ivanhoe, over an area of approximately 15,170 km^2 that is 210 km wide by 170 km long. This area includes the town of Ivanhoe.

The extent of the potential release areas is shown in **Figure 3**.

The potential release areas have been identified by the Geological Survey of NSW and are based on a buffer of approximately 4 km from the geological extent of the troughs. The potential release areas exclude:

- land within 4 km of the township of Wilcannia;
- land within a Nature Reserve or Conservation Area (Mutawintji Nature Reserve, Paddington Nature Reserve, Morrison's Lake Nature Reserve, Kajuligah Nature Reserve, Nombinnie Conservation Area, and Yathong Nature Reserve); and
- land within a National Park (Mutawintji National Park).

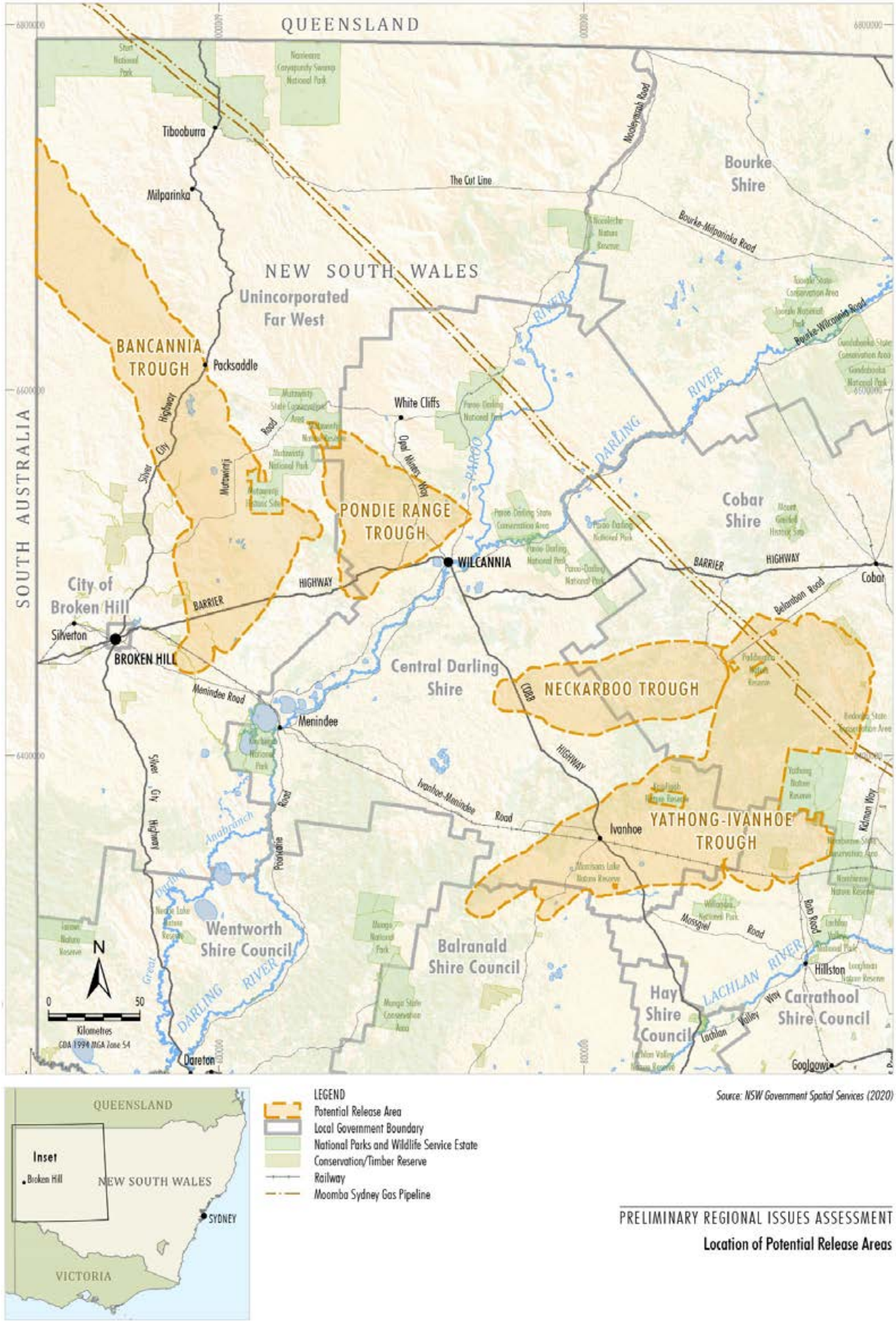


Figure 3: Location of Potential Release Areas

2.0 Overview of the Gas Resources

The potential release areas occur in a geological formation called the Darling Basin, which is a sedimentary basin in western NSW (**Figure 4**). The Darling Basin is the largest onshore basin in NSW and covers an area of approximately 100,000 km^2. The Basin is comprised of 11 sub-basins (troughs), including the Bancannia Trough, Pondie Range Trough, Yathong-Ivanhoe Trough and Neckarboo Trough.

The Eromanga Basin (part of the Great Artesian Basin) and Murray Basin overlap with the Darling Basin (**Figure 4**) as described further in **Section 5.1**.

2.1 History of Gas Exploration

Exploration in the Darling Basin began in 1956, reaching a peak in the 1960s before declining. Since the late 1990s, the Geological Survey of NSW and Geoscience Australia have conducted seismic surveys and drilling to assess the potential for gas and other petroleum resources in the region.

Several petroleum exploration licences have been granted over parts of the Bancannia Trough, Pondie Range Trough, Neckarboo Trough and Yathong-Ivanhoe Trough in the past (see **Appendix A**). Previous exploration activity is shown in **Figure 5** to **Figure 8**.

Modern data processing methods have enabled older seismic data to be used as a more accurate tool for exploration and identifying potential gas resources.

2.2 Petroleum Resource Potential

The Bancannia Trough, Pondie Range Trough, Neckarboo Trough and Yathong-Ivanhoe Trough are considered 'frontier basins' with respect to gas and other petroleum exploration. This means that they are underexplored relative to other parts of NSW.

The resource assessment completed by the Geological Survey for NSW suggests that the four potential release areas are prospective for both tight gas and conventional gas.

A conventional gas resource occurs where there are reservoirs of gas that are trapped between impermeable layers of rock. In this case, gas can generally be extracted using conventional drilling methods. Tight gas occurs in more complex geological formations such as reservoirs with very low permeability. The low permeability of these reservoirs limits the ability for gas to migrate using conventional drilling methods. Therefore, different methods are required to extract tight gas such as horizontal drilling and hydraulic fracturing.

A petroleum resource requires four main elements including a source rock, which contains the matter to commence the process of petroleum formation, a reservoir, which is where the petroleum accumulates after migrating from the source rock, and seals and traps, which are features that prevent the escape of petroleum.

Geological Survey of NSW has advised that all four elements of a petroleum deposit appear to be present in the Bancannia Trough and Neckarboo Trough. All elements are potentially present in the Pondie Range Trough and Yathong-Ivanhoe Trough, however more exploration is needed to confirm that all elements are present.

Although exploration wells have been drilled within parts of each potential release area, none have intercepted potential petroleum 'traps' to date.

The four potential release areas are not prospective for coal seam gas. While conventional gas is stored in porous rock formations under high pressure and capped by impermeable rock, coal seam gas is found in coal seams attached to the coal with gas stored under water pressure. The water that is naturally present with coal seam gas requires extraction to access these gas resources. The geological formations that may support coal seam gas are not present in the potential release areas.

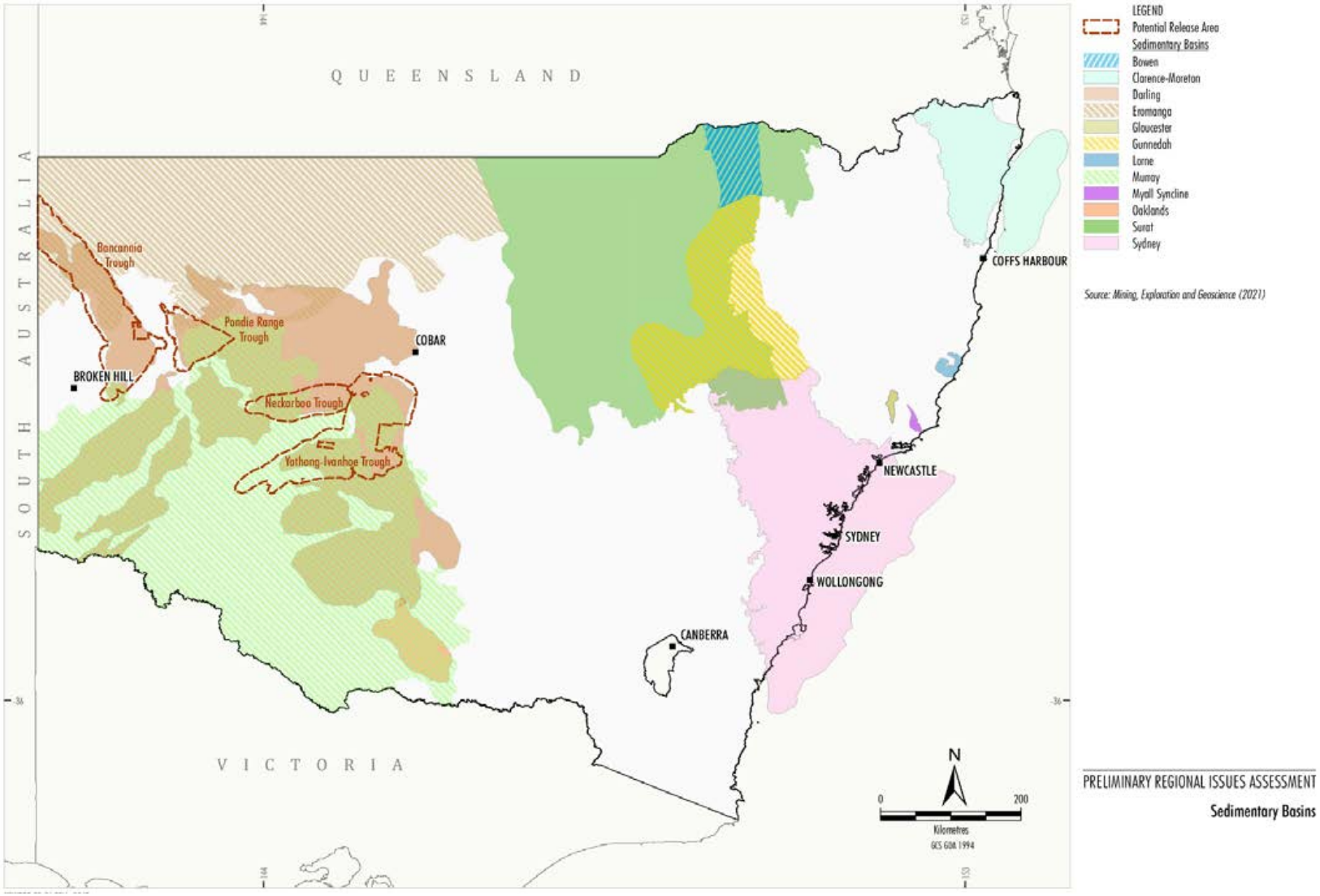


Figure 4: Major Sedimentary Basins in NSW

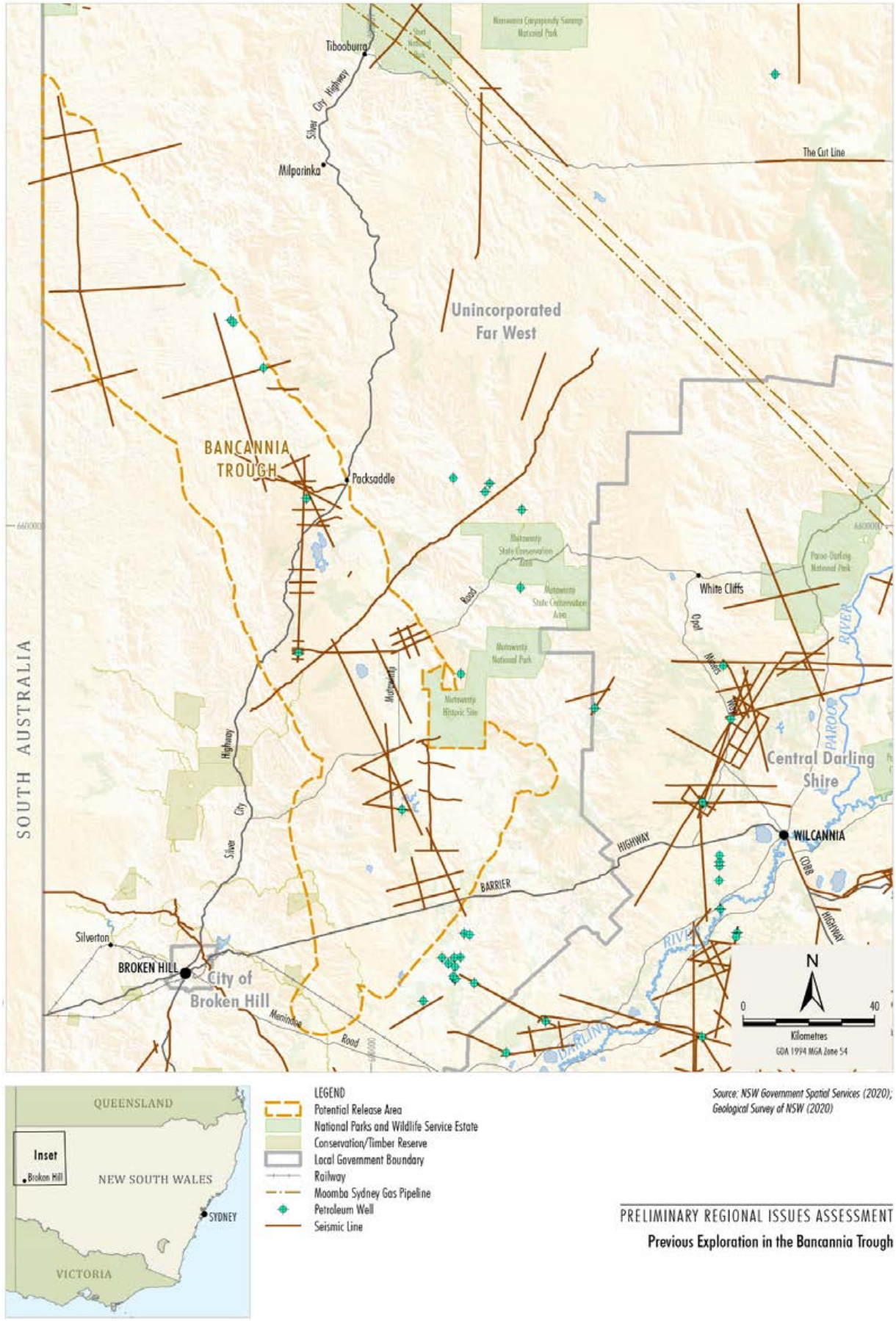


Figure 5: Previous Exploration in the Bancannia Trough

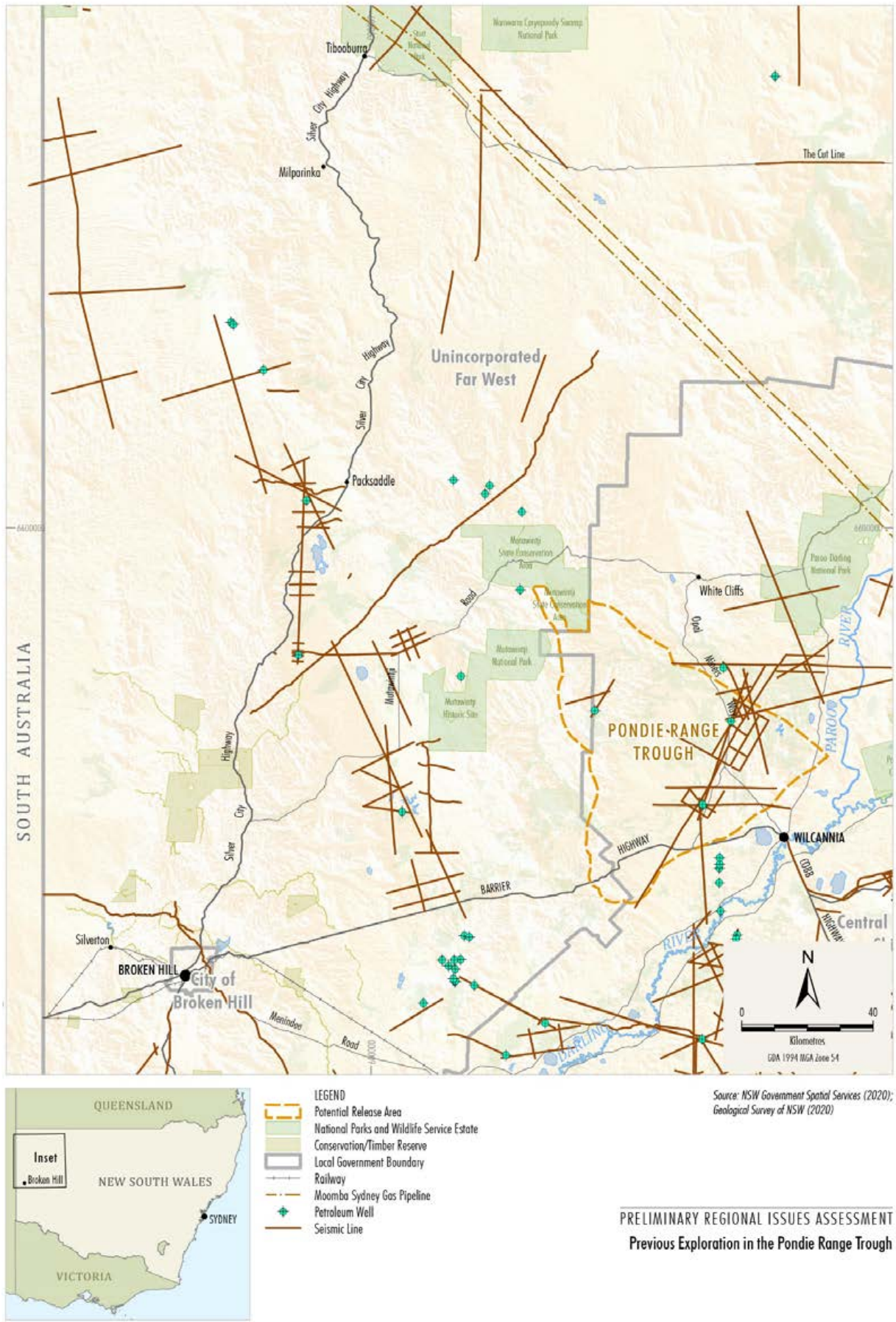


Figure 6: Previous Exploration in the Pondie Range Trough

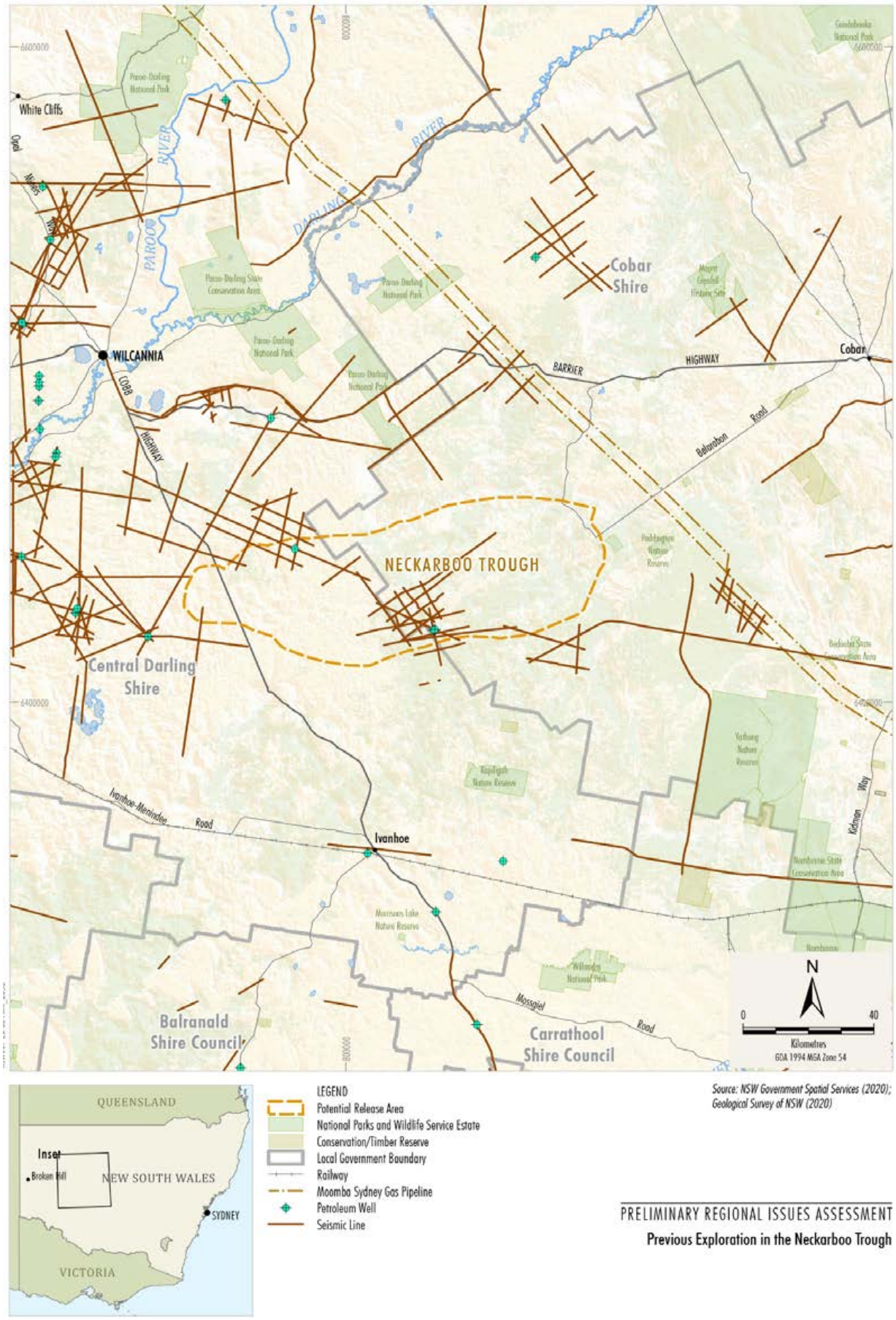


Figure 7: Previous Exploration in the Neckarboo Trough

Figure 8: Previous Exploration in the Yathong-Ivanhoe Trough

2.3 Development Scenarios

Exploration

The purpose of exploration within the potential release areas would be to locate areas where petroleum resources may be present, to establish the quality and quantity of those resources, and to investigate the viability of extracting the resources.

Exploration licences would have an initial term of up to 6 years if granted overall, or part, of the potential release areas.

The nature and location of any exploration activities would be determined by the tenement holder and would likely be conducted in stages. Initial exploration generally involves activities with limited disturbance, such as airborne surveys and ground-based surveys. Exploration drilling would also be conducted if the initial exploration activities indicate that further exploration is warranted.

The tenement holder would need to reach relevant access agreements with landholders for its exploration activities and obtain relevant approvals for exploration activities under Part 5 of the EP&A Act (see **Section 3.6**).

Production

Gas exploration does not always lead to gas production. In many cases, it does not result in development of a gas production project. In cases where development does proceed, it is typically a smaller portion of the larger area where exploration has occurred.

As this PRIA occurs at an early stage in the evaluation of the potential gas resource, knowledge of the likelihood and nature of any future gas extraction and production is limited.

However, any gas production would be expected to include the drilling and operation of wells. This could involve extraction by conventional drilling methods, in the case that conventional gas resources are identified, or horizontal drilling and hydraulic fracturing in the case that tight gas resources are identified.

Hydraulic fracturing, or 'fracking' involves the injection of water, sand and chemicals at high pressure down and across into horizontally drilled wells below the surface. The pressurised mixture causes the rock layer containing the gas resource to crack. These fissures are held open by the sand particles so that the gas from the rock layer can flow up the well. Consequently, tight gas extraction may involve the use of material amounts of water to stimulate the release of gas (see **Section 5.1**).

Development of gas wells, both for the extraction of tight gas and conventional gas resources, would typically involve:

- establishing the well pad (generally a few hectares);
- drilling operations (drilling several kilometres deep);
- casing of the well;
- installation of a wellhead at the top of the well (which controls the flow); and
- well completion.

It is anticipated that the following infrastructure would also be required to support any gas production activities:

- a network of pipelines from the wellheads to processing facilities (known as gathering systems);
- gas, liquid hydrocarbon (condensate) and water separation facilities;
- gas compression and cooling systems;
- condensate handling facilities;
- other gas processing facilities;

- water extraction and treatment facilities for managing water that is separated from condensate and also for use in hydraulic fracturing (in the event that tight gas resources are identified);
- pipeline connection(s) to the Moomba Sydney Gas Pipeline;
- accommodation and administration facilities; and
- utilities and other supporting infrastructure.

Gas extraction wells can have a lifecycle of several decades. Following the end of a well's productive life, the well would be decommissioned and all associated disturbance areas rehabilitated.

Any future proposed gas production activities in the potential release areas would be subject to a merit assessment by the NSW Government, which would include significant community consultation.

3.0 Strategic Planning Context

3.1 Regional and Sub-Regional Context

The potential release areas are located in the following local government areas (see **Figure 9** and **Figure 10**):

- **Bancannia Trough** - Unincorporated Far West (not governed by a local council). The City of Broken Hill local government area is located to the southwest of the Bancannia Trough.
- **Pondie Range Trough** - Primarily the Central Darling Shire, with a small western portion within the Unincorporated Far West.
- **Neckarboo Trough** - Western portion within the Central Darling Shire and eastern portion within the Cobar Shire.
- **Yathong-Ivanhoe Trough** - Primarily Cobar Shire (northern portion) and Central Darling Shire (western portion), with small southwestern and southeastern portions within Balranald Shire and Carrathool Shire, respectively.

Key population and services centres in proximity to the potential release areas include Broken Hill (population 17,814[1]), Wilcannia (745), Ivanhoe (327), Cobar (3,990) and Hillston (1,465). Other communities and localities include Packsaddle, Milparinka, Silverton, White Cliffs and Menindee. Aboriginal people make up a larger proportion of the population in western NSW (between approximately 6% and 30%) compared to all of NSW (2.9%) (see **Section 5.6**).

Broken Hill is located approximately 32 km southwest of the southern extent of the Bancannia Trough and 277 km south of the northern extent. It also located between 125 km and 208 km west of the Pondie Range Trough. Wilcannia is southeast of the Pondie Range Trough (between 10 km and 110 km) and northwest of the Neckarboo Trough (between 70 km and 165 km). Cobar is northeast of the Neckarboo Trough (between 98 km and 223 km) and Yathong-Ivanhoe Trough (between 40 km and 296 km). Hillston is between 44 km and 194 km southeast of the Yathong-Ivanhoe Trough while Ivanhoe is located within the western portion of the potential release area.

Land use in and around the potential release areas is characterised by grazing (sheep, cattle, goats), dryland and irrigated agriculture, mining, tourism and nature conservation uses. The area is classified as arid to semi-arid rangelands and has less than 400 mm annual average rainfall.[2]

Key natural features in and around the potential release areas include the Barrier Ranges west of the Bancannia Trough; the Darling River and its tributaries the Paroo River and Barwon River south and east of the Bancannia Trough and Pondie Range Trough; the Lower Lachlan River south of the Yathong-Ivanhoe Trough; the Mutawintji National Park and associated protected areas which border the Bancannia Trough and Pondie Range Trough; as well as the Yathong-Ivanhoe Nature Reserve and the Willandra Lakes Region World Heritage Area which sit east and south of the Yathong-Ivanhoe Trough, respectively.

---

1 https://www.abs.gov.au/websitedbs/D3310114.nsf/Home/2016%20QuickStats
2 http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp.

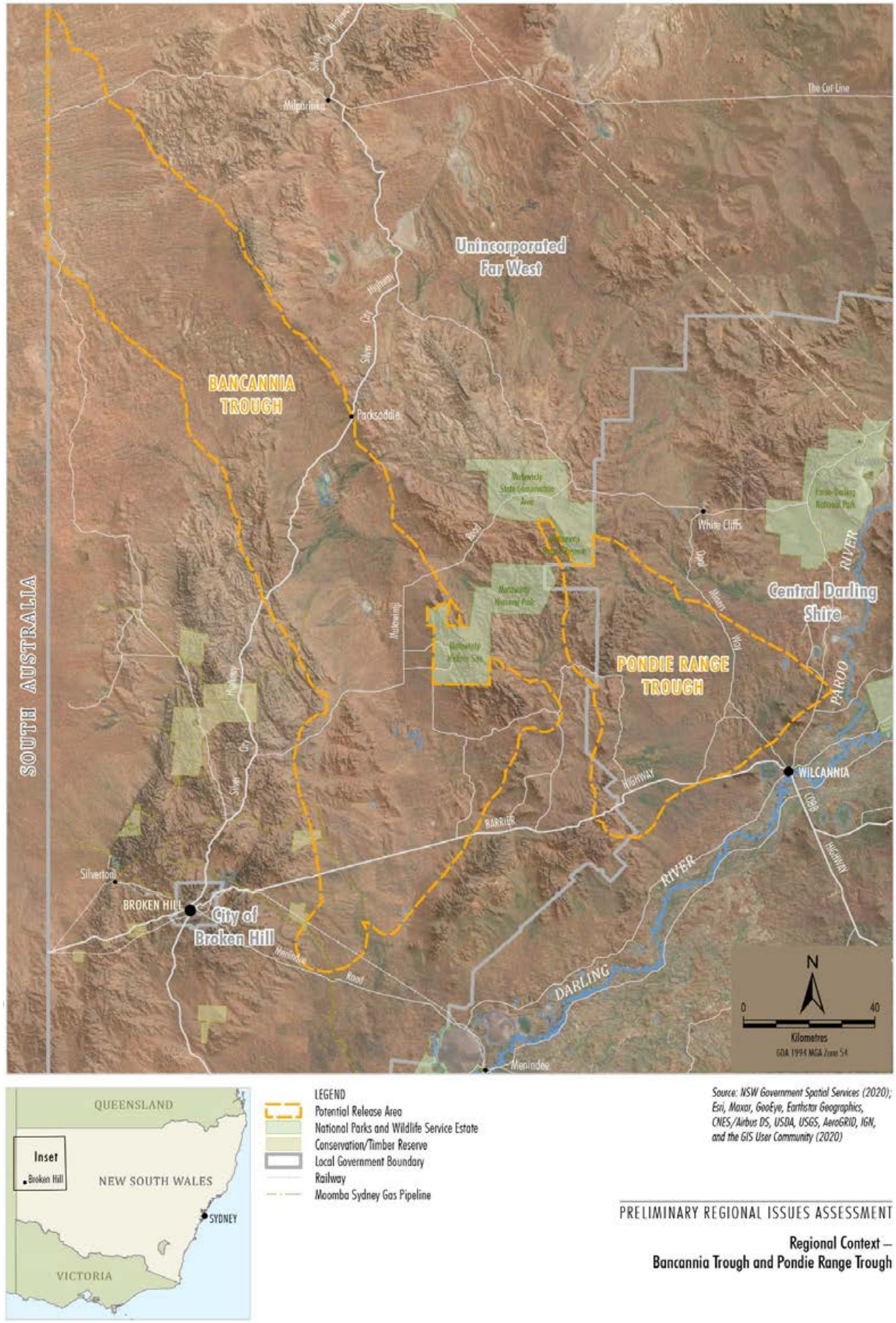


Figure 9: Regional Context - Bancannia Trough and Pondie Range Trough

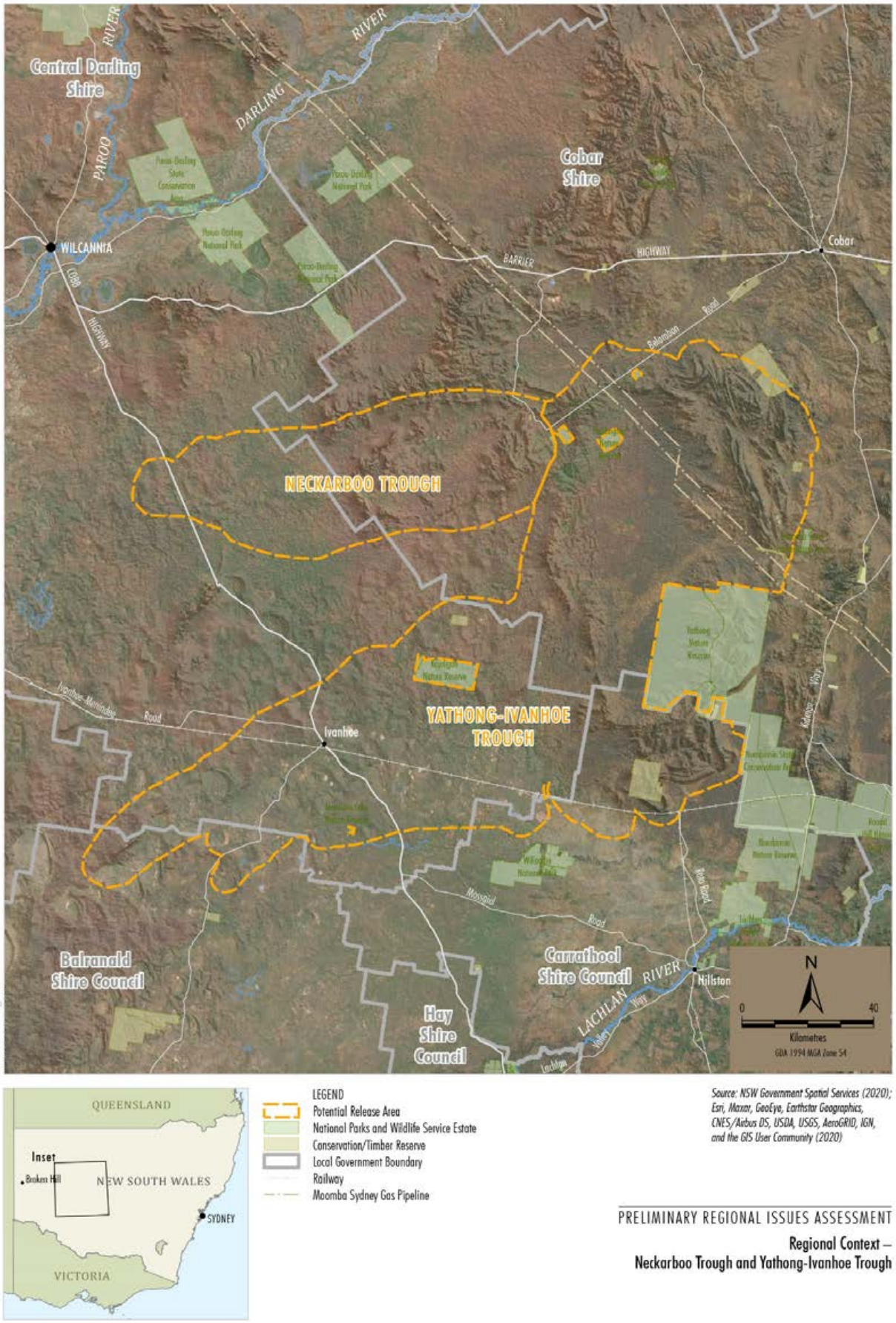


Figure 10: Regional Context - Neckarboo Trough and Yathong-Ivanhoe Trough

The main industries of employment are accommodation and food services, agriculture, forestry and fishing, education and training, health care and social assistance, manufacturing, mining, public administration and safety, and retail trade.

Nearly half (47%) of employment in the Australian Bureau of Statistics (ABS) Broken Hill and Far West Level 3 Statistical Area (SA3) boundary (**Figure 11**) is in health care and social assistance, retail trade, mining, and accommodation and food services[3]. The Broken Hill and Far West SA3 includes all of Bancannia Trough and Pondie Range Trough, part of Neckarboo Trough and Yathong-Ivanhoe Trough, and the key population centre of Broken Hill.

Approximately 54% of employment in the Bourke - Cobar - Coonamble SA3 is in agriculture, forestry and fishing, health care and social assistance, education and training, and mining. The Bourke - Cobar - Coonamble SA3 includes part of Neckarboo Trough and Yathong-Ivanhoe Trough and the key population centre of Cobar (**Figure 11**).

Broken Hill and Cobar host significant mining workforces at local mining operations (e.g. Broken Hill North Mine and Cobar Mine Complex, see **Section 5.3.6**). The mining industry employs 745 people in the Broken Hill ABS Level 2 Statistical Area (SA2), where mining is the third-largest industry of employment behind retail and health services, and 649 people in the Cobar SA2, where mining is the largest employer. This significant existing local workforce is expected to possess a range of skills that are directly transferrable to gas exploration and/or extraction in western NSW.

Employment in the Griffith – Murrumbidgee (West) SA3, which includes part of Yathong-Ivanhoe Trough and the key population centre of Hillston, is mainly in manufacturing, agriculture, forestry and fishing, and retail trade (42% combined).

A small part of the Yathong-Ivanhoe Trough is within the Lower Murray SA3 (**Figure 11**), which is dominated by employment in agriculture, forestry and fishing, health care and social assistance, and retail trade (42% combined).

The main road transport links in the region are the Barrier Highway, Silver City Highway and Cobb Highway. The Barrier Highway is a sealed road that provides a regional connection between Broken Hill, Wilcannia and Cobar. The Silver City Highway is partially sealed and links Broken with Tobooburra and the Queensland border to the north and Mildura to the south. Finally, the Cobb Highway is a partially unsealed road which provides a connection between Wilcannia and Ivanhoe.

Other major/minor roads in the region, such as between Broken Hill and Ivanhoe, and Hillston and Ivanhoe are largely unsealed which limits all-weather road access in these areas.

The Sydney to Adelaide rail route runs through the southern extent of both the Bancannia Trough and Yathong-Ivanhoe Trough. The Sydney to Adelaide rail route will link to the future Melbourne to Brisbane Inland Rail and provide direct rail access to the NSW Government's special activation precincts of Parkes, Wagga Wagga and Moree.

The potential release areas are located in proximity to the Moomba Sydney Gas Pipeline, which crosses through the northern part of the Yathong-Ivanhoe Trough (see **Figure 3**).

[3] Source: 2016 ABS Census, http://itt.abs.gov.au/itt/r.jsp?databyregion

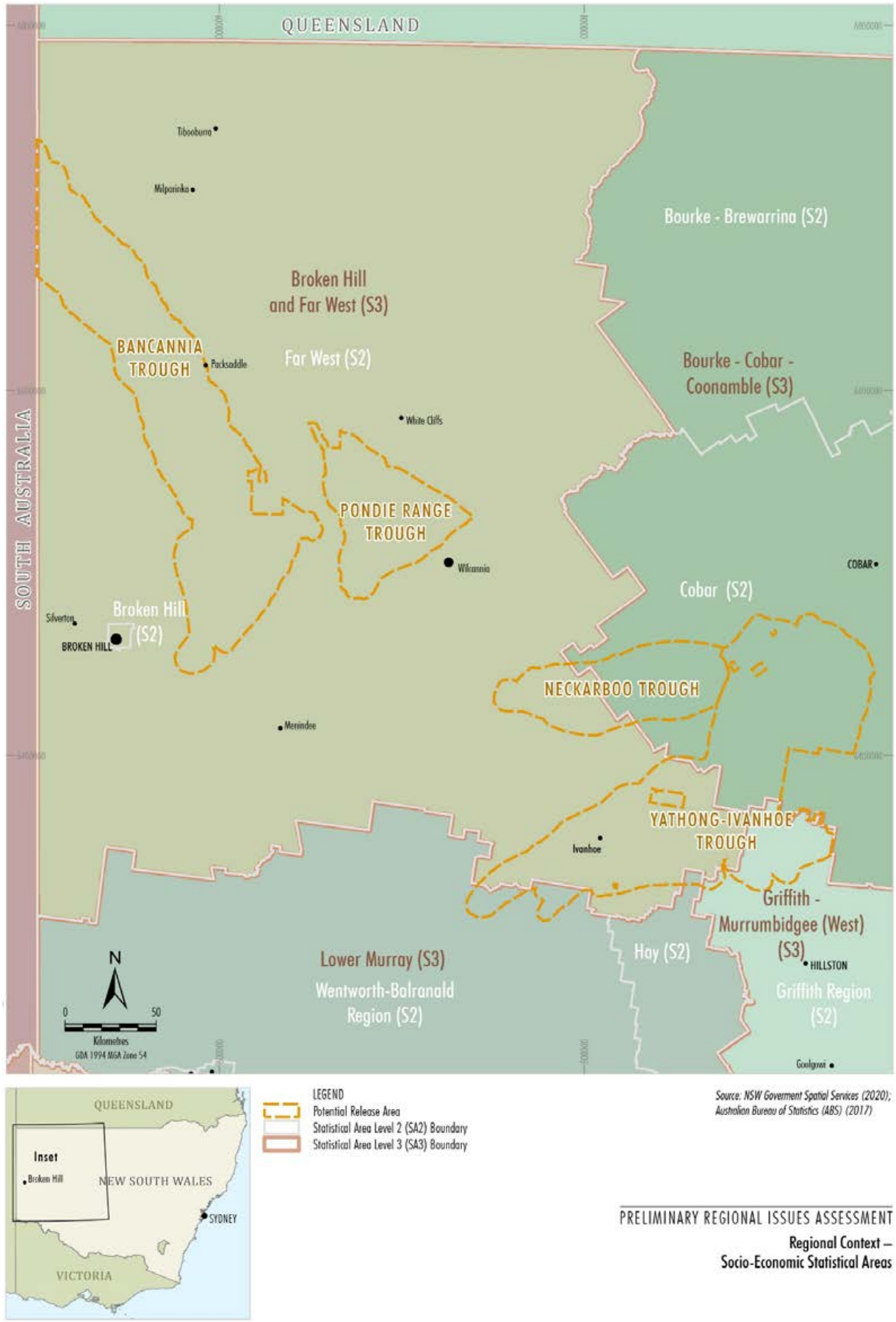


Figure 11: Regional Context – Socio-Economic Statistical Areas

3.2 NSW Gas Plan

The *NSW Gas Plan*, which was released in November 2014, outlines a policy framework for the onshore gas industry. The Plan recognises that the safe and sustainable development of an onshore gas industry in NSW will create significant benefits to households and businesses across the State.

In addition, the *NSW Gas Plan*:

- excludes National Parks from petroleum exploration licences (including gas exploration); and
- establishes the independent Environment Protection Authority (EPA) as the lead regulator for gas exploration and production.

3.3 Gas in Regional NSW

The *Strategic Opportunities for Gas in Regional NSW* statement, released in November 2020, describes how affordable energy and safe, sustainable domestic gas production are important to support NSW industry and help drive economic recovery in regional NSW. The statement outlines the range of activities underway to realise the benefits of additional gas supply across NSW, including examining opportunities for further exploration in western NSW under the Strategic Release Framework.

3.4 NSW Regional Plans

The Department's Far West Regional Plan 2036 (Far West Plan) sets out the strategic vision for the far west region of NSW which includes eight local government areas: Balranald, Brewarrina, Bourke, Broken Hill, Central Darling, Cobar, Walgett and Wentworth. The Unincorporated Area is also located within the Far West region.

The potential release areas are primarily contained within the area covered by the Far West Plan, however parts of the Yathong-Ivanhoe Trough are also covered by the Riverina Murray Regional Plan 2036 (Riverina Murray Plan) which covers 20 local government areas, including Carrathool Shire.

The Far West Plan sets out the strategic vision for the Far West region based on three key goals: a diverse economy with efficient transport and infrastructure networks; exceptional semi-arid rangelands traversed by the Barwon-Darling River; and strong and connected communities.

The Riverina Murray Plan sets out the strategic vision for the Riverina Murray region based on four key goals: a growing and diverse economy; a healthy environment with pristine waterways; efficient transport and infrastructure networks; and strong, connected and healthy communities.

Importantly, both of these plans recognise the importance of mining and resources to the regional economies of the Far West and the Riverina Murray, but also identify the need to manage potential land use conflicts.

The plans also set out a vision for current and future infrastructure and upgrades, such as investment in improving the Barrier Highway from Dubbo to Broken Hill, and sealing of all remaining unsealed sections of the Cobb and Silver City Highways.

3.5 NSW Climate Change Policy Framework

The *NSW Climate Change Policy Framework*, released in November 2016, defines the NSW Government's role in reducing carbon emissions and adapting to the impacts of climate change, and sets policy directions to guide implementation of the framework.

As part of the *NSW Climate Change Policy Framework*, the NSW Government endorses the United Nations Paris Agreement on climate change. The NSW Government is taking action that is consistent with the level of effort to achieve Australia's commitments to the Paris Agreement and complements national action.

The *NSW Climate Change Policy Framework* recognises there are a number of different pathways to reducing greenhouse gas emissions, involving different combinations of action on:

- renewable energy;
- energy efficiency;
- carbon sequestration; and
- emissions savings from other sectors such as agriculture and land use.

The safe and sustainable development of an onshore gas industry in NSW (as outlined in the *NSW Gas Plan*) is not inconsistent with the *NSW Climate Change Policy Framework* and its aspirational targets.

Strategic energy planning by the Australian Energy Market Operator (AEMO) indicates that natural gas will continue to be an important component of the dispatchable energy supply mix for the foreseeable future, particularly as it is 'flexible' (i.e. can be turned on and off quickly), and can complement variable renewable sources at times of low wind and solar availability (e.g. at night).

Importantly, the *NSW Climate Change Policy Framework* does not seek to prevent private development, including gas industries, as a means for Australia to meet its commitments under the Paris Agreement or the long-term aspirational objective of the Framework.

3.6 Regulatory and Planning Framework

The current regulatory and planning framework has been considered during the process of identifying and considering key issues, opportunities and constraints.

The Strategic Release Framework represents the first stage in the exploration and potential development of a gas resource.

If the areas are released for exploration, the NSW Government has processes in place to assess, monitor and manage any impacts associated with gas exploration and production activities.

Assessment of exploration activities would occur under Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Any future proposed gas production activities in the potential release areas would be subject to a detailed merit assessment under the State Significant Development (SSD) provisions of the EP&A Act, which includes significant community consultation.

In addition to the above, the Commonwealth *Native Title Act 1993* provides the framework for the recognition and protection of native title and interaction with holders of native title.

A number of Codes of Practice would apply to exploration activities through conditions imposed on the exploration licence and regulated by the EPA. These Codes of Practice would include:

- Exploration code of practice: community consultation.
- Exploration code of practice: environmental management.
- Exploration code of practice: produced water management, storage and transfer.
- Exploration code of practice: rehabilitation.

The Resources Regulator has released guidance material on drilling practices, most notably the *Guideline for mineral exploration drilling; drilling and integrity of petroleum exploration and production wells*. This Guideline provides information and seeks to inform industry practices.

Exploration

Before exploring for gas, an explorer must first obtain an exploration licence under the *Petroleum (Onshore) Act 1991.* An application for an exploration activity approval is generally accompanied by a Review of Environmental Factors (REF), which provides information about the specific nature and location of exploration activities and how the environmental impacts of the activity will be controlled. An Environmental Impact Statement (EIS) is required if the activity will significantly affect the environment.

In assessing an application for an exploration activity approval, Section 5.5 of the EP&A Act requires the Resources Regulator to 'examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity'. Section 5.5 also requires the Resources Regulator to consider the effects on conservation agreements, BioBanking agreements, wilderness areas, critical habitat, protected fauna and flora and threatened species, populations and ecological communities and their habitats.

Following the completion of the Part 5 assessment process, the Resources Regulator may grant or refuse an application for approval to carry out a particular exploration activity. Any approval will typically be issued subject to terms. These terms will usually require compliance with any commitments made in an REF. Other terms may require the tenement holder to prepare additional plans, undertake specific mitigating measures or limit the proposed activity in some way to minimise harm to the environment.

The assessment and approval of an exploration activity under the *Petroleum (Onshore) Act 1991* does not affect any obligation to comply with the requirements (including any requirement to obtain an approval) under other legislation. Examples of legislation imposing such requirements include the *National Parks and Wildlife Act 1974* (NPW Act), *Protection of the Environment Operations Act 1997*, *Roads Act 1993*, *Water Management Act 2000*, *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and *Native Title Act 1993*.

A petroleum exploration licence would provide the tenement holder with exclusive rights to explore for gas resources within the designated area, but it would not permit gas extraction, nor would it guarantee that a production lease or a planning approval would be granted.

Exploration licences are granted subject to standard and/or special conditions, including strict environmental management conditions to protect native vegetation, fauna, land, water resources, heritage and community values.

Tenement holders are also required to rehabilitate areas disturbed by exploration activities and must provide financial security to cover the likely rehabilitation costs in the event that they default on this obligation.

Development Consent

Future gas production in the potential release areas would be considered State Significant Development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011*. This is because these types of development are major economic developments which are significant from a state-wide social, environmental and economic perspective.

All SSD applications must go through a rigorous merit assessment process in accordance with the mandatory matters for consideration in Section 4.15 of the EP&A Act. An Environmental Impact Statement (EIS) is required for SSD applications which must be prepared in accordance with requirements issued by the Department and include a detailed assessment of the environmental, social and economic impacts of the proposal. The EIS must also be prepared in consultation with the community and government agencies.

In assessing an application for SSD, the Department will publicly exhibit the application which allows the community to have a say on the project before a final decision is made.

For most major resource projects, the Independent Planning Commission is the consent authority and will make the final decision on the merits of a project. Any approval will typically be granted subject to a range of conditions that require the applicant to undertake specific monitoring, management and offsetting measures to minimise and compensate for the residual impacts of the project.

4.0 Community and Stakeholder Engagement

The development of this PRIA was informed by engagement with interested and potentially impacted stakeholders. The engagement process was designed to:

- inform the community and other stakeholders of the scope of the PRIA process, including the Strategic Release Framework, and potential for future exploration and production activities in the four potential release areas;
- identify potential risks, opportunities and constraints; and
- document and report on the input from the community as part of this PRIA.

All feedback from engagement activities conducted as part of the 2018 PRIA process have also been considered in this PRIA.

4.1 Consultation with Public Authorities

The Department has consulted with State and Federal Government agencies in preparing the PRIA, which has included interagency meetings and data sharing. This agency engagement enabled the Department to:

- identify and collate relevant environmental, social and economic data on the four potential release areas; and
- examine available information to categorise and prioritise key issues, opportunities and constraints associated with potentially releasing the areas for gas exploration.

Input has been provided by the Biodiversity and Conservation Group, the Water Group and Crown Lands within the Department; NSW EPA; Department of Primary Industries – Agriculture; Geological Survey of NSW; Geoscience Australia; Department of Premier and Cabinet (including Heritage NSW); Transport for NSW; and Western Local Land Services.

The Department also engaged directly with the relevant local Councils (Central Darling Shire Council, Cobar Shire Council, Broken Hill City Council, Balranald Shire Council and Carrathool Shire Council).

The information received from public authorities has been incorporated and considered in this PRIA, including in the summary of feedback received on key potential risks, opportunities and constraints provided in **Section 4.3**.

4.2 Engagement Activities

Community members and other interested stakeholders were initially notified of the potential release areas and provided with the opportunity to register an interest to participate in the PRIA process. This notification process was designed to understand the level of community interest and tailor engagement options to suit stakeholders' needs.

The process initially included advertisements in local and State papers and notification of landowners and stakeholders through a combination of letters, emails and phone calls. These stakeholders included Aboriginal groups such as Local Aboriginal Land Councils and Native Title Groups, community organisations such as the Pastoralists' Association of West Darling, and other special interest groups.

Following a high level of stakeholder interest and feedback about the engagement process, further notices were published providing extended opportunities for people to engage and provide feedback.

Feedback was obtained from stakeholders through a variety of methods including email, phone conversations, video and in-person meetings, and completion of an online feedback form.

Video meetings were held with the Pastoralists' Association of West Darling, Country Women's Association, the Environmental Defenders Office NSW (EDO), Nature Conservation Council, Fowler's Gap Research Station, NSW Farmers, Lock the Gate and the Office of Roy Butler MP – Member for Barwon.

Representatives from the Department attended a community meeting in Ivanhoe on 30 March 2021, at the request of the Yathong-Ivanhoe Neckarboo Aquifer Alliance (a community group formed in response to the PRIA process).

This meeting involved an explanation of the PRIA process and provided an opportunity for members of the Yathong-Ivanhoe Neckarboo Aquifer Alliance, and any other community members, to provide verbal feedback to the Department. The meeting was attended by 218 people, all of which strongly object to the release of the areas for gas exploration.

4.3 Feedback Received

Nature of the Feedback Received

The Department received feedback from a total of 382 community members, community and industry groups, and local Councils.

This included 188 responses to the Department's online form, 218 people in attendance at the community meeting in Ivanhoe, 19 by way of letter or emails and 7 by way of phone conversations or video meetings. Some members of the community provided feedback by multiple avenues.

The large majority of feedback is opposed to any gas exploration in the areas. In 2018, the Department conducted a similar process for potential release of the Bancannia Trough and Pondie Range Trough for conventional gas resources. At the time, there was very limited community concern about the proposal and only 25 people and groups contributed to the engagement process.

Consequently, it is possible that a large portion of the community concern for this PRIA is related to the potential release of the newly identified areas (being Yathong-Ivanhoe Trough and Neckarboo Trough), as well as the potential for tight gas resources and unconventional drilling methods.

Key Risks, Constraints and Opportunities Raised

A summary of all the feedback received during consultation is provided in **Table 2**.

The issues raised during the Department's community engagement process have been considered in the discussion of opportunities and constraints in **Section 5.0** and in developing the Department's recommendations in **Section 6.0**.

The most commonly raised concern was potential impacts on groundwater resources, particularly the quality and availability of shallower groundwater resources that are sole water supply for landholders and agricultural businesses. This concern was strongly supported by community members in the Yathong-Ivanhoe and Neckarboo Troughs (including at the community meeting in Ivanhoe) and Carrathool Shire Council. The community also expressed concerns about the process of hydraulic fracturing including the potential for contamination of ground water resources.

There is a general sentiment from the community that any risk to groundwater, no matter how little, is too great, as any impact on groundwater resources would have a detrimental impact on the local community and agricultural businesses.

There was also significant concern from the community regarding potential impacts on agricultural activities and businesses including biosecurity concerns, impacts to mustering activities from vehicle movements and aerial exploration and impacts to internal farm roads.

The Aboriginal community have raised concerns about impacts to the land as it is a vital part of the Aboriginal people's story and is integral to the Aboriginal culture. Broken Hill City Council also raised the need for ongoing consultation with the Aboriginal community and avoidance of impacts to sites and values.

While the large majority of stakeholders raised concerns about potential gas exploration and production, some stakeholders recognised the potential employment, economic and infrastructure development opportunities that might result from gas exploration. These opportunities were raised by Broken Hill City, Central Darling Shire and Cobar Shire Councils who also recognised the need to diversify employment to reinvigorate the region and maintain the population.

Other stakeholders thought that local employment and other flow-on economic benefits would not be realised in the locality or region, particularly in areas of Ivanhoe and Hillston as they do not have an existing employment base in the resource industry and are quite remote from other main centres.

The other most commonly raised concerns from the community were:

- potential impacts on surface water, particularly the health and sustainability of the Darling River;
- greenhouse gas emissions associated with gas extraction and use (and associated potential climate change impacts);
- mental health impacts on the community;
- potential lack of integration with fly-in-fly-out (FIFO) and/or drive-in-drive-out (DIDO) workers, with a strong desire for local and community-based employment opportunities;
- potential impacts on road conditions and other community infrastructure;
- potential loss of value to land and properties; and
- ensuring suitable rehabilitation of any disturbance caused by exploration activities.

Table 2: Summary of Key Matters Raised

Issue	
Water resources	• Significant levels of concern about any potential impacts on groundwater resources (both quality and availability), particularly the Lower Lachlan Alluvium and the Great Artesian Basin, given the reliance on groundwater by landholders (for agricultural activities and domestic use). • Particular concerns about hydraulic fracturing and whether regulation and controls would be sufficient. • Significant levels of concern about any potential impacts on surface water resources in the Murray Darling Basin, particularly the Darling River. • Concerns about any potential for impacts on town water supplies for Ivanhoe and Wilcannia. • Concerns about potential impacts on springs. • Concern about potential local-scale impacts on water drainage. • Potential benefits associated with improved knowledge of hydrogeological systems through data collection was also recognised.
Interactions with Agricultural Activities	• Creation of new access tracks generating excessive dust or sediments or affecting water movements if poorly constructed. • Disturbance and degradation of existing access tracks and roads if not maintained appropriately.

	• Disturbance to livestock from vehicle movements (principally in the vicinity of watering points and including lambing ewes and kidding/nanny goats), potentially resulting in loss of livestock, if proper consultation and coordination with landholders is not conducted. • Disturbance to gates and/or fences affecting available paddocks or livestock movements, particularly if proper consultation and coordination with landholders is not conducted. • Vehicle movements acting as vectors for the spread of invasive species or being biosecurity risks, if proper washdown procedures are not implemented. • Aerial exploration surveys interacting with, or affecting the timing of, aerial mustering activities if proper notification, consultation and coordination with landholders is not conducted. • Impacts on the organic rating of particular agricultural properties due to chemicals used during exploration and/or extraction activities if proper consultation and coordination with landholders is not conducted. • Impacts on the availability of water for agricultural activities if tenement holders do not identify suitable water supplies in consultation with the landholder and/or there are impacts on surface water or groundwater systems. • Long-term impacts on the productivity of the land if rehabilitation is not adequately completed. • Risks to the health and safety of employees and family members if proper consultation and coordination with landholders is not conducted and potential implications for the availability of public liability insurance. • Timing and expertise associated with liaising and negotiating with any tenement holder. • Concerns about livestock access to mud pits and evaporation ponds.
Aboriginal values, connection to Country and Aboriginal communities	• Concerns about any impacts to the landscape or subsurface land. • Concerns about any impacts to the Darling River, springs and other water resources given their cultural significance. • Concerns about impacts to any culturally significant areas including landforms, creation events, plants, ceremonial places, art sites, favourite food areas, burials, animals, water, occupation sites, and other places used by Aboriginal people. • The potential for local employment and development opportunities and funding for heritage surveys, teaching of lore and on-ground country experiences was also noted.
Social and Economic Impacts	• Potential for local economic benefits, particularly through support for secondary industries (e.g. catering, fuel supply, technical services, laundry) and associated developments (e.g. industrial land for warehouses). • Potential for local economic opportunities to bring new vitality into areas with declining and aging populations. • Potential for gas exploration and development to diversify economic and employment opportunities in the regions. • Potential for synergies with existing mining and service industries in Broken Hill and Cobar. • Concerns about fly-in-fly-out (FIFO) and/or drive-in-drive-out (DIDO) workers, with a strong desire for local and community-based employment opportunities. • Concern that the lack of available accommodation in some areas (e.g. Wilcannia, Ivanhoe and Menindee) may lead to:

	o increased living costs that would disproportionately affect vulnerable and low income people; o reduced accommodation capacity for tourism; and/or o the use of accommodation camps. • Significant concerns about mental health and other social and health impacts associated with concerns regarding impacts on amenity and livelihoods. Potential for loss of social fabric if families relocate from the area. • Concerns that the benefits of exploration and production would not be realised in some areas including Hillston and Ivanhoe.
Biodiversity	• Concerns about potential impacts on flora and fauna habitat. • The potential for interactions with the Fowlers Gap Conservation Area. • The significance of Mutawintji National Park and Yathong Nature Reserve were raised (noting these areas are outside the potential release areas). • Concerns about potential impacts of flaring on wildlife movements.
Greenhouse Gas Emissions and Climate Change	• Greenhouse gas emissions associated with gas extraction and use (and associated potential climate change impacts). • Calls for the NSW Government to invest in renewable energy rather than gas.
Infrastructure	• Potential for impacts on road conditions, particularly on unsealed roads and in wet weather periods. • Potential for the development to result in infrastructure upgrades (e.g. to telecommunication or transport facilities), which could benefit the broader community. • Concerns about additional strain on existing telecommunications infrastructure.
Amenity and Health	• Concerns about health and amenity (e.g. air quality, visual) impacts. • Concerns about amenity impacts affecting tourism (i.e. gas exploration activities detracting from an “outback” experience).
Strategic Considerations	• Objection to gas remaining part of NSW’s energy supply mix. • Desire to understand the potential for local gas supply opportunities.
Rehabilitation of Any Exploration Disturbance	• Desire for suitable rehabilitation of any disturbance caused by exploration activities. • Desire for the provision of adequate rehabilitation cost security.
Other Issues	• Concerns about fire and subsidence risks. • Concerns about impacts on traffic safety. • Desire for ongoing consultation with Councils and the local community. • Request for inclusive consultation that does not rely upon internet access (which can be limited in these areas).

5.0 Identification and Preliminary Assessment of Environmental, Social and Economic Matters

This section considers key environmental, social and economic matters based on available data and the outcomes of community and stakeholder engagement. In addition to the environmental and heritage matters occurring within each potential release area, consideration has also been given to environmental and built features in the vicinity of each of the areas (such as the Darling River, Paroo River Overflow, Barrier Highway, and the towns of Broken Hill, White Cliffs, Wilcannia, Menindee, Cobar and Hillston).

Key sources of data that have informed this PRIA include:

- feedback obtained through community and stakeholder engagement;
- the Far West Regional Plan and Riverina Murray Regional Plans;
- topographic and cadastral data and aerial imagery from NSW Spatial Services;
- geological data and information from Geological Survey of NSW;
- regional geological and hydrogeological studies (e.g. by CSIRO and Geoscience Australia);
- information on catchments, highly productive groundwater, groundwater use and groundwater dependent ecosystems from Department of Planning, Industry and Environment – Water, the NSW Water Register and in Water Sharing Plans or Water Resource Plans;
- spatial data on wetlands and lakes from the Biodiversity, Conservation and Science Directorate (BCS);
- key fish habitat spatial data provided by the Department of Primary Industries;
- spatial data on threatened flora and fauna species sightings provided by the BCS;
- spatial data on land systems, regional biophysical strategic agricultural land, land and soil capability, landform type, declared wilderness and State heritage made publicly available by the BCS;
- spatial data on wildlife refuge, conservation agreements and the Saving Our Species Program management sites provided by the BCS;
- spatial data from the Department of Environment, Climate Change and Water (DECCW) (2009) and of conservation areas provided by the BCS;
- information on matters of national environmental significance from the Commonwealth Department of Agriculture, Water and the Environment;
- information on Native Title Claims, Aboriginal land claims and Indigenous Land Use Agreements made publicly available by the National Native Title Tribunal;
- Australian Bureau of Statistics (ABS) census data and Small Area Labour Markets data;
- agricultural gross value production (GVP) estimates provided by the Department of Primary Industries;
- information on other major projects, primarily available from the Department's Major Projects portal and State Infrastructure Strategy; and
- information on tenements under the *Mining Act 1992* from Mining, Exploration and Geosciences (MEG).

The Department considers that sufficient information was available through existing Government data sources and through consultation with the community and stakeholders to identify high-level strategic issues and constraints.

5.1 Groundwater Resources

The potential impacts of gas exploration and production activities on the quality and quantity of groundwater resources was raised as a key issue of concern during community engagement for the PRIA.

The Department engaged Mr George Gates PSM to assist with reviewing available groundwater information and understanding the groundwater systems in the potential release areas. Mr Gates has over 40 years of experience in hydrogeology and is a former Director of Water Management at the NSW Office of Water.

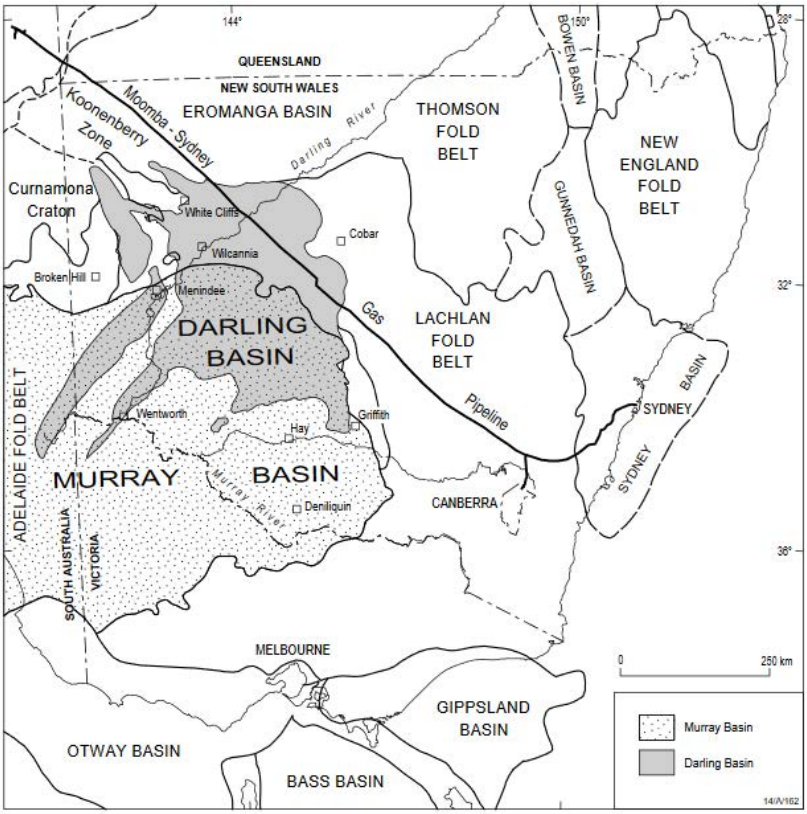
Mr Gates has extensive knowledge of the State's groundwater systems and has developed a number of groundwater policies for NSW. A complete copy of the report prepared by Mr Gates is provided in **Appendix B**.

The potential release areas occur in a geological formation called the Darling Basin, which is a deep sedimentary basin (**Section 2.0**). The Darling Basin underlies part of the Eromanga Basin (a sub-basin of the Great Artesian Basin) in the north, whilst the central and southern parts of the Darling Basin underlie the Murray Geological Basin (**Figure 12**).

It is difficult to interpret the exact southern boundary of the Great Artesian Basin. However, recent work conducted by the Geological Survey of NSW (2018) has confirmed that the Great Artesian Basin overlaps portions of the Bancannia Trough and Pondie Range Trough (**Figure 13**). The Murray Basin overlaps all four potential release areas (**Figure 4**).

The available information suggests that current groundwater usage in the Darling Basin is minimal, and that the Darling Basin contains brackish to saline groundwater suitable for limited stock use and industrial/mining purposes.

Higher beneficial uses exist for the overlying Great Artesian Basin sandstone aquifers in the Eromanga Basin (which underlies the Bancannia Trough and Pondie Range Trough). The water in these sandstone aquifers is suitable for town water, stock, some domestic purposes and industrial/mining requirements. It has been classified as 'highly productive' under the *NSW Aquifer Interference Policy* (the AIP), and is a locally important groundwater source with dependent ecosystems (springs and swamps).



Source: Wilcox *et al.* (2003).

Figure 12: Darling Basin and Surrounding Geological Provinces

Productive aquifers also exist within the Murray Basin and in the vicinity of the Lachlan River (south of Yathong-Ivanhoe Trough) and the Darling River (east of Pondie Range Trough).

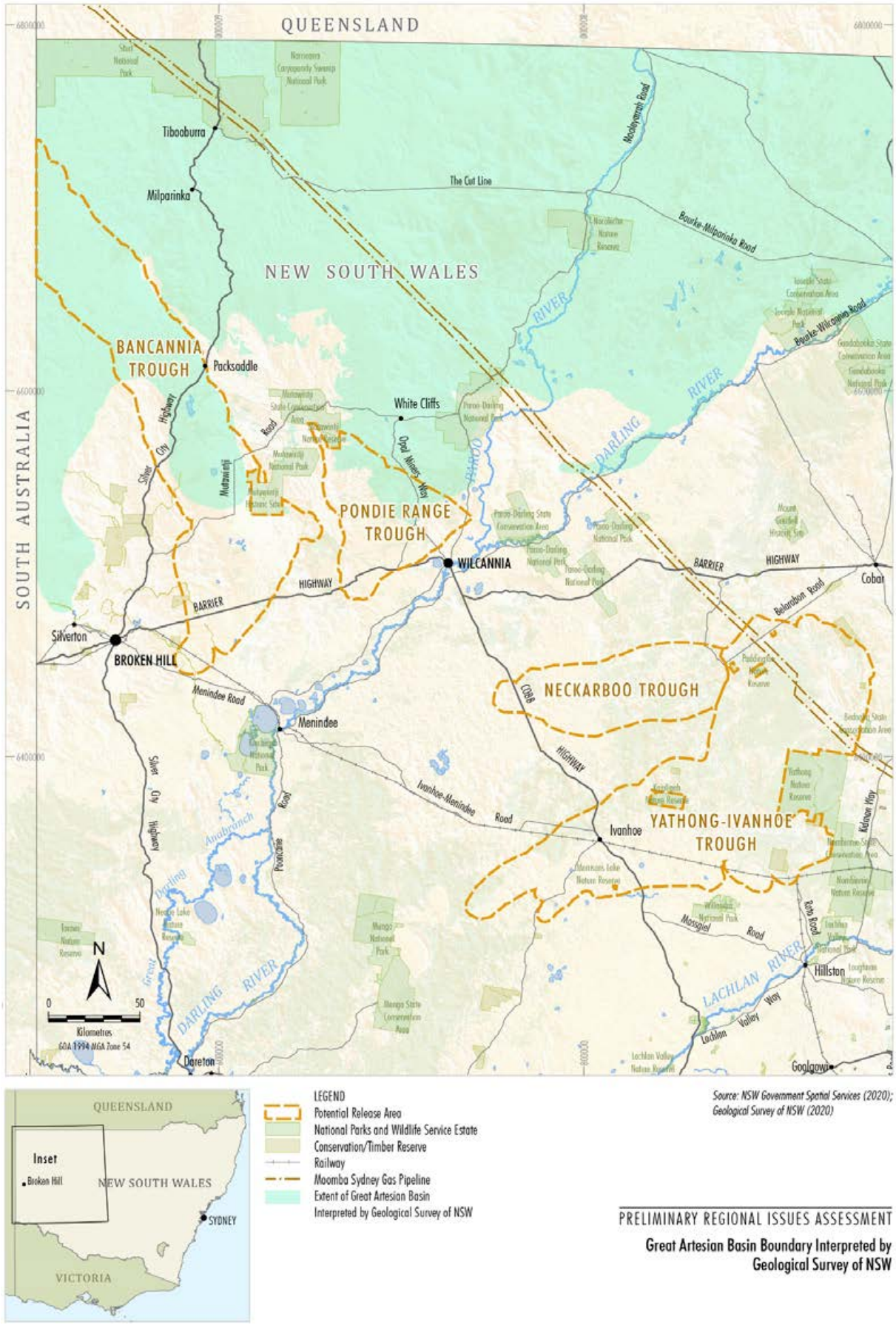


Figure 13: Great Artesian Basin Boundary Interpreted by Geological Survey of NSW

In areas away from these river systems, including in areas that underly the Neckarboo Trough and Yathong-Ivanhoe Trough, groundwater salinity in the Murray Basin may approach that of seawater and is suitable for mining purposes and occasionally for stock use.

The Upper Darling Alluvium is located near the Pondie Range Trough and is a 'highly productive' aquifer which is highly connected with the Darling River. In the vicinity of Wilcannia, water moves from surface water to the underlying alluvium. Water from the alluvium is suitable for domestic and stock purposes and is also used for Wilcannia town water supply during dry periods.

The Lower Lachlan Alluvium is another 'highly productive' aquifer that intersects the southern Yathong-Ivanhoe Trough. The Lower Lachlan Alluvium contains fresh groundwater that is mainly used for domestic and stock supply, irrigation, and for town water supply. However, groundwater salinity is elevated and generally unsuitable for irrigation purposes in the vicinity of the Yathong-Ivanhoe Trough potential release area and alluvial bores in this area are used for stock and limited domestic purposes.

All other aquifers in the potential release areas are classified as 'less productive' under the AIP.

The community has raised concerns about the potential impacts of gas exploration and production activities including potential for:

- contamination of aquifers during the development of drillholes or wells, the use of chemically-modified fluids to extract tight gas through fracture stimulation, or due to longer-term gas leakage;
- contamination due to mishandling of waste products including drilling fluids and chemicals;
- contamination due to surface spills and pipe breakages as a result of human error; and
- changes in groundwater pressures or flows, particularly from the use of large water volumes to extract tight gas through fracture stimulation, that result in impacts on water supply and/or impacts to ecosystems (springs, swamps and vegetation).

In considering these issues, the Department notes that the hydraulic connection between the Great Artesian Basin and Murray Basin sedimentary rocks and the underlying Darling Basin rocks is low or very low in the potential release areas.

Mr Gates has noted that tight gas is generally found at considerable depth (say 1,000 m and deeper) with many hundreds, and sometimes thousands of metres, of sedimentary rocks between the gas reservoir and the shallow privately used aquifers (50 to 250 m).

Mr Gates concluded that these seals (low permeability shales and siltstones) would offer natural protection to overlying aquifers and that there would be no material impact on the overlying shallower aquifers and dependent ecosystems that are used for domestic and stock purposes as a result of groundwater or gas extraction in the potential release areas.

Notwithstanding, Mr Gates notes that some literature suggests there is a risk of hydraulic fracturing resulting in fractures propagating towards overlying aquifers if pre-existing transmissive faults exist. Mr Gates concluded that more work is required to understand whether groundwater could be transmitted through existing faults at the boundary of each of the potential release areas as part of any future assessment of any gas exploration or production activities.

To this end, the Department notes that there is limited information on groundwater resources within the potential release areas and considers that any future exploration program should collect data to improve knowledge of the area and to provide a sound basis for any future environmental assessment. This should include the matters identified by Mr Gates including:

- identifying all water sources from which water is to be taken for drilling purposes;

- recording all water-bearing zones during drilling and undertaking drill stem tests (DST) on significant aquifers for yield estimation and calculation of hydraulic parameters;
- undertaking wire line geophysical logs to establish detailed lithology;
- measuring the standing water level (pressure level) of all significant aquifers;
- collecting water samples for chemical analysis and isotopic age dating to better understand the groundwater flow regime;
- survey levelling the measuring points that water levels are taken from;
- undertaking studies to better understand the location of major geological faults and how groundwater moves through these faults;
- using sensing technology to closely monitor the fracture stimulation process, particularly any upward vertical growth of fractures into local transmissive faults; and
- setting up a network or monitoring piezometers at various depths so the impacts of gas extraction can be directly measured and reported.

It is noted that a condition requiring the preparation and implementation of a Groundwater Monitoring and Modelling Plan is a typical condition of exploration licences. If the areas are released for gas exploration, then these plans should be required to address these matters. The information collected as part of the plans would provide important baseline information for any detailed assessment of water impacts that would be required to support a development application.

The amount of water produced during exploration activities is expected to be very small as only small volumes of water, in the form of condensate, would be removed with the gas.

However, tight gas extraction may involve the use of large amounts of water to stimulate the release of gas. For example, tight gas production operations in South Australia's Cooper Basin estimate that hydraulic fracturing of a well would require up to 24 megalitres of water.[4]

The community raised concerns about the use of large volumes of water and the impact this could have on water supply for stock and domestic use. In considering this issue, the Department notes that this volume of water is relatively low compared to the total amount of water used for agriculture and other productive purposes each year (hundreds of megalitres in the Lachlan Fold Belt Murray Darling Basin groundwater source and Lower Lachlan Alluvium). Furthermore, any water used in the fracturing process can be reused multiple times before it is treated and/or disposed of.

The Department also notes that any future tenement holder would need to obtain a water access license for these volumes of groundwater under the *Water Management Act 2000*. The amount of water used or produced during gas production activities would need to be assessed under the requirements of the AIP.

Water licences are obtainable from all groundwater sources in vicinity of the proposed release areas, either through trading of water (limited market) or direct from the NSW Government through a controlled allocation tender/auction process.

Water licences in the higher productivity aquifers (e.g. the Lower Lachlan Alluvium) are typically only available through trading with existing licensees and licences and not through the NSW Government controlled allocation process.

[4] Environmental Impact Report Cooper Basin Petroleum Production Operations (Beach Energy, 2019)

These licences are generally more expensive to purchase on the trading market than the other less productive aquifers where water licences are offered through the NSW Government controlled allocation process. Consequently, it is anticipated that market mechanisms would encourage the use of lower value water, and reuse of water where possible.

As discussed above, the community has raised concerns about the use of chemicals in the hydraulic fracturing process, and the potential for these chemicals to contaminate aquifers. The Department notes that the use of chemicals in any hydraulic fracturing would be tightly controlled through conditions imposed on the licence and activities under the *Petroleum (Onshore) Act 1991* and through conditions of an Environment Protection Licence which would be regulated by the EPA.

The *Code of Practice for Coal Seam Gas Fracture Stimulation* establishes a best practice framework covering the hydraulic fracturing process, the use of chemicals, water sources and the protection of aquifers. Under this code, the use of harmful chemicals (known as BTEX) is banned in NSW and stringent testing and reporting protocols are required for coal seam gas activities.

While the potential release areas are not prospective for coal seam gas, the Department recommends that similar requirements be imposed on any future exploration and/or production of conventional or tight gas should the potential release areas be released.

With this measure in place, the Department considers that there are no significant or fundamental groundwater constraints that would preclude the release of the four areas for exploration or development and that the current regulatory and planning framework is sufficient to manage potential impacts on groundwater resources.

5.2 Surface Water Resources

The potential impacts of gas exploration and production on surface resources, particularly the health and sustainability of the Darling River and Lower Lachlan River was raised as a key issue of concern during community engagement.

As show on **Figure 14** and **Figure 15**, the potential release areas are located within the broader catchments of:

- the inland catchments of Lake Frome and Lake Bancannia;
- the Darling River, including its tributary the Paroo River; and
- the Lachlan and Benanee catchments.

The inland catchments of Lake Frome and Lake Bancannia consist of ephemeral streams and drainage systems that terminate in shallow lakes and flood outs. Most of the small streams within the NSW portion of the Lake Frome catchment contribute no runoff into Lake Frome. Feedback from local pastoralists indicates that these catchment boundaries can easily change as a result of minor landform modifications and are, to some extent, arbitrary, due to the low level of topographic relief in some areas.

The Darling River is considered to have unregulated flow above the Menindee Lakes, located approximately 80 km south east of Broken Hill (see **Figure 14**). Surface water from the Darling River is used for town water supply, livestock grazing, and (in the regulated Darling River below Menindee Lakes and unregulated Barwon-Darling system upstream of the release areas) irrigated agriculture. Irrigated agriculture water users in the Barwon-Darling fill on-farm water storages with water diverted from the river for subsequent use for irrigation.

The sinuous nature of the Barwon-Darling River has resulted in the formation of many small lagoons and anabranches along its length, including Lake Woytchugga which is located outside of the Pondie Range Trough potential release area.

The Paroo River is free of regulation and significant water extraction. The Paroo River floodplain widens to encompass a complex network of channels and wetlands which are known as the Paroo Overflow. During large floods, water from the Paroo River joins the Darling River just upstream of Wilcannia. The Paroo Overflow is outside the eastern edge of the Pondie Range Trough potential release area.

The Lachlan and Benanee catchments consist of extensive alluvial river floodplains. The sinuous nature of the Lachlan River and low-lying alluvial floodplain has resulted in the formation of many small lagoons and creeks along its length, including Willandra Creek which traverses the southern edge of the Yathong-Ivanhoe Trough potential release area.

Water flows into Willandra Creek from the Lachlan River (via a weir off-take) and is used to supply water for irrigated agriculture (horticulture and broadacre), domestic and stock purposes. Willandra Creek feeds into a series of lakes including Morrison's Lake which is excluded from the Yathong-Ivanhoe Trough potential release area. Under very wet conditions, surface water may flow into the Willandra Lakes Region. This is discussed further in **Section 5.4**.

Exploration activities are considered unlikely to result in any material changes to regional surface water quality of flows. This is because exploration is a temporary activity, and the area used at any one time is very small.

Any tight gas or conventional gas exploration or production activities would also need to be designed to:

- include appropriate erosion and sediment control measures;
- mitigate the potential for broad-scale changes in water movements and sheet flows as result of disturbance (including construction of access tracks);
- manage potential contamination risks;
- include appropriate measures in the vicinity of river banks and lakes to avoid impacts on water flow and fish habitat (e.g. Managing Urban Stormwater: Soils and Construction Requirements: Volume 2C Unsealed Roads [DECC, 2008] and Policy and Guidelines for Fish Habitat Conservation and Management [Department of Primary Industries, 2013]);
- obtain appropriate sources of water through adequate consultation with the landholder and obtaining appropriate water licences; and
- include appropriate measures to reuse or dispose of any excess water.

The Department is satisfied that the current regulatory and planning framework is sufficient to manage potential impacts of any tight gas or conventional gas exploration or production activities on surface water. This framework includes the need to assess any changes to water quantity, water quality and flow regimes and also includes the regulation of water licensing under the *Water Management Act 2000*.

Figure 14: Catchment Boundaries – Bancannia Trough and Pondie Range Trough

Figure 15: Catchment Boundaries – Neckarboo Trough and Yathong-Ivanhoe Trough

5.3 Town Water Supplies

The potential impacts of gas exploration and production on town water supply, particularly in Ivanhoe, was raised as a key issue of concern during engagement with Councils and the community.

Wilcannia sources its main water supply from the Wilcannia weir pool on the Darling River, with the water treated at a water treatment plant. The existing weir is expected to be replaced by a new weir located downstream of Wilcannia by 2022. An alluvial bore provides back-up water supply to Wilcannia during drought periods.

Broken Hill and surrounding areas source water from the Murray River via the Wentworth to Broken Hill Pipeline. Water is treated at the Mica Street treatment plant in Broken Hill.

Surface water runoff is used for water supply for both the White Cliffs and Tibooburra communities.

Cobar sources its water from the Macquarie River via the Albert Priest Channel and overland pipeline.

Ivanhoe sources its water supply from the Lachlan River via Willandra Creek or from a nearby alluvial bore field, while Hillston relies on a series of alluvial bores for its water supply.

As described in **Section 5.1**, the significant depth of potential gas targets and the low permeability shales and siltstones that occur above the potential gas resources offer natural protection to the Darling River alluvium, which provides back-up water supply to Wilcannia, and the Lachlan River alluvium, which supplies the Ivanhoe and Hillston communities.

Consequently, the Department is satisfied that any conventional or tight gas exploration or production activities are unlikely to have material conflicts with town water supplies.

5.4 Groundwater Dependent Ecosystems, Wetlands and Fish Habitat

Several groundwater dependent ecosystems, including two karst systems (a complex underground cave and water system), are located within a 5 to 80 km radius of the potential release areas. High priority groundwater dependent springs and karst environments identified in relevant Water Sharing Plans are presented on **Figure 16** and **Figure 17**.

In addition, recent amendments to relevant Water Sharing Plans have mapped high priority groundwater dependant vegetation ecosystems in the Paroo River and Darling River alluvium (outside of the Bancannia and Pondie Range Troughs), porous and fractured rock groundwater sources (within parts of all four potential release areas), and in the Lower Lachlan River alluvium (including small patches within the Yathong-Ivanhoe Trough and along Willandra Creek outside of the Yathong-Ivanhoe Trough). This vegetation (which is not shown on **Figure 16** and **Figure 17**) gets at least some of its water from shallow groundwater.

Springs are located within the broader area, are generally associated with the Great Artesian Basin and are structurally controlled. Springs in this arid area are highly valued and are often sites of cultural significance. There are no listed springs within the potential release areas. Further field validation and use of Aboriginal and landholder knowledge would be required during any future assessment and exploration activities to make sure all known springs are recorded.

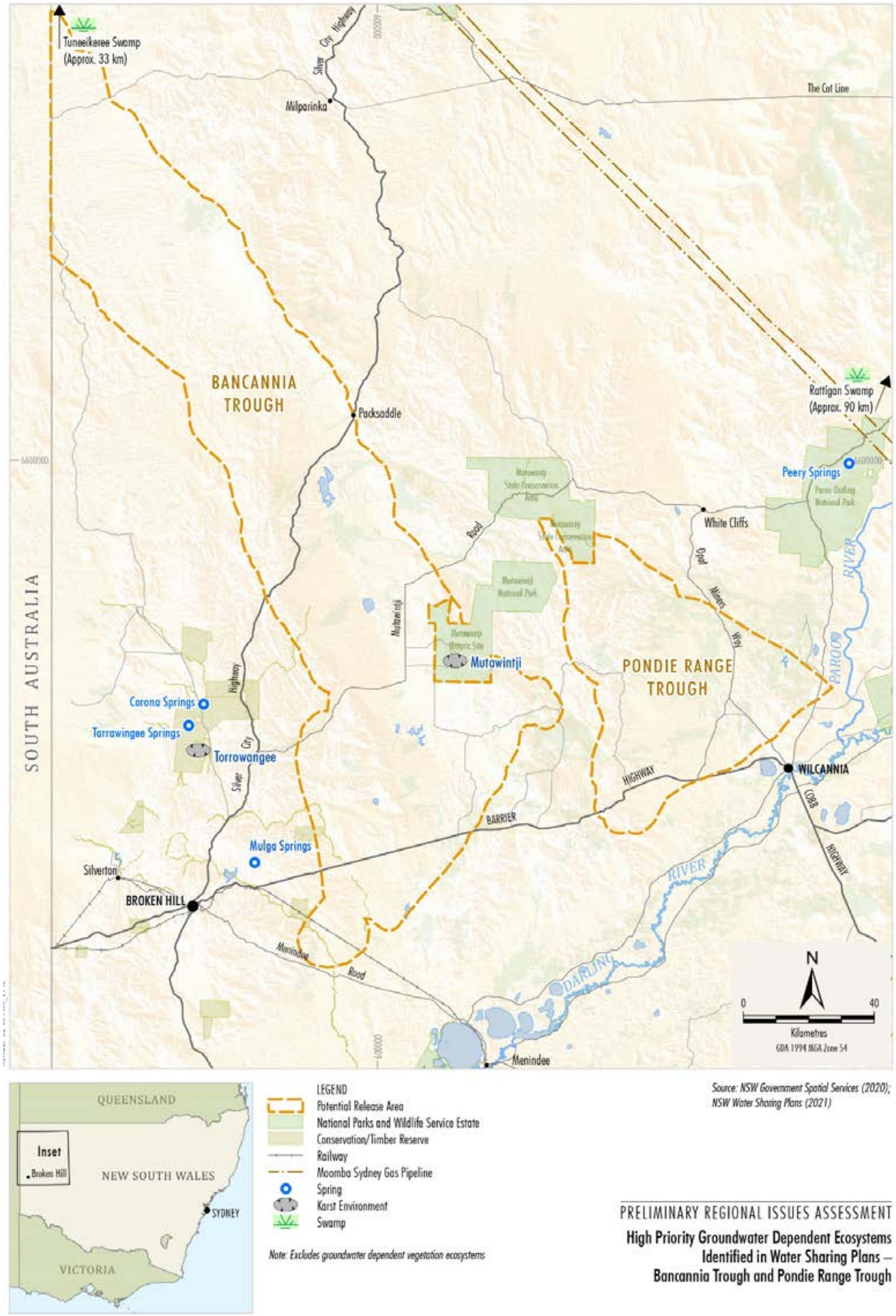


Figure 16: High Priority Groundwater Dependent Ecosystems Identified in Water Sharing Plans – Bancannia Trough and Pondie Range Trough

Figure 17: High Priority Groundwater Dependent Ecosystems Identified in Water Sharing Plans – Neckarboo Trough and Yathong-Ivanhoe Trough

Given that there is unlikely to be any material impact to groundwater resources, due to the significant depth of potential gas resource and the low permeability shales and siltstones that occur above the potential gas resource, (**Appendix B**), there is unlikely to be any measurable impact on these springs and groundwater dependent ecosystems.

The Department of Primary Industries provided spatial data on key fish habitats and wetlands in the potential release areas and surrounds, which are presented on **Figure 18** and **Figure 19**. Mapped key fish habitat is an area that is important to the maintenance of fish populations and/or the survival and recovery of threatened aquatic species.

The Paroo River Wetlands, a declared Ramsar wetland, are located approximately 40 km upstream of the Pondie Range Trough potential release area (**Figure 18**). A 'declared Ramsar wetland' is a wetland that is rare or unique or important for conserving biological diversity.

Given that the Paroo River Wetlands are located upstream of the potential release areas, it is unlikely that any conventional or tight gas exploration or production activities would have any material effect on the Ramsar wetland.

The Willandra Lakes Region World Heritage Area is located in close proximity to the southwest portion of the Yathong-Ivanhoe Trough (**Figure 19**). The site is a system of lakes that has formed over the last two million years which are now dry[5]. Surface water flow from Yathong-Ivanhoe Trough potential release area to the Willandra Lakes Region is thought to be intermittent, occurring only under very wet conditions.

Any surface water flow from any gas exploration or production activities in the Yathong-Ivanhoe Trough potential release area would be highly diluted and, with the implementation of control measures and consideration through further assessment, is unlikely to have any material effect on the World Heritage Area.

Notwithstanding, the Department recommends that any future gas exploration and or production be avoided in close proximity to the Willandra Lakes Region to avoid impacts to the curtilage and heritage values of this heritage item.

With the implementation of appropriate groundwater and surface water control measures (**Sections 5.1** and **5.2**), the Department is satisfied that the current regulatory and planning framework is sufficient to manage potential impacts of conventional or tight gas exploration or production activities on groundwater dependent ecosystems, wetlands and fish habitat.

[5] https://www.environment.gov.au/heritage/places/world/willandra.

Figure 18: Wetlands and Key Fish Habitat – Bancannia Trough and Pondie Range Trough

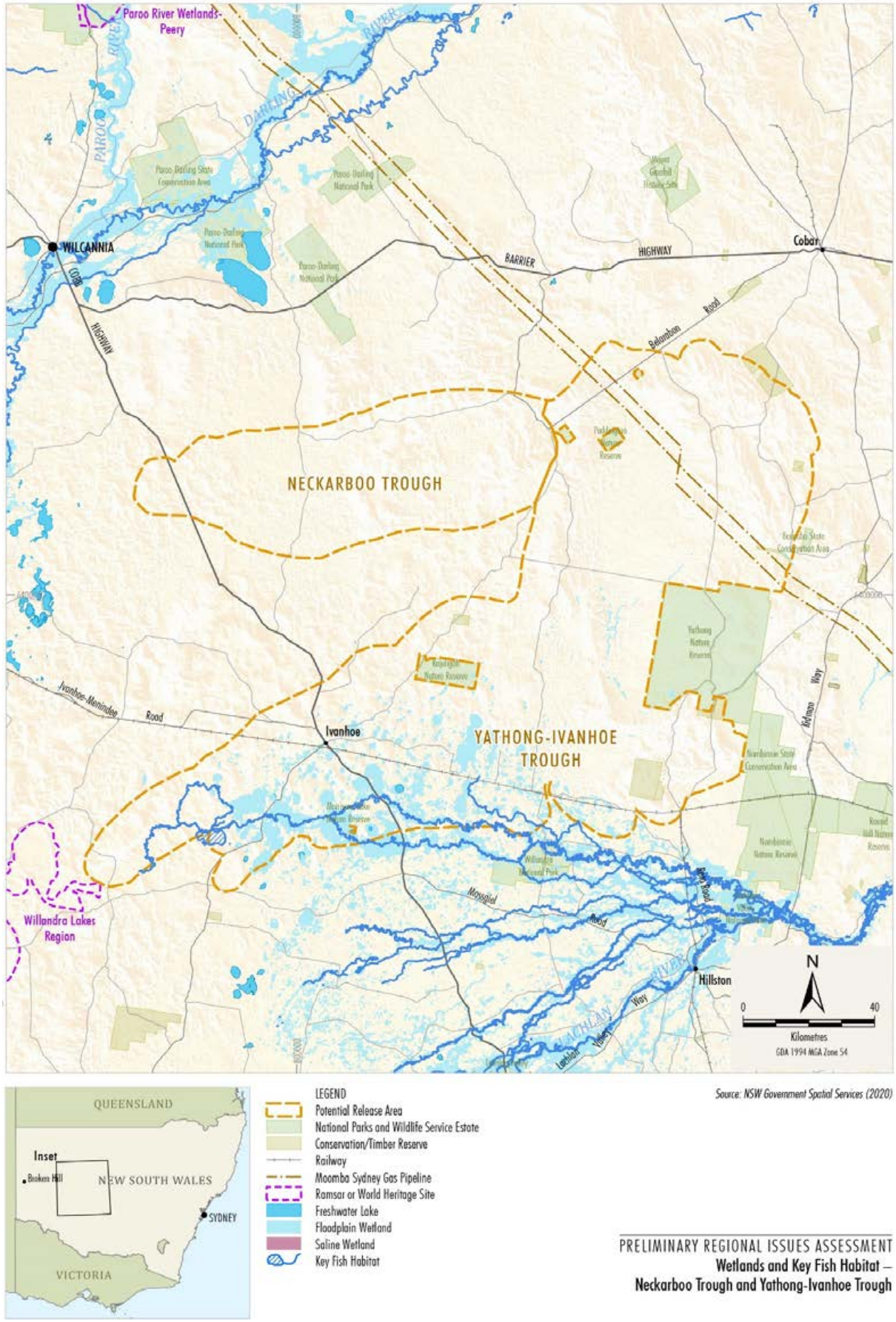


Figure 19: Wetlands and Key Fish Habitat – Neckarboo Trough and Yathong-Ivanhoe Trough

5.5 Land Systems and Capability

The former Soil Conservation Service of NSW mapped the land systems of Western NSW, including the potential release areas. A summary of this mapping is presented on **Figure 20** and **Figure 21**.

The potential release areas are characterised by basalt, high hills, cliffs, sand dunes (including lunette dunes, high dunes and irregular dunes) and limestone/dolomite systems. The predominant land systems within the potential release areas include:

- Mulga;
- plains and ridges with bimble box and white cypress pine;
- riverine plains with saltbush and bluebush;
- sandplains and dune fields;
- stony downs and associated plains with saltbush and bluebush; and
- undulating sandplains.

State-wide land and soil capability mapping by the former Office of Environment and Heritage is presented on **Figure 22** and **Figure 23**. Land in the potential release areas range from Class 3 (moderate limitations) to Class 8 (extreme limitations).

Class 3 land, which is described as high capability land with moderate limitations and is capable of sustaining cropping with cultivation, is located along the Paroo, Darling and Lachlan rivers, with a portion located at the northern edge of the Yathong-Ivanhoe Trough potential release area (approximately 129 km^2).

The Bancannia Trough and Pondie Range Trough areas are predominantly Class 5 to Class 8 land (98% and 96% by area, respectively), with a very small amount classified as Class 4 land.

The Neckarboo Trough includes mostly Class 5 to Class 8 land (72%) with the remaining 28% being Class 4. Class 4 land is described as moderate capability land and is capable of a variety of uses including cropping with restricted cultivation, pasture cropping and grazing.

The Yathong-Ivanhoe Trough contains Class 4 land (just under 40%) and Class 5 to Class 8 land (just under 60%). The majority of Class 4 land is located in the alluvial floodplain of the Lachlan River including areas near Willandra Creek, in areas north of Ivanhoe and north west of the Yathong Nature Reserve.

No regionally mapped biophysical strategic agricultural land is located in the potential release areas. Notwithstanding, if any portion of the potential release areas forms part of a future production project, the proponent would be required to undertake a site verification process to verify if any of the land is classified as biophysical strategic agricultural land.

This would need to include an assessment of the soil in areas that overlie highly productive groundwater sources (such as the Great Artesian Basin and Lower Lachlan Alluvium). If biophysical strategic agricultural land is found to be present, any future development would be required to be considered by the Mining and Petroleum Gateway Panel (which is now a sub-committee of the Independent Planning Commission).

Providing that the more productive areas of Class 3 and 4 land in the Yathong-Ivanhoe Trough are avoided, the Department is satisfied that the land systems and soils in the potential release areas do not form a constraint that should preclude conventional or tight gas exploration or production activities.

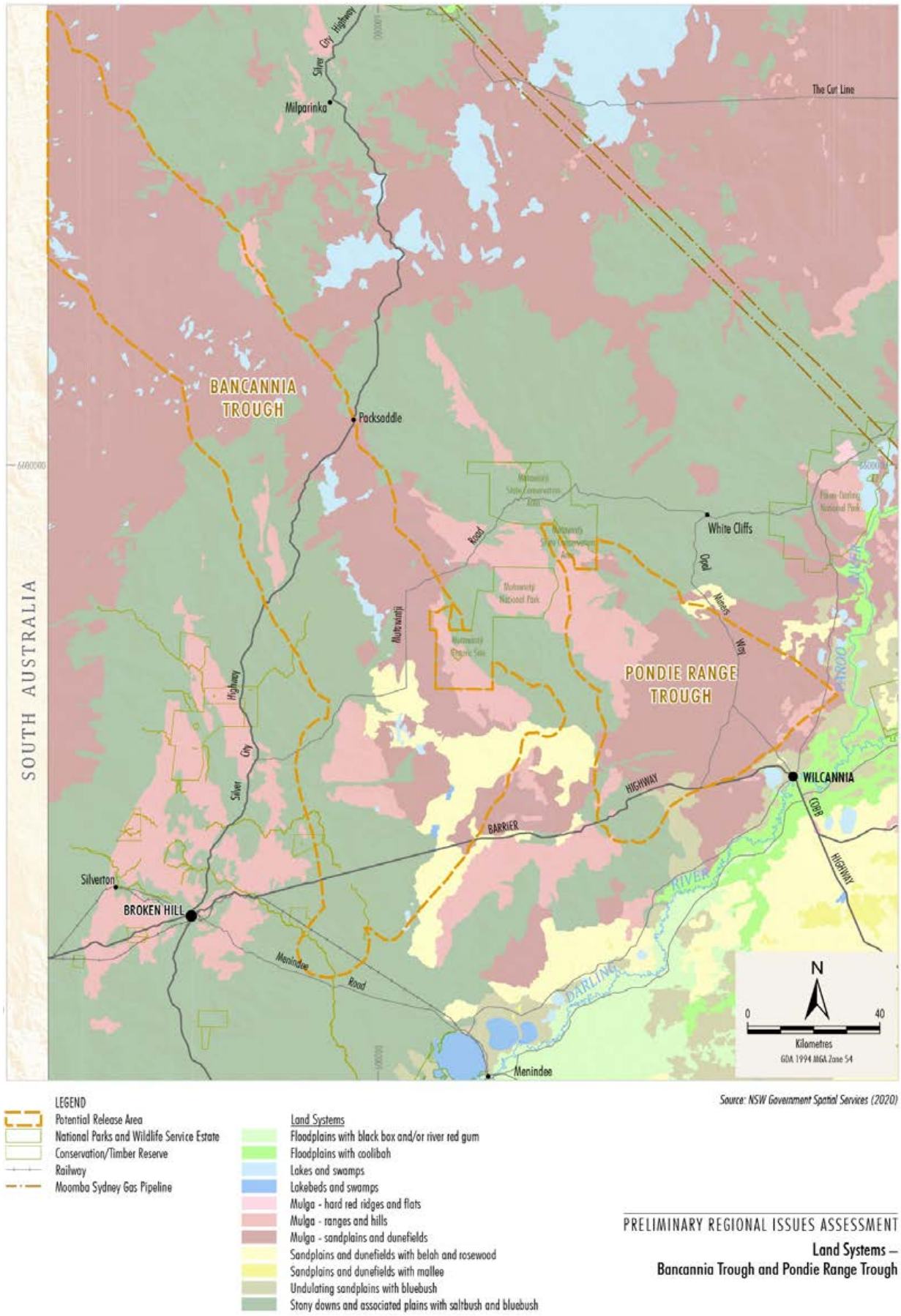
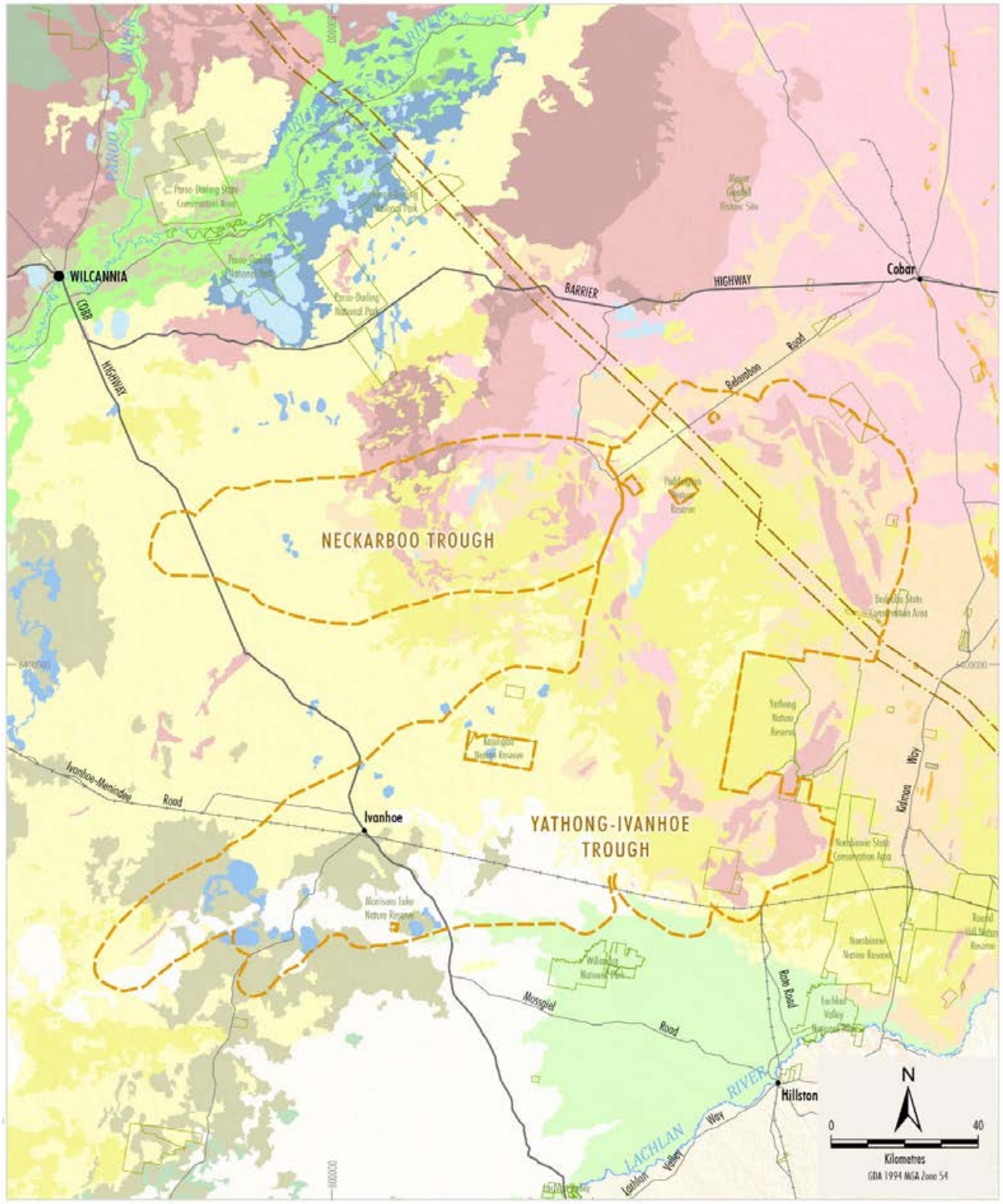


Figure 20: Land Systems – Bancannia Trough and Pondie Range Trough



LEGEND

- Potential Release Area
- National Parks and Wildlife Service Estate
- Conservation/Timber Reserve
- Railway
- Moomba Sydney Gas Pipeline

Land Systems

- Floodplains with black box and/or river red gum
- Floodplains with coolibah
- Floodplains with mitchell grass
- Lakes and swamps
- Lakebeds and swamps
- Scalded floodplains
- Mulga - hard red ridges and flats
- Mulga - ranges and hills
- Mulga - sandplains and dunefields
- Plains and ridges with bimble box and white cypress pine
- Ranges and hills with gum and ironbark
- Ranges and hills with white cypress pine
- Riverine plain with saltbush and bluebush
- Sandplains and dunefields with belah and rosewood
- Sandplains and dunefields with mallee
- Scalded plains
- Southern grasslands
- Undulating sandplains with bluebush
- Stony downs and associated plains with saltbush and bluebush

Source: NSW Government Spatial Services (2020)

PRELIMINARY REGIONAL ISSUES ASSESSMENT

Land Systems –
Neckarboo Trough and Yathong-Ivanhoe Trough

Figure 21: Land Systems – Neckarboo Trough and Yathong-Ivanhoe Trough

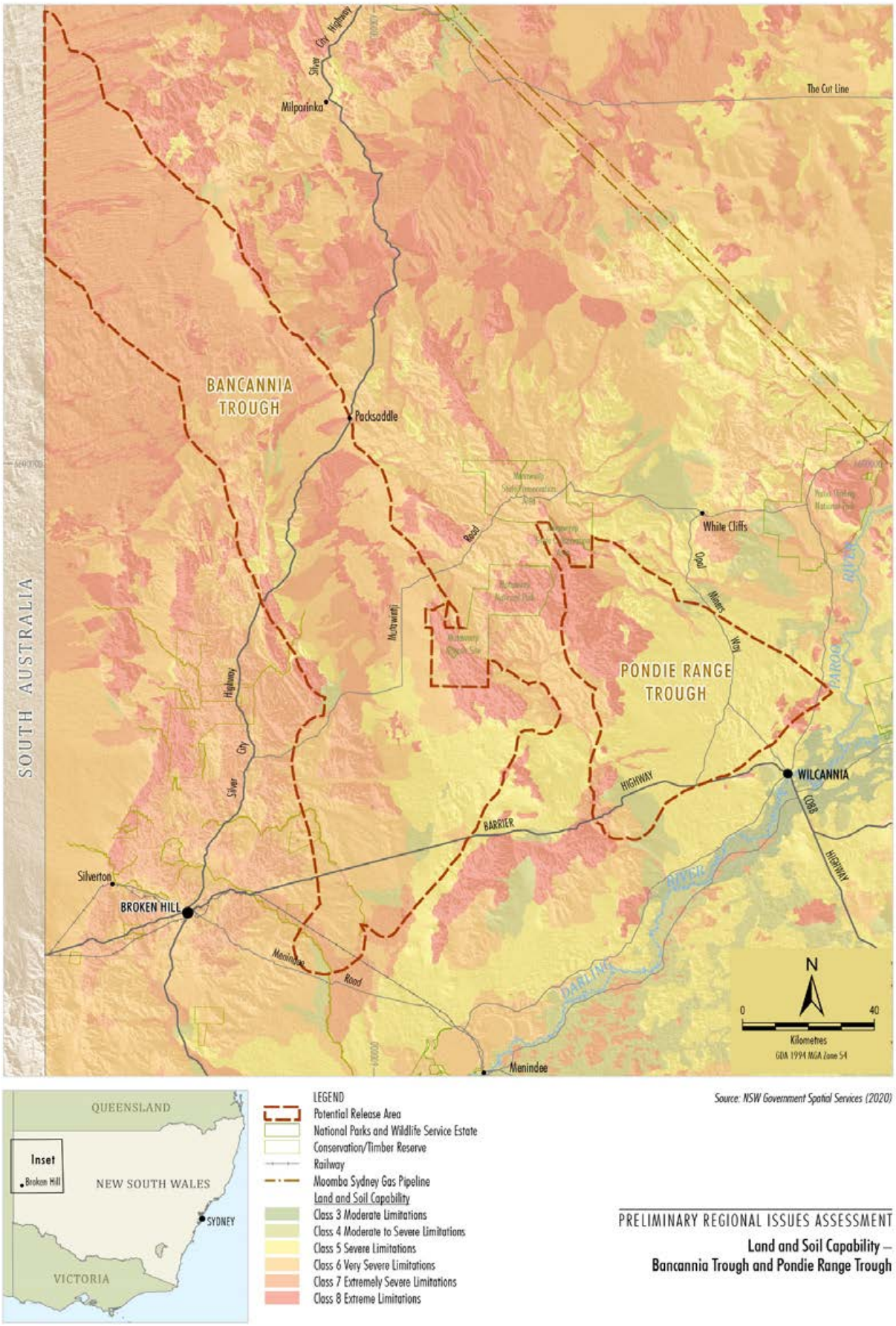


Figure 22: Land and Soil Capability – Bancannia Trough and Pondie Range Trough

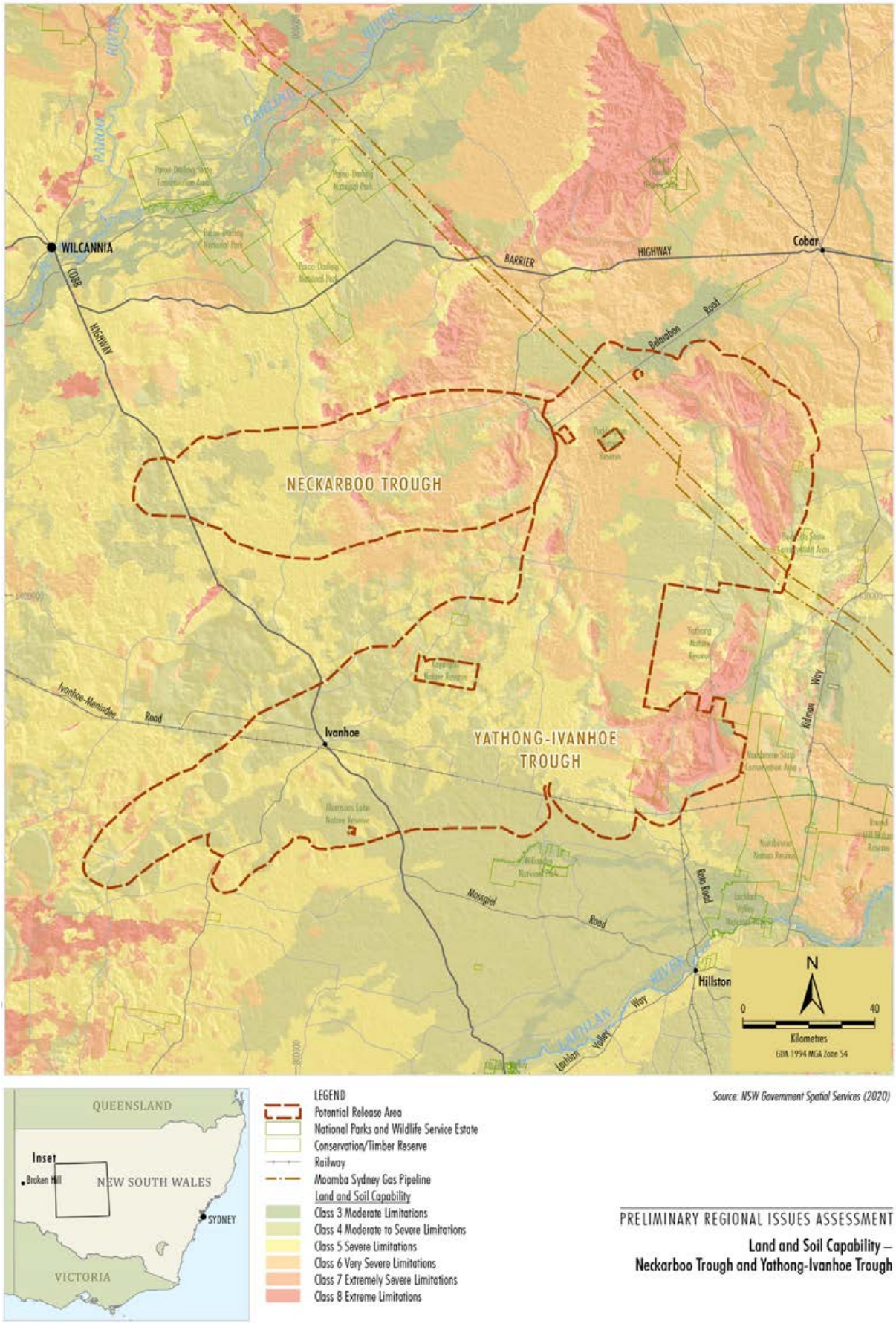


Figure 23: Land and Soil Capability – Neckarboo Trough and Yathong-Ivanhoe Trough

5.6 Social and Economic Considerations

The potential release areas are sparsely populated with the exception of the town of Ivanhoe (population 327)[6] which is located within the Yathong-Ivanhoe Trough potential release area. The communities in western NSW are also quite remote.

This has resulted in variable and unique communities that have tight connections within the community and a strong attachment to the land and place.

The Department notes that the connection that Aboriginal and non-Aboriginal people have to the land was a consistent theme in the development of the Far West Regional Plan and Riverina Murray Regional Plan

Indigenous peoples make up a larger proportion of the population within the relevant statistical areas (up to 30% in the Far West Statistical Area) compared to other areas of NSW (average of 2.9%). **Table 3** presents the population of the statistical areas covering the potential release areas.

Each community has a local identity, needs and challenges. There is a high level of social disadvantage in some areas.

Table 3: Population in the Statistical Areas Covering the Potential Release Areas

Area	Total Population 2019	Indigenous Population (2016) (% of 2016 population)
Far West (SA2)	2,449	944 (30.1%)
Cobar (SA2)	4,672	808 (13.6%)
Griffith Region (SA2)	13,194	1,070 (6.5%)
Hay (SA2)	2,974	227 (5.9%)
Wentworth-Balranald Region (SA2)	3,655	303 (6.7%)
Total NSW	8,089,817	265,685 (2.9%)

Throughout a gas development lifecycle, there would be different benefits and impacts for the community, from exploration and construction to production and decommissioning. The Department notes that there is no guarantee that a project would proceed through all of the phases, as a potential resource may be determined to be not viable for extraction at any point.

The Department recognises that this could cause uncertainty and anxiety for the community and notes that the mental wellbeing of individuals and communities was raised as a key concern during community engagement. Communities in the Ivanhoe region have reported an increase in anxiety and stress as a result of learning of the PRIA process.

This concern appears to be related to the small amount of certainty as to the scale and location of any exploration and production, as well as the potential for impacts including, but not limited to, water resources and agricultural land uses (see **Section 4.3** for a complete list of concerns).

[6] https://www.abs.gov.au/websitedbs/D3310114.nsf/Home/2016%20QuickStats.

At the community meeting in Ivanhoe, community members expressed the view that they would be unlikely to benefit from any exploration or gas production in the region.

During exploration, the number of people working in the area is anticipated to be limited and would fluctuate during different stages of exploration. It is unlikely that gas exploration would materially affect employment levels in the area. Exploration activities are likely to result in some local purchasing in the area and associated flow-on benefits (e.g. purchase of food/catering from local businesses, use of local road maintenance contractors). If a gas production project were to proceed, the local employment and flow on benefits are likely to be much greater.

A proportion of the workers are likely to be employed on a drive-in, drive-out or fly-in, fly-out basis. The Department notes that any exploration in areas closer to Broken Hill and Cobar would have the potential to generate employment opportunities for the existing resource employment base in these areas.

The small workforce typically associated with exploration activities is unlikely to materially affect the availability of services in the region.

Notwithstanding, some communities can feel that temporary or itinerant workforces affect community cohesion and/or safety. The tenement holder would need to work with the community to mitigate these concerns. This would be guided by the *Exploration code of practice: community consultation.*

NSW Roads and Maritime Services (RMS) provided input that drive-in, drive-out or fly-in, fly-out employment arrangements can potentially contribute to accidents and/or fatalities on the road if fatigue is not properly managed. RMS can provide assistance to companies in developing Fatigue Management Plans to mitigate risks associated with workers driving while fatigued.

Areas of western NSW are known to experience low rental vacancies periodically. For example, SQM Research estimates that residential vacancy rates are below 1% in areas of western NSW[7].

From the PRIA engagement activities, it is understood that both Wilcannia and Ivanhoe both have rental shortages. This reduces the likelihood that workers would be based in these towns. It is anticipated that any exploration or production staff would be housed in either Broken Hill, Cobar, Hillston or temporary accommodation facilities.

If a gas production project were to proceed, further work would be required to determine the capacity of the local and regional community to manage any social impacts associated with a production project. This would occur, at the appropriate time, as part of a Social Impact Assessment that would be prepared in accordance with the *Social Impact Assessment Guideline: For State significant mining, petroleum production and extractive industry development* (September 2017) (or its latest version, noting that the Department recently exhibited a revised Social Impact Assessment Guideline).

Agricultural Land Uses

The vast majority of the potential release areas are zoned RU1 for primary production. The potential impacts of gas exploration and/or production activities on agricultural land uses were raised as a key issue of concern during community engagement for the PRIA.

[7] Source: SQM Research residential vacancy rates data for 'Broken Hill-Dubbo', 'Riverina' and 'Lower Murray': https://sqmresearch.com.au/graph_vacancy.php?sfx=&region=nsw%3A%3ABroken+Hill-Dubbo&t=1

Based on discussions with pastoralists, the primary agricultural land use in the potential release areas appears to be low-intensity grazing of cattle, sheep and goats. Cropping occurs more frequently within the Neckarboo Trough and Yathong-Ivanhoe Trough potential release areas, consistent with the relatively higher land and soil capability in these areas.

Most of the potential release areas and surrounding area are unsuitable for intensive agriculture due to low and unpredictable rainfall. Access to water for domestic and stock use can be particularly constrained during periods of drought.

Nevertheless, agricultural land uses are a significant part of the regional economy, generating hundreds of millions of dollars per annum (see **Figure 24**). Beef, sheep meat and wool are the main drivers of agricultural output in the Bancannia and Pondie Range Troughs (see Far West in **Figure 24**) while broadacre cropping makes up a greater portion of agricultural output in the Neckarboo and Yathong-Ivanhoe Troughs (see Western Plains, Western Riverina, and Lower Murray in **Figure 24**).

The Far West Regional Plan describes that access to sufficient skilled labour on properties can often be difficult. These effects can be compounded by factors such as higher labour demands from mining centres within and outside the region. Agriculture in the Far West also faces challenges associated with transport logistics and infrastructure.

The Far West Regional Plan and Riverina-Murray Regional Plan include directions and actions aimed at protecting productive agricultural land, reducing fragmentation, and planning for greater land use compatibility.

Concerns were raised during consultation that conventional or tight gas exploration and/or production activities may have negative interactions with agricultural activities (see **Section 4.3)**.

Exploration tenement holders are required to address the concerns raised in engagement through the negotiation of land access agreements with the landholder. The *Exploration code of practice: environmental management* requires the tenement holder to:

- implement all practicable measures to prevent the introduction and spread of weeds, pest animals and animal and plant diseases;
- implement all measures to prevent, so far as practicable, causing adverse impacts to livestock;
- consult with relevant landholders prior to establishing any new roads or tracks; and
- plan, design, construct, maintain and use roads and tracks in a manner which minimises the area and duration of disturbance to the environment and landholders to as low as practicable.

An exploration activity application must also assess whether the activity is likely to significantly disrupt or change current land uses and/or create biosecurity risks, and describe the mitigation measures that would be implemented to address these risks.

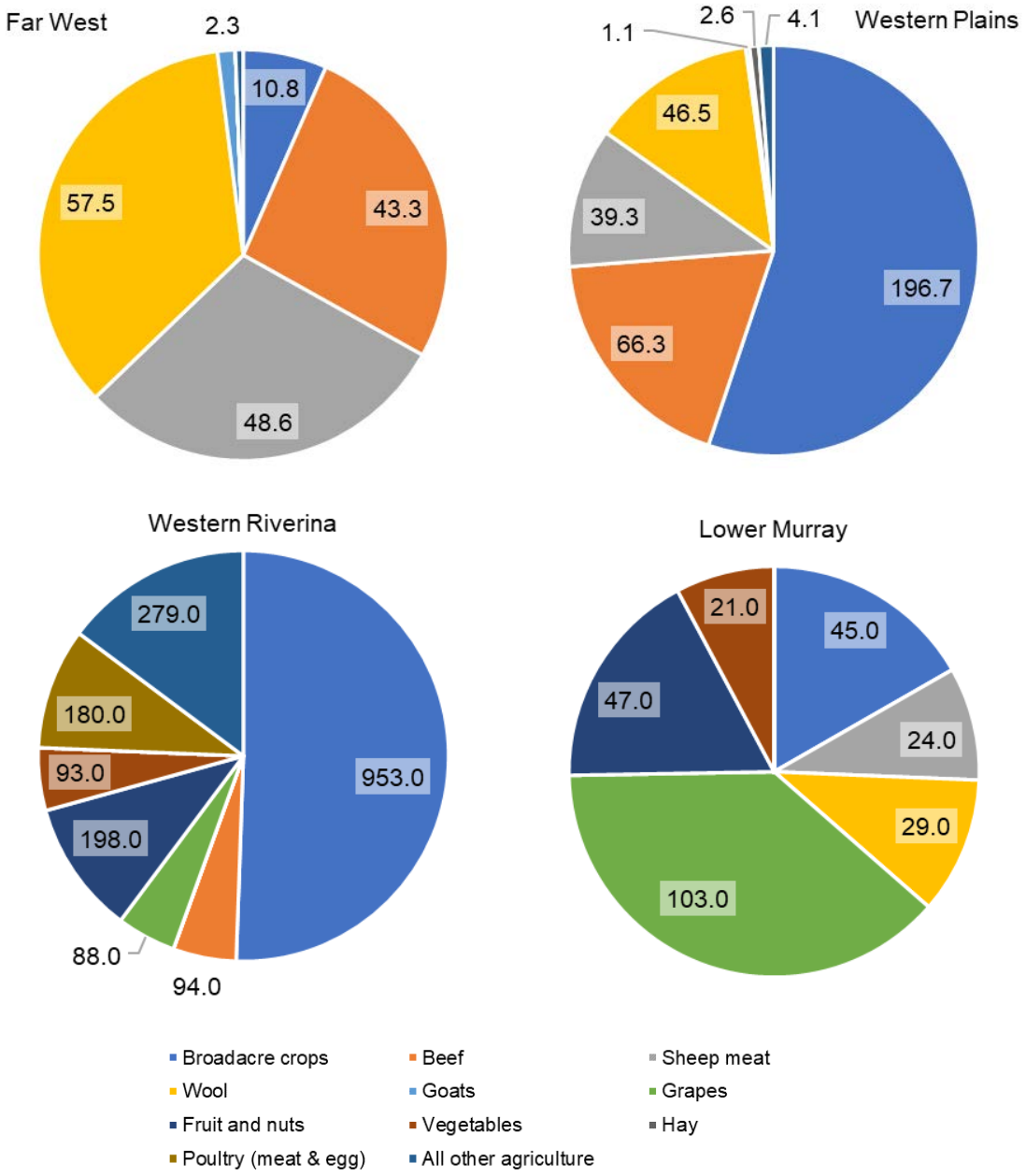
Similar measures would be identified and implemented for any future gas production activities through the merit assessment process under the SSD provisions of the EP&A Act.

Based on the above, the Department is satisfied that the current regulatory and planning framework is sufficient to manage potential impacts to agricultural land uses in the potential release areas.

In addition to the above, a number of potential benefits to agricultural land uses associated with any conventional gas exploration and/or production activities were identified, including:

- the potential for these activities to create supplementary incomes for pastoralists associated with compensation payments or payments for the provision of accommodation, machinery and/or water supply to exploration companies;

- the potential for improvements to shared infrastructure, such as roads; and
- the potential for these activities to identify new groundwater resources, with landholders interested in the potential for gas boreholes to be converted/repurposed as water bores (subject to necessary water licences being obtained).



Source: Department of Primary Industries, Agriculture Industry Snapshots for Planning – Far West, Western Plains, Western Riverina and Lower Murray Sub Regions. Based on ABS 2015/15.

Figure 24: Estimated Agriculture GVP ($M) in 2015-16 for Western NSW

5.7 Aboriginal Cultural Heritage

There are numerous Aboriginal community organisations and individuals that have an interest in the potential impacts of conventional and tight gas exploration or production activities on Aboriginal heritage values and the Aboriginal community. The Local Aboriginal Land Councils (LALCs) that cover the potential release areas include the Broken Hill LALC, Mutawintji LALC, Wilcannia LALC, Tibooburra LALC, Menindee LALC, Cobar LALC and Ivanhoe LALC (which is currently inactive).

The Department has reviewed the Aboriginal Sites Decision Support Tool to identify the potential for Aboriginal sites within the release areas. This tool has been developed to support the assessment of Aboriginal sites in NSW at a broader landscape-scale.

The Department has not used data from the NSW Aboriginal Heritage Information Management System (AHIMS) as it is not considered to provide an accurate representation of Aboriginal heritage in the potential release areas. This is due to the lack of formal systematic survey and the unwritten knowledge of some site locations (only known by the Aboriginal community and the landholder).

As shown in **Figure 25,** the Aboriginal Sites Decision Tool indicates a higher likelihood of sites (artefacts, rock art, burials, and a range of others) present in some parts of the release areas, such as the features areas surrounding Mutawintji National Park and the Paroo, Darling and Lachlan River floodplains.

The work completed by DECCW (2009) included contributions from Aboriginal community members to identify places with high conservation value (see **Figure 26** and **Figure 27**). These places included landforms, creation events, plants, ceremonial places, art sites, favourite food areas, burials, animals, water, occupation sites, other places used by people over thousands of years and places where culture can be practised today.

These areas were not a complete list of sites of significance, but provided some examples of the types of sites in the Western catchment.

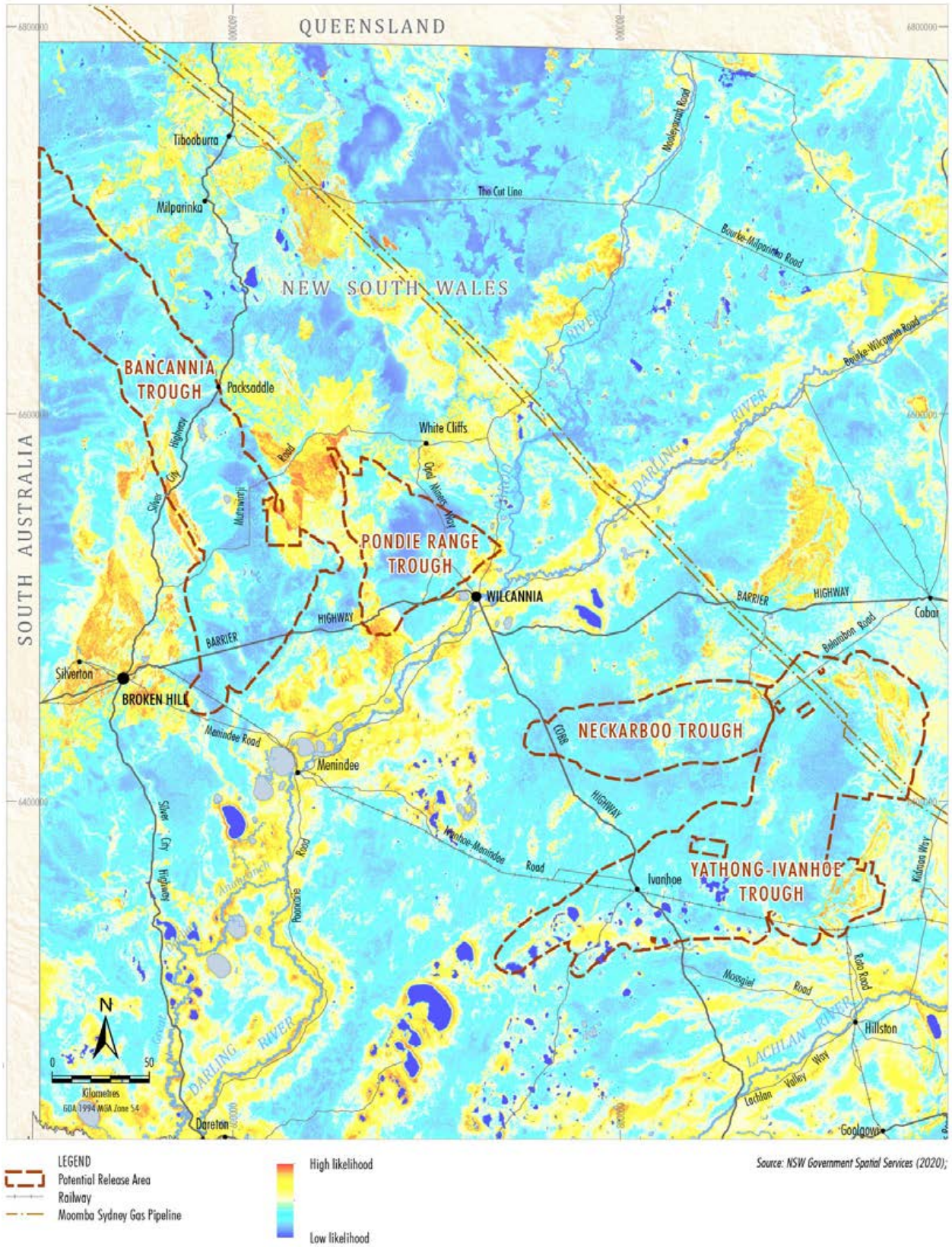


Figure 25: Aboriginal Sites Decision Support Tool - All Combined Features

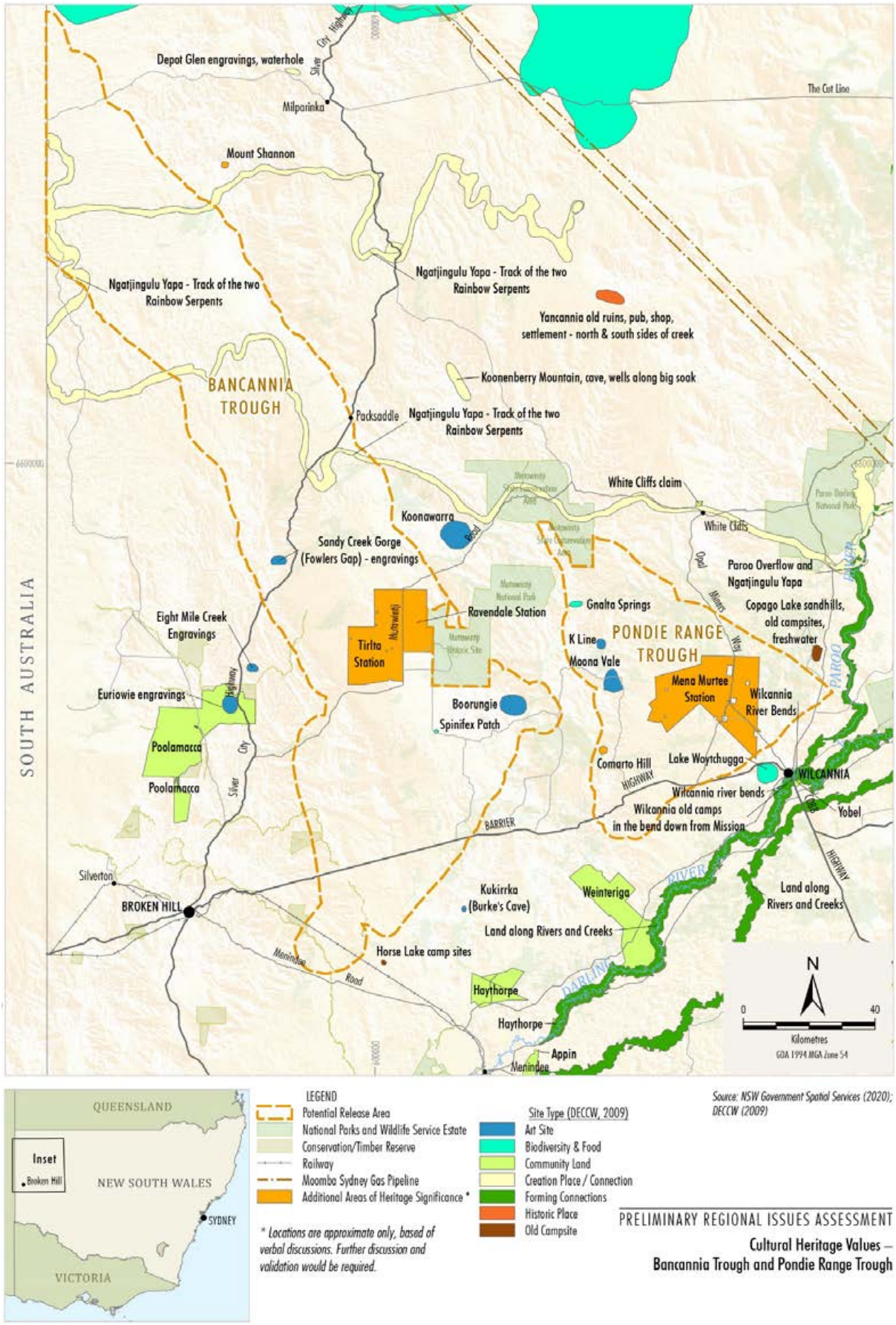


Figure 26: Cultural Heritage Values – Bancannia Trough and Pondie Range Trough

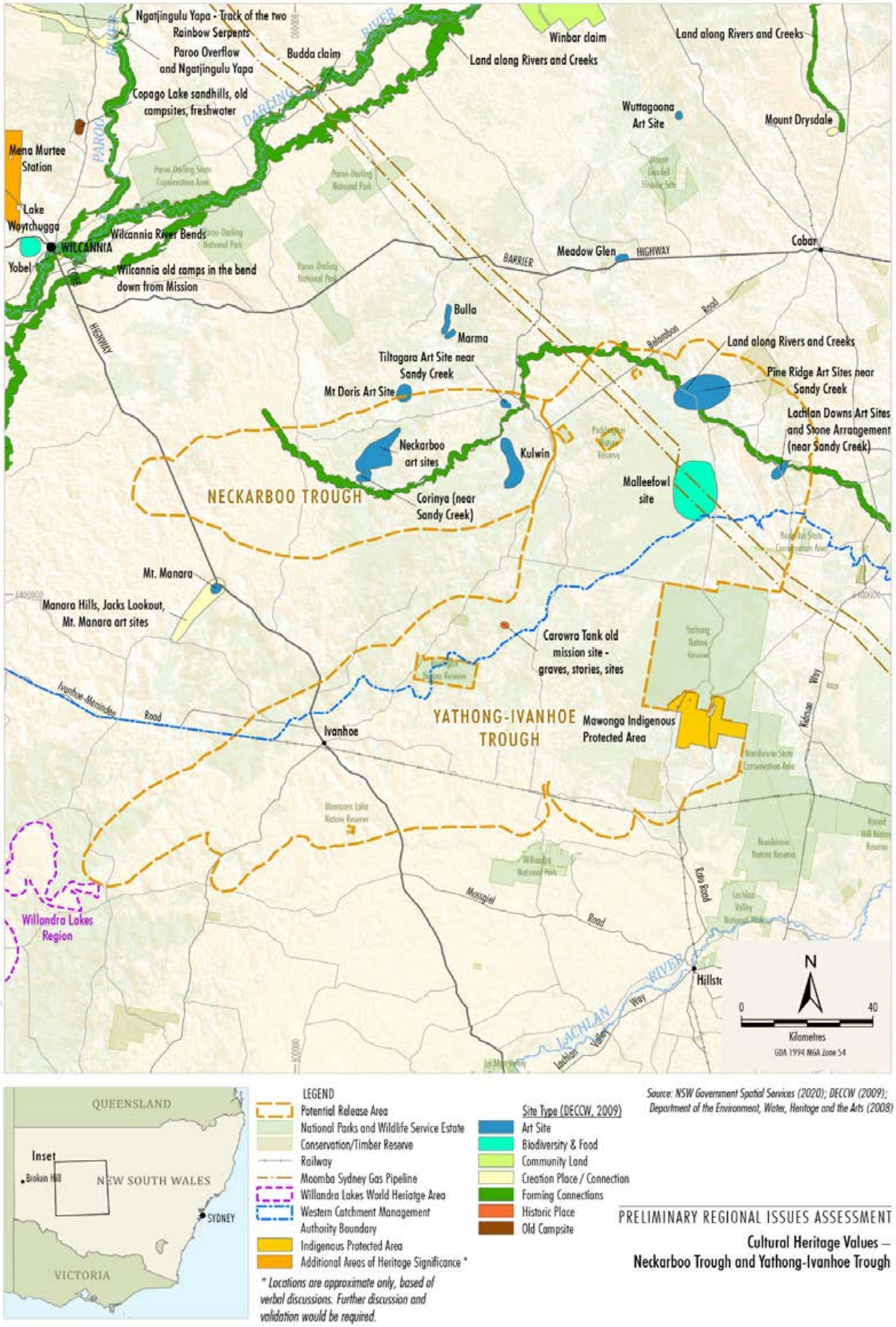


Figure 27: Cultural Heritage Values – Neckarboo Trough and Yathong-Ivanhoe Trough

The Department notes that the property of “Mawonga” (a 20,000 ha property that adjoins the Yathong Nature Reserve is located within the Yathong-Ivanhoe Trough potential release area (**Figure 27**). This property is an Indigenous Protected Area (IPA) managed by Indigenous groups for Aboriginal cultural heritage and biodiversity conservation through a voluntary agreement with the Australian Government. The Department recommends that any exploration avoid direct impacts to this area.

Descriptions of rock paintings and carvings in the Neckarboo Trough and northern part of the Yathong-Ivanhoe Trough potential release areas were also provided during engagement activities. The NSW Aboriginal Land Council also noted that there is significant Aboriginal Heritage in the Neckarboo Trough, however exact locations were not provided for the sites and features.

Consultation with an Aboriginal elder for the PRIA, Mr William (Badger) Bates, identified a number of additional cultural heritage sites that are present within the Bancannia Trough and Pondie Range Trough potential release areas. Mr Badger Bates identified the following additional areas of heritage significance in the Bancannia Trough and Pondie Range Trough potential release areas (**Figure 26** and **Figure 27**): Mount Shannon; a Desert Pea patch near the Barrier Highway (not shown); lakes on the Ravendale and Tirlta properties near Mutawintji Road; Comarto Hill; and the lake on the Mena Murtee property.

In addition to these identified areas, the Department notes that Aboriginal heritage values were raised as a key issue of concern during community engagement and there are a number of Aboriginal community organisations and individuals that are concerned about potential impacts of exploration or production activities on Aboriginal heritage values and the Aboriginal community.

The Barkandji Native Title Group Aboriginal Corporation has a determined Native Title Claim and Indigenous Land Use Agreement over portions of the potential release areas, including relatively small areas of Native Title in the southern parts of the Bancannia and Pondie Range Troughs. Aboriginal persons representing, or identifying as part of this group, raised concerns about impacts on physical heritage and the fabric of theirmythological culture and the mental health impacts this could have on the Aboriginal community.

The Ngemba, Ngiyampaa, Wangaaypuwan and Wayilwan People also have a Native Title Claim accepted for registration that covers large parts of the Neckarboo Trough and Yathong-Ivanhoe Trough potential release areas.

Processes to manage access to Native Title lands are set out in the Commonwealth *Native Title Act 1993* and the NSW *Aboriginal Land Rights Act 1983*. These processes would apply to any exploration activities in the potential release areas.

Aboriginal Land Claims under the *Aboriginal Land Rights Act 1983* also exist over parts of the Pondie Range Trough and Yathong-Ivanhoe Trough potential release areas.

In considering the potential impacts to Aboriginal Cultural Heritage, the Department notes that there is flexibility to avoid or minimise impacts as part of any gas exploration or production in consultation with Registered Aboriginal Parties.

Where impacts to Aboriginal heritage may occur as a result of exploration activities, the tenement holder must obtain an Aboriginal Heritage Impact Permit (AHIP) under the NPW Act. The AHIP application process requires a process of consultation with the Aboriginal community.

The potential impacts to Aboriginal heritage as a result of any future gas production activities would be also be subject to detailed assessment under the SSD provisions of the EP&A Act, which requires extensive consultation with the Aboriginal community.

Nevertheless, the Department acknowledges that the impacts of gas exploration and production activities may cause concern to the Aboriginal community, some of which has already been evident through the engagement process.

Consequently, the Department considers that any future tenement holder should implement a transparent plan for consultation with the Aboriginal community about proposed activities and potential opportunities.

The potential heritage impacts of any future connection to the Moomba Sydney Gas Pipeline were also raised by the Aboriginal community during consultation. The Department notes that the route of any future pipeline is unknown at this stage and that any proposal would be subject to a detailed environmental assessment that includes consultation with the Aboriginal community.

5.8 Non-Aboriginal Heritage

There are historic heritage sites in the vicinity of the potential release areas including in the City of Broken Hill, the towns of Wilcannia and Cobar, the Willandra Lakes Region World Heritage Area and Willandra National Park.

As discussed in **Section 5.2**, Department recommends that any future gas exploration and or production be avoided in close proximity to the Willandra Lakes Region to avoid impacts to the curtilage and heritage values of this heritage item.

The Department is not aware of any sites of significance within the potential release areas. There is some potential for sites of local or limited significance associated with historic pastoral activities, such as homesteads. These could be identified through site inspection of any proposed exploration and/or production disturbance areas.

The Department is satisfied that the current regulatory and planning framework is sufficient to avoid any significant European heritage impacts, and ensure any other impacts associated with gas exploration and/or production activities are suitably managed (**Section 3.6**).

5.9 Biodiversity

The potential release areas contain remnant vegetation and habitat for a wide variety of flora and fauna, including threatened species. The *NSW BioNet Indicative Threatened Ecological Community, Population and Species Distributions* dataset indicates that 47 threatened flora species and 87 threatened fauna species are known to occur in the potential release areas.

This includes three species that are listed as critically endangered under the *Biodiversity Conservation Act 2016* including the Pink Velvet Bush (*Lasiopetalum behrii*), Red-lored Whistler (*Pachycephala rufogularis*) and Desert Mouse (Pseudomys desertor).

BCS also provided threatened species data for the potential release areas, which indicates where threatened species have been sighted (see **Figure 28** and **Figure 29**).

One sighted threatened fauna species – the Thick-billed Grasswren (north-west NSW subspecies) (*Amytornis modestus obscurior*) – is listed under the *Biodiversity Conservation Act 2016* as critically endangered, 10 are listed as endangered, and a further 42 as vulnerable. Five threated fauna species sighted in the release areas have a conservation status of 'presumed extinct' under the BC Act.

There have been no sightings of threatened flora species listed under the BC Act as critically endangered in the release areas, however, 8 threatened flora species listed as endangered have been sighted, and a further 3 listed as vulnerable have been sighted. One threated flora species sighted has a conservation status of 'presumed extinct' under the BC Act.

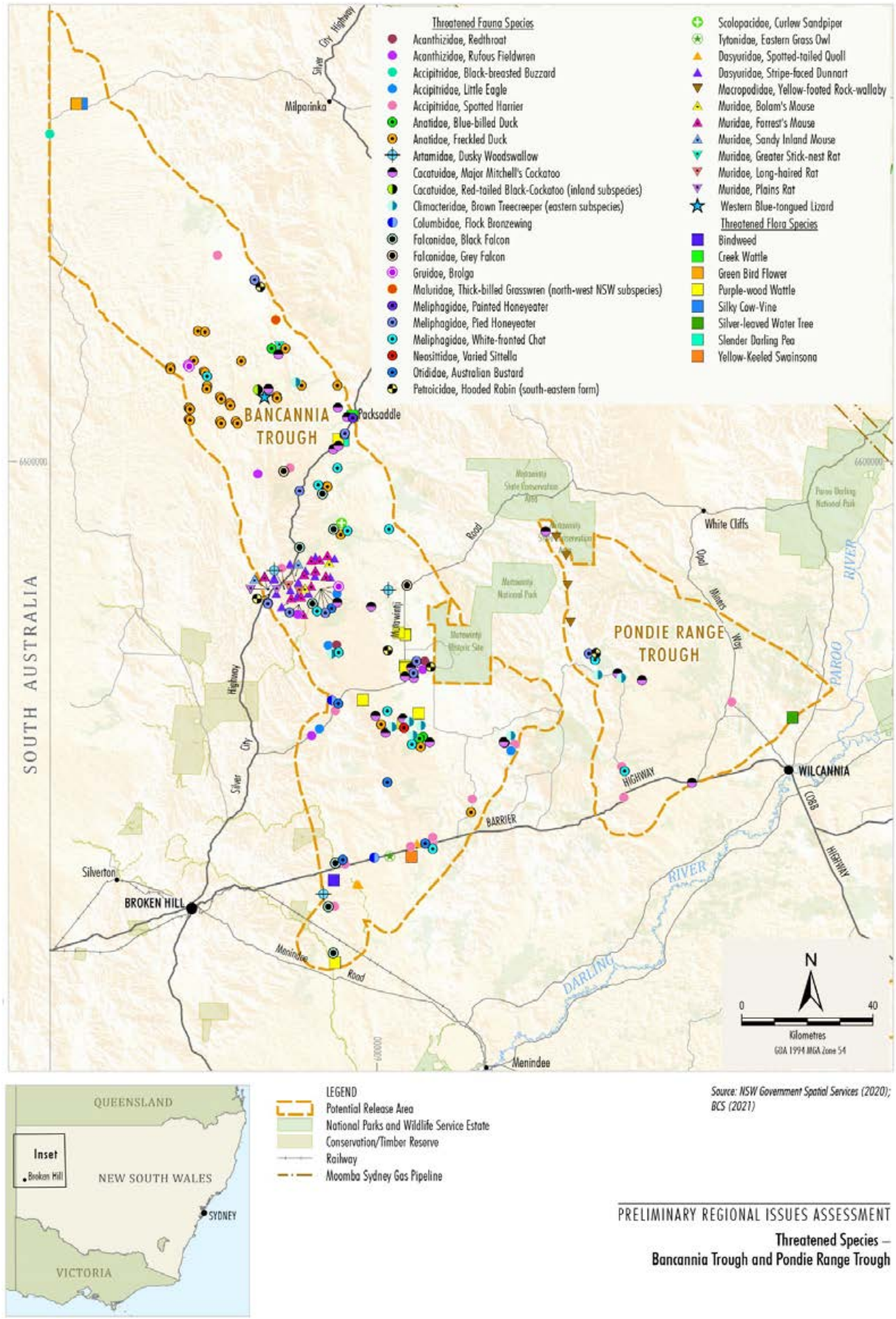


Figure 28: Threatened Species – Bancannia Trough and Pondie Range Trough

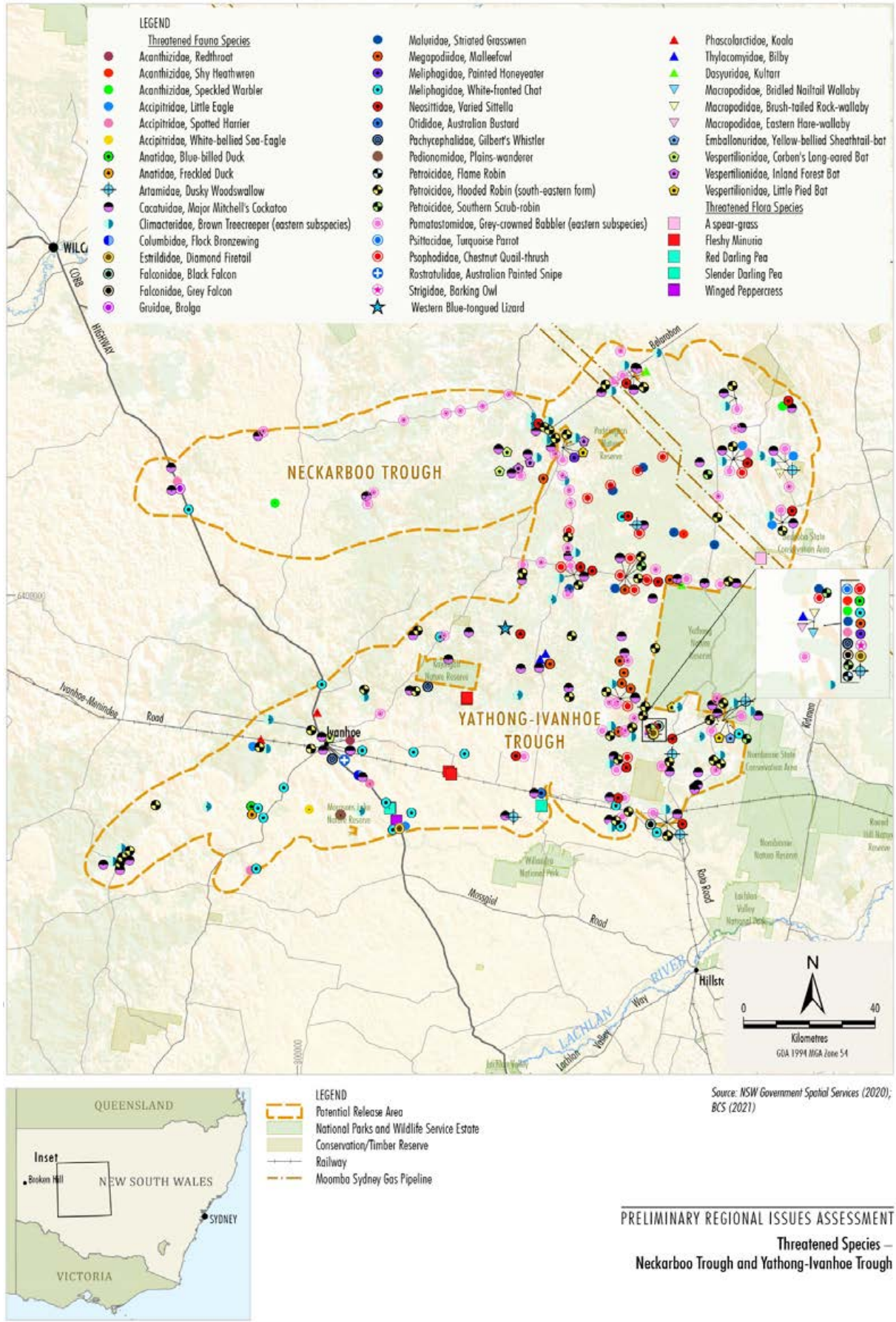


Figure 29: Threatened Species – Neckarboo Trough and Yathong-Ivanhoe Trough

In addition, the BCS noted that:

- The Mukarrthippi Grasswren (*Amytornis striatus striatus*), which occurs in the mallee spinifex areas in the Yathong-Ivanhoe Trough area, may be listed as critically endangered under the *Biodiversity Conservation Act 2016* in the future.
- The Bancannia Trough may include the only known sandhill in NSW with Eyrean Grasswren (*Amytornis goyderi*).

The Darling River, Paroo River and Lachlan River, including their effluent creeks and anabranches, provide habitat for the Silver Perch and Olive Perchlet which are listed as threatened under the *Fisheries Management Act 1994*. In addition, parts of the Lachlan River including Willandra Creek provide habitat for the Flathead Galaxias which is also listed as threatened under the *Fisheries Management Act 1994*. Parts of the Lachlan River upstream of the potential release areas provide habitat for the Eel Tailed Catfish which is listed as threatened under the *Fisheries Management Act 1994*.

Any gas exploration and/or production in potential release areas would have the potential to impact on the range of threatened species, populations and communities. However, given there is relatively high degree of flexibility in siting gas exploration and production activities, the Department anticipates that these activities could be designed to avoid or minimise significant impacts on threatened species, populations and communities.

In addition to direct disturbance, gas exploration and production activities would have the potential to have indirect impacts on biodiversity, for example through the spread of weeds or pests. The *Western Regional Strategic Weed Management Plan* and *Riverina Regional Strategic Weed Management Plan* provide information on priority weeds in the potential release areas and surrounding region. The *Exploration code of practice: environmental management* requires the tenement holder to implement all practicable measures to prevent the introduction and spread of weeds, pest animals and animal and plant diseases.

The Department is satisfied that there are no significant or fundamental constraints to the release of the areas from a biodiversity perspective and that the current regulatory and planning framework is sufficient to manage potential impacts of any conventional or tight gas exploration and production activities. This would include the need to implement the exploration Codes of Practice and avoid, mitigate or offset potential impacts in accordance with the requirements of the *Biodiversity Conservation Act 2016*.

5.10 Matters of National Environmental Significance

Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of national environmental significance, require approval from the Australian Government Minister for the Environment. The nine matters of national environmental significance protected under the EPBC Act are considered in **Table** 4.

If there is likely to be a significant impact on listed threatened species and ecological communities or migratory species, the tenement holder would be required to refer the proposed exploration and/or production activities to the Commonwealth Department of Agriculture, Water and the Environment for consideration under the EPBC Act.

Table 4: Consideration of Matters of National Environmental Significance

Matter	Consideration
World heritage properties	There are no world heritage properties within the potential release areas. The Willandra Lakes Region World Heritage Area is outside of the Yathong-Ivanhoe Trough potential release area with limited surface water connection (**Section 5.4**).
National heritage places	There are no national heritage places within the potential release areas. The City of Broken Hill, a listed National heritage place, is located outside of the Bancannia Trough potential release area.
Wetlands of international importance (listed under the Ramsar Convention)	The Paroo River Wetlands, a declared Ramsar wetland, are located upstream of the Pondie Range Trough potential release area (**Figure 18**), and are unlikely to be materially affected by conventional gas exploration or production activities.
Listed threatened species and ecological communities	Habitat is present within the potential release areas. Potential impacts on listed threatened species and ecological communities as a result of gas exploration or production activities would require detailed consideration by the tenement holder.[8]
Migratory species protected under international agreements	Habitat is present within the potential release areas. Potential impacts on migratory species as a result of gas exploration or production activities would require detailed consideration by the tenement holder.
Commonwealth marine areas	Not relevant.
Great Barrier Reef Marine Park	Not relevant.
Nuclear actions (including uranium mines)	Not relevant.
A water resource, in relation to coal seam gas development and large coal mining development	Not relevant as there is no potential for coal seam gas.

5.11 Other Protected and Significant Areas

The Mutawintji National Park is located within the Bancannia Trough however, it is excluded from the potential release area. Parts of the Mutawintji National Park are a declared wilderness area under the *Wilderness Act 1987*. Mutawintji National Park is managed by the local Aboriginal community through a Board of Management.

[8] It is an offence under Part 3 of the EPBC Act to take an action that will have a significant impact on a listed threatened species, ecological community or migratory species without approval under the EPBC Act (or other relevant defence).

The Yathong-Ivanhoe Trough potential release area adjoins a number of conservation areas including Paddington Nature Reserve, Morrison's Lake Nature Reserve, Kajuligah Nature Reserve, Nombinnie Conservation Area, and Yathong Nature Reserve. These areas are managed by NSW National Parks and Wildlife Service under plans of management and in accordance with principles of the *National Parks and Wildlife Act 1974*.

The Department is advised that National Parks and Wildlife Service is exploring potential for additional conservation areas in and around the potential release areas.

The *Developments adjacent to National Parks and Wildlife Service lands*[9] guideline notes that consent authorities need to consider the following issues when assessing proposals adjoining National Parks and land managed by the National Parks and Wildlife Service:

- erosion and sediment control;
- stormwater runoff;
- wastewater;
- management implications relating to pests, weeds and edge effects;
- fire and the location of asset protection zones;
- boundary encroachments and access through National Parks and Wildlife Service lands;
- visual, odour, noise, vibration, air quality and amenity impacts;
- threats to ecological connectivity and groundwater-dependent ecosystems; and
- cultural heritage.

On the basis that adequate consideration is given to the *Developments adjacent to National Parks and Wildlife Service lands* guideline as part of the assessment process for any gas exploration or production activities (**Section 3.6**), the Department is satisfied that any significant conflicts with the existing conservation uses adjacent to the Bancannia and Yathong-Ivanhoe Troughs are likely to be avoidable.

The locations of other conservation areas have been provided by the BCS and include:

- land voluntarily protected by the landholder under a Conservation Agreement or as a Wildlife Refuge under the NPW Act (now managed under the *Biodiversity Conservation Act 2016*) or Biodiversity Stewardship Site Agreement, including Fowlers Gap Research Station operated by the University of NSW located within the Bancannia Trough; and
- areas subject to a targeted conservation project for a threatened species under the NSW Government Saving Our Species program.

The locations of these conservation areas are shown on **Figure 30** and **Figure 31** and include two wildlife refuges (Topar and Bijerkerno), the Fowlers Gap conservation agreement, and a Purple-wood Wattle management area within the Bancannia Trough, three wildlife refuges (Churinga, Cootawundi and Kalyanka) in the Pondie Range Trough, one wildlife refuge in the Neckarboo Trough and one wildlife refuge in the Yathong-Ivanhoe Trough.

The DECCW (now the Department's Biodiversity Conservation and Science Directorate) completed a study in 2009 that identified areas in the Western Catchment with high biodiversity, Aboriginal cultural heritage and geodiversity values.

---

[9] https://www.environment.nsw.gov.au/research-and-publications/publications-search/developments-adjacent-to-national-parks-and-wildlife-service-lands.

In addition to areas discussed in **Sections 5.7** and **5.9**, the following specific areas were identified as having particular value:

- Cambrian rocks at Mount Wright (including limestone containing trilobite fossils), located in Mutawintji National Park adjacent to the Bancannia potential release area;
- Barrier Ranges, located west of the Bancannia Trough potential release area;
- Darling River and its paleochannel, located southeast of the Pondie Range Trough and northwest of the Neckarboo Trough potential release areas;
- Downs and lowlands adjoining Mutawintji National Park, located between the Bancannia Trough and Pondie Range Trough potential release areas.
- Areas north-west of Yathong Nature Reserve that contain areas of large dunes with 'whipstick' mallee, located within the Yathong-Ivanhoe Trough.

The location of each of these areas is shown on **Figure 32**. With the exception of the dune areas with Mallee in the Yathong-Ivanhoe Trough, the other areas are located outside the potential release areas are unlikely to be impacted by any future gas exploration and production and would not form a constraint to the release of the areas.

Gas exploration or production activities would need to be managed to avoid conflict with the above conservation land uses. Given there is some flexibility in the location of these activities, it is envisaged that these activities could be modified to avoid any significant conflicts. Notwithstanding, the Department recommends that any exploration avoid the areas of land protected under a Conservation Agreement or Biodiversity Stewardship Site Agreement.

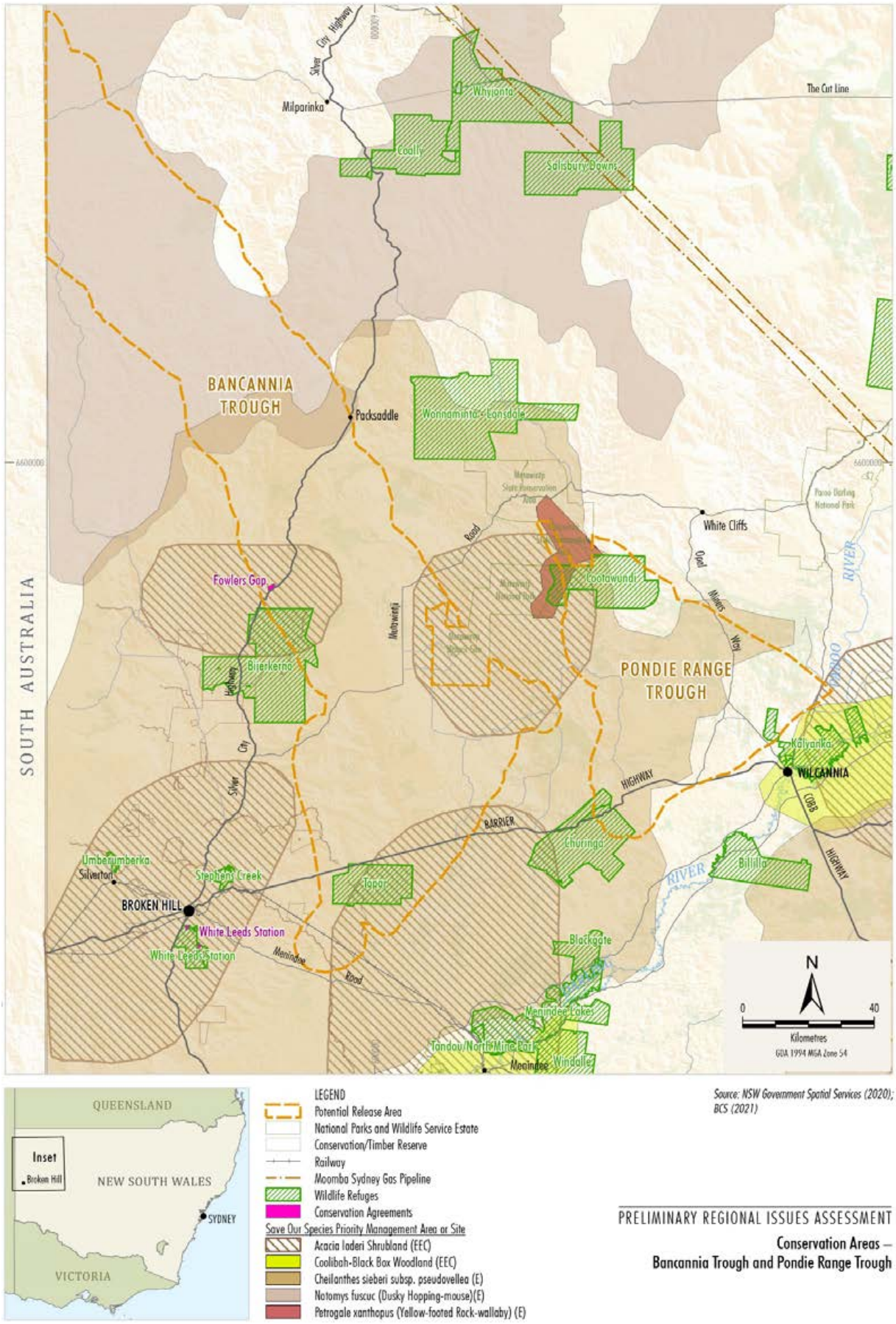


Figure 30: Conservation Areas – Bancannia Trough and Pondie Range Trough

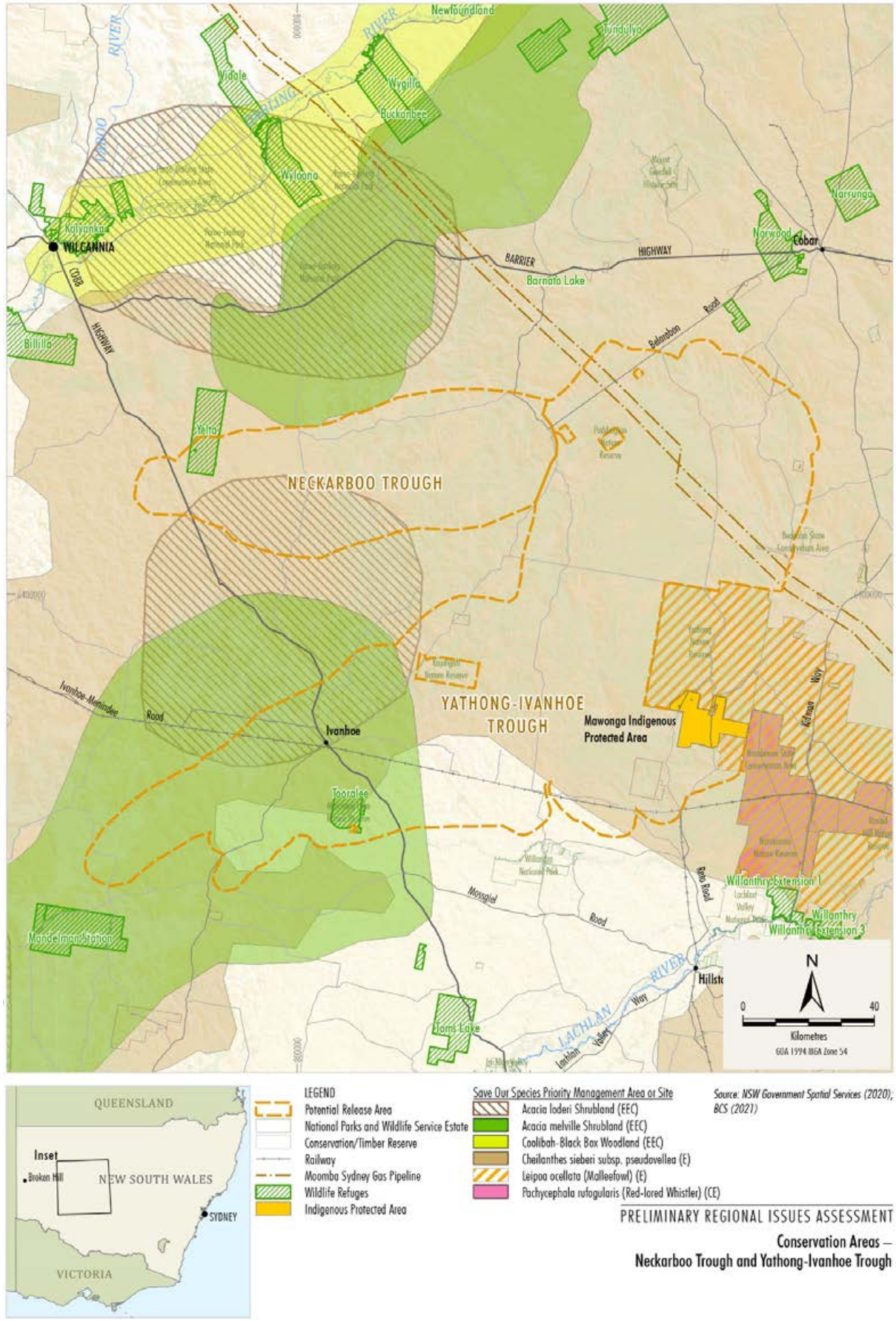


Figure 31: Conservation Areas – Neckarboo Trough and Yathong-Ivanhoe Trough

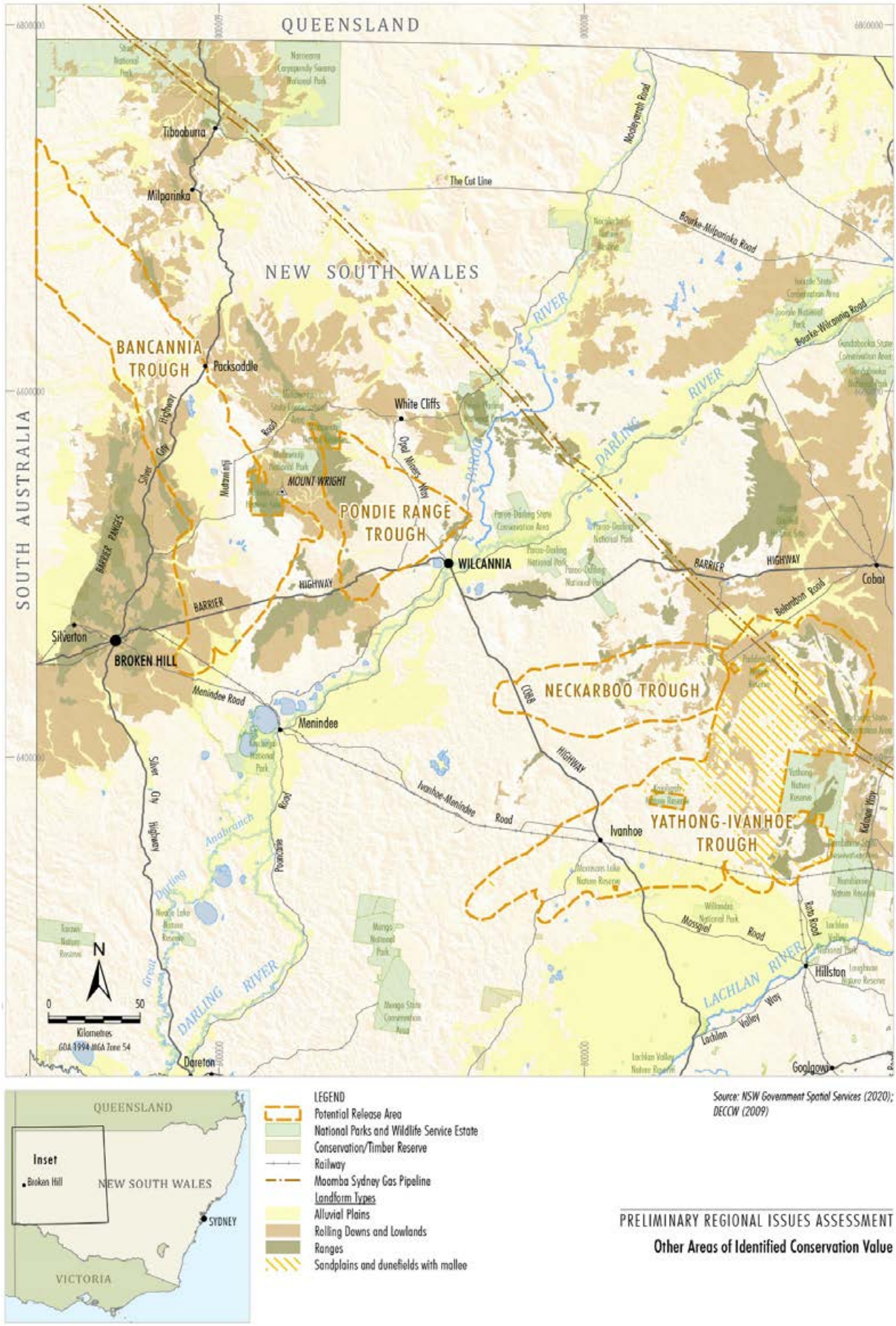


Figure 32: Other Areas of Identified Conservation Value

5.12 Potential Impacts to Health and Amenity of Local Communities

Conventional or tight gas exploration and production activities have the potential to create noise, dust and other gaseous emissions. This may affect the amenity of people in close proximity to the activities or, if unmitigated, may have health impacts.

The NSW Government has policies and processes to assess, monitor and manage noise and air quality impacts. This includes the following key policies:

- **Approved Methods for the Modelling and Assessment of Air Pollutants in NSW** – outlines methods to assess impacts on air quality and impact assessment criteria for common pollutants to protect the amenity, health and safety of people.
- **Noise Policy for Industry** – provides noise levels for assessing the potential impact of noise from industry and includes a framework for considering feasible and reasonable noise mitigation measures.
- **Voluntary Land Acquisition and Mitigation Policy** – describes the NSW Government's policy for voluntary mitigation and land acquisition to address noise and dust (particulate matter) impacts from State significant gas developments (as well as mining, other petroleum and extractive industry developments).

Any future gas infrastructure would also have the potential to create visual impacts. Concerns were raised during the PRIA engagement process regarding potential amenity impacts that would detract from the "outback experience" that attracts tourism to the broader area, including Broken Hill.

In considering this issue, the Department notes that a large majority of the potential release areas are sparsely populated, and this would allow a tenement holder to design any gas exploration or production activities to minimise potential health, safety and amenity impacts on local residents and communities.

Notwithstanding, the Department recognises that the Yathong-Ivanhoe Trough includes the township of Ivanhoe which is more densely populated than other parts of the potential release areas. The town has a population of 327 people and is zoned RU5 Rural Village under the *Central Darling Local Environmental Plan* which is characterised by relatively small rural residential lots.

The Department recommends that a 2km buffer zone from any land zoned or identified as Residential (R1, R2, R3, R4, R5), Rural Village (RU5) and/or future growth areas in an environmental planning instrument be excised from the Yathong-Ivanhoe Trough release area to avoid amenity impacts including noise, dust and visual impacts on the town of Ivanhoe. Other social considerations and potential negative impacts on this community are discussed in **Section 5.6**.

With this measure in place, and assuming appropriate design and siting of infrastructure and implementation of operational controls, the Department is satisfied that the current regulatory and planning framework is enough to manage potential noise, air quality, and visual impacts that might result from any future gas exploration or production.

5.13 Greenhouse Gas Emissions

The context of the potential gas resource in relation to NSW Government's Climate Change Policy is discussed in **Section 3.5**.

Given the limited exploration that has occurred in the potential release areas to date, knowledge of the size and characteristics of any gas resource is limited. Therefore, the potential greenhouse gas emissions associated with exploring, extracting or developing any potential gas resource cannot be reliably quantified.

However, based on the Department's experience, Scope 1 and Scope 2 emissions form only a small proportion of the emissions associated with energy generation. Scope 3 emissions associated with use of the gas (either domestically or abroad) would generate much higher levels of greenhouse gas emissions, but the generation of these emissions is likely to occur regardless of whether gas production proceeds in any of the potential release areas.

To this end, the Department notes that Scope 3 emissions can be a significant contributor to anthropological climate change and any future project would need to include an assessment of the potential impacts to climate change in NSW in accordance with the requirements of the EP&A Act and the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*.

The production of a local gas supply has the potential benefit of reduced emissions associated with distribution compared to the importation of gas via sea or interstate pipelines.

5.14 Strategic Resource Significance

The *NSW Gas Plan* recognises that the safe and sustainable development of an onshore gas industry in NSW will create significant benefits to households and businesses.

NSW households and businesses consume approximately 140 petajoules (PJ) of gas annually, of which only 3.5% is currently produced within NSW. While the Narrabri Gas Project is expected meet up to 50% of forecast gas demand use in NSW, without the development of new gas resources, NSW will continue to import a significant portion of its gas supply from interstate or overseas from 2024.

The potential release areas are located in proximity to the Moomba Sydney Gas Pipeline. The pipeline passes through the Yathong-Ivanhoe Trough and is located approximately 125 km from the edge of the Bancannia Trough, 56 km from the edge of the Pondie Range Trough and 13 km from the edge of the Neckarboo Trough.

The Moomba Sydney Gas Pipeline connects to the Junee Griffith Gas Pipeline 25 km from the edge of the Yathong-Ivanhoe Trough. Therefore, there is potential that feasible distribution methods could be developed to get any gas to market should gas be produced in any of the areas in the future.

5.15 Availability and Access to Infrastructure and Utilities

Access to the potential release areas is available via:

- Road – Barrier Highway (sealed), Silver City Highway (partially sealed), Cobb Highway (partially sealed) and other major/minor roads, with all-weather road access limited in some areas.
- Rail – Orange to Broken Hill (which connects to Sydney), and Broken Hill to Adelaide.
- Air – with regular air passenger services to Broken Hill and Griffith, and other aerodrome facilities available in the region (e.g. Tibooburra, Wilcannia, Ivanhoe and Cobar).

Apart from these roads, there are very few formed roads throughout the potential release areas. Consequently, it is possible that obtaining access and providing services to some parts of the potential release areas would be difficult.

The Department notes that planned sealing and upgrade work for the Silver City Highway (identified in the Far West Regional Plan), Cobb Highway, Barrier Highway, and The Wool Track from Balranald to Ivanhoe (all identified in *Future Transport 2056*[10]) would assist exploration and any potential future development in the potential release areas.

The community raised concerns about existing road conditions and the potential for impacts on unsealed roads. The Department notes that any exploration is not likely to generate any significant traffic volumes. However, upgrades to additional roads might be required to support any future gas production in the area.

The majority of infrastructure and services in western NSW are concentrated in Broken Hill, Wilcannia, Cobar, Hillston and Ivanhoe. With the exception of Ivanhoe, these towns and centres are located over 200 km from some parts of the potential release areas (**Section 3.1**).

Consequently, it is anticipated that any future gas exploration and/or production activities would need to be supported by temporary accommodation facilities given the remote nature of the area. Any temporary facilities would need to obtain necessary approvals and may require consultation with Crown Lands and leaseholders in relation to works on Western Land Leases.

It is also recognised that access to telecommunications is unreliable in the area, with mobile blackspots and overloaded base stations. Community members expressed concern about gas exploration and/or production activities placing additional demand on telecommunication infrastructure, affecting access for the local community. These impacts could be mitigated by upgrading existing facilities (which has occurred in some parts of western NSW through the Federal Mobile Black Spot Program).

Any gas production would likely require a connection to the Moomba Sydney Gas Pipeline in order to distribute gas to market. The route of any future connection cannot be identified at this stage and would be subject to further technical, environmental and heritage considerations by the tenement holder. Notwithstanding, no obvious constraints to establishing a connecting pipeline have been identified at this stage.

5.16 Other Industries and Land Uses

Other major projects in the vicinity of the potential release areas include:

- The Broken Hill Solar Plant located west of Broken Hill – construction completed in 2015.
- The Silverton Wind Farm located north of Broken Hill – commissioned in 2019.
- Wentworth to Broken Hill water supply pipeline – commissioned in 2019.
- Rasp Mine in Broken Hill – currently operating with an approved life to 2026.
- Broken Hill North Mine in Broken Hill – ongoing operations.
- Broken Hill Mineral Separation Plan on the southwestern outskirts of Broken Hill – currently operating with an approved life to 2032.
- Ginkgo Minerals Sands Project and Snapper Minerals Sands Project approximately 170 km southeast of Broken Hill – operating with an approved life of 2023 and 2026 respectively.
- Atlas-Campaspe Mineral Sands Project east of the Mungo State Conservation Area – commencing operations in 2021 with an approved life to 2034.
- New Cobar Mine Complex and Peak Mine Complex near Cobar – currently operating with a proposal to extend the life of mine to 2035.

[10] https://future.transport.nsw.gov.au/sites/default/files/media/documents/2018/Regional_NSW_Services_and_Infrastructure_Plan_1.pdf.

- Wilcannia Weir Replacement – construction expected to commence in 2021.

These projects are all located outside the potential release areas and are unlikely to be affected by any gas exploration or production. Depending on the location of any future gas production, any future tenement holder may need to consider the cumulative impacts, particularly on infrastructure and services in towns and centres, including Broken Hill.

Exploration Licences

The majority of the Pondie Range Trough potential release area overlaps with an exploration licence held by the NSW Government for geothermal energy (EL 8066). Small portions of the Pondie Range Trough release area also overlap with several exploration licences held for metallic minerals (EL 6400, EL 6803, EL 8919 EL 8722, EL 8790, and EL 8909) and corundum, diamond, ruby and sapphire (EL 8874).

Through the Coal Innovation NSW Fund, MEG is undertaking geological assessment work under EL 8065 and EL 8066 in the Pondie Range Trough to investigate potential CO_2 geological storage options as mitigation for greenhouse gas emissions. This program of work is known as the NSW CO_2 Storage Assessment Program.[11]

Parts of the Yathong-Ivanhoe Trough potential release area (north of the Yathong Nature Reserve) also overlap with an exploration licence for geothermal energy held by the NSW Government (EL 8065). Small portions of the area also overlap with exploration licenses for metallic minerals (EL 8724, EL6155, EL 6302, EL 6482 EL 7345, EL 7515 and EL 8498, EL 8802, EL 8071, EL 8070, EL 8843 and EL 8844) and a Mining License held by Manuka Resources for copper, gold, lead, silver and zinc (ML 1659).

The majority of the Bancannia Trough release area is not covered by any other active titles. However, small portions of the potential release area overlap with exploration license for metallic minerals (EL 8722, EL 8791, EL 8941, EL 8434 and EL8732).

Aside from a very small area overlapping an exploration licence for metallic minerals (EL 9007) and part of the NSW Government's geothermal exploration license (EL 8065 mentioned above), the Neckarboo Trough potential release area is not covered by any other active titles.

The Department notes that overlapping parts of the above mentioned metallic mineral exploration titles are relatively small compared to the potential release areas. Consequently, the Department considers that there is unlikely to be any material conflicts between any conventional or tight gas exploration and/or production activities and the current exploration activities for metallic minerals in the potential release areas.

However, the Department considers that there is potential for interaction between any exploration activities in the Pondie Range Trough and Yathong-Ivanhoe Trough and the exploration activities being undertaken by the Coal Innovation NSW Fund. It is possible that landholders in this area may get confused about the separate exploration programs, or become fatigued as result of negotiating and coordinating with two separate exploration entities.

The Department recommends both tenement holders carefully consult with the community to explain the differences between the exploration work being completed by the Coal Innovation NSW Fund and any proposed gas exploration.

[11] https://www.resourcesandenergy.nsw.gov.au/investors/coal-innovation-nsw/research-projects/nsw-co2-storage-assessment-project.

6.0 Findings and Considerations

The PRIA outlines the Department's advice to the Advisory Body for Strategic Release on environmental, social and economic matters relating to the potential release of the Bancannia Trough, Pondie Range Trough, Neckarboo Trough and Yathong-Ivanhoe Trough potential release areas in western NSW for conventional and tight gas exploration.

In preparing this PRIA, the Department has visited the area, consulted with the community and key stakeholders, and reviewed existing Government data sources.

The PRIA has considered general development scenarios that could flow from the release of the four potential release areas for conventional or tight gas exploration, and identified the key issues associated with these scenarios at a regional scale. **Table 5** summarises and compares some of the Department's key findings for each of the potential release areas.

While gas exploration and/or production activities would undoubtedly result in some impacts to these areas, the Department has concluded that the existing regulatory and planning framework is sufficiently robust to protect areas that are valuable, and to ensure that any impacts associated with gas exploration and/or production comply with Government policies, guidelines and standards and are appropriately minimised and managed.

The Department has not identified any fundamental environmental, social or economic constraints that would preclude the release of the residual areas for conventional and tight gas exploration and/or development. In this regard the Department notes that:

- The potential release areas are generally sparsely populated, and any gas exploration and production could be sited to avoid and minimise impacts.
- Any future gas production is likely to have socio-economic benefits for the region, households and the State as a whole.
- The gas resource is strategically significant and could support local and export markets.
- Extensive work by the NSW Government and the Australian Energy Market Operator (AEMO) has shown any greenhouse gas emissions are likely to occur irrespective of whether the area is released for exploration as there will continue to be domestic demand for gas for household needs and developing needs for electricity firming capacity. With that said, the Department notes that Scope 3 emissions can be a significant contributor to anthropological climate change, and any future production project would need to include an assessment of the potential impacts to climate change in NSW.
- Although agricultural land uses are important drivers of the regional economy, the land is not highly productive and is used mainly for grazing purposes.
- While the area contains productive aquifers that are associated with the Great Artesian Basin, Darling River, and Lachlan River, independent expert advice from Mr George Gates suggests that there is unlikely to be any measurable impact on these water resources given the depth at which the gas is likely to occur and the many intervening impermeable sedimentary layers between the resource and aquifers.

With that said, the Department notes that parts of the potential release areas are more constrained than others.

In this regard, the Department notes that the Yathong-Ivanhoe Trough and Neckeraboo Trough have much higher land and soil capability than the Bancannia Trough and Pondie Range Trough. The southern extent of the Yathong-Ivanhoe Trough and the western extent of the Neckarboo Trough have the highest land and soil capability. The Yathong-Ivanhoe Trough is also the most densely populated of all the potential release areas, the large majority of which is concentrated in Ivanhoe and the associated rural residential land uses. The Yathong-Ivanhoe Trough is also located adjacent to the Willandra Lakes Region World Heritage Area.

Table 5: Comparison of the Potential Release Areas

	Bancannia	Pondie Range	Neckarboo	Yathong-Ivanhoe
Total Area	13,160 km^2	4,000 km^2	4,380 km^2	15,170 km^2
Local Government Area (LGA)	Unincorporated Far West	Central Darling, Unincorporated Far West	Central Darling, Cobar	Cobar, Central Darling, Balranald, Carrathool
Highly Productive Groundwater	Great Artesian Basin	Great Artesian Basin; Proximal to Upper Darling Alluvium	-	Lower Lachlan Alluvium
Surface Water Catchment	Lake Frome, Lake Bancannia and Darling River	Darling River and its tributary Paroo River	Darling River	Darling River, Lachlan River and Benanee (Willandra Lakes)
Nearby Town Water Supplies	-	Proximal to Wilcannia town water supply from Darling River and Upper Darling Alluvium	-	Ivanhoe town water supply from Lower Lachlan Alluvium
Key Matters of National Environmental Significance[12]	-	Peery Wetlands (Ramsar site) located upstream	-	Willandra Lakes Regional World Heritage Area located immediately adjacent
Land and Soil Capability (percentage of release area)	Class 3 – not present Class 4 – 235 km^2 (1.8%) Classes 5 to 8 – 12,925 km^2 (98.2%)	Class 3 – not present Class 4 – 160 km^2 (4.0%) Classes 5 to 8 – 3,840 km^2 (96.0%)	Class 3 – not present Class 4 – 1,206 km^2 (27.6%) Classes 5 to 8 – 3,174 km^2 (72.4%)	Class 3 – 129 km^2 (0.9%) Class 4 – 6,000 km^2 (39.5%) Classes 5 to 8 – 9,041 km^2 (59.6%)
Cultural Heritage	Connection to Country and tangible and intangible heritage values across all potential release areas			
Private Landholders within Release Area	56	30	22	217 (inclusive of 103 in the town of Ivanhoe)
Distance to Services	Broken Hill 32 km - 277 km Wilcannia 71 km – 325 km	Broken Hill 125 km - 208 km Wilcannia 10 km - 110 km	Wilcannia 70 km - 165 km Cobar 98 km – 223 km	Cobar 40 km – 296 km Hillston 44 km – 194 km

[12] There is habitat for listed threatened species and ecological communities and migratory species protected under international agreements present within all potential release areas.

The Department heard strong concerns about potential gas exploration from the community, particularly in the Ivanhoe area and from members of the Yathong-Ivanhoe Neckarboo Aquifer Alliance. The Yathong-Ivanhoe potential release areas is the most densely populated of all prospective areas, and this has led to concerns about the impacts of any production on a range of matters including water quality and quantity, conflicts with agricultural land uses, impacts on infrastructure, impacts on health and wellbeing and more.

This community feels that they are unlikely to benefit from any gas exploration as the relatively isolated from other centres and do not have an existing employment base in the resources sector.

While all four troughs have suitable geological features to suggest prospectivity for conventional and tight gas resources, they are underexplored and further exploration would be required to determine whether these areas host economic resources.

This means that there is no certainty about whether further exploration in these areas would lead to commercial gas production. The Department recognises that this has the potential to create uncertainty for the community and will make it difficult to anticipate or plan for the implications of any future development should the areas be released.

Given the large volume of land being considered for release in this instance, the Department considers that there is an opportunity to balance some of these issues, and to prioritise the release of some areas to avoid some of the constraints and avoid unnecessarily prolonging community uncertainty in particular areas.

The Department recommends that the Bancannia Trough and Pondie Range Trough potential release areas could be prioritised and released in whole and that the Yathong-Ivanhoe Trough and Neckarboo Trough potential release areas could be released in part (**Figure 1**).

The Department considers that the southern extent of the Yathong-Ivanhoe Trough and the western extent of the Neckarboo trough should form the lowest priority for any release given the considerations outlined above. These areas could be reassessed for release at a later date informed by the outcomes of exploration data and environmental and social performance of activities in the other areas proposed for release.

Areas in the northern extent of the Yathong-Ivanhoe Trough (north of the Yathong-Ivanhoe Nature Reserve) and in the eastern extent of the Neckarboo Trough are more strategically significant due to proximity to the Moomba Sydney Gas Pipeline and the town of Cobar, and could be considered a higher priority than other parts of these troughs. The Department considers that the Cobar local government area is more likely to benefit from the development of any gas resource in the future than Ivanhoe noting that it has a greater population, greater rental capacity, and an existing employment base in the resource sector.

The Department has also identified several issues that should be considered in any future exploration or development assessment process if the four areas are release for gas exploration and production.

These issues include:

- the implementation of a transparent plan for consultation with the Aboriginal community about proposed activities and potential opportunities;
- the need to minimise impacts on Class 3 and 4 agricultural land where possible;
- the need to avoid conflicts with areas of conservation value, including land voluntarily protected (or to be protected) under a Conservation Agreement or Biodiversity Stewardship Site Agreement;
- the need to continue strict regulation of hydraulic fracturing activities, including continued enforcement of the ban on harmful chemicals known as BTEX and the requirement for stringent testing and reporting protocols; and

- the collection of suitable groundwater data to improve knowledge of the area and provide a sound basis for any future environmental assessment.

In the event that the southern extent of the Yathong-Ivanhoe Trough is released in the future, the Department recommends:

- a 2km buffer zone from any land zoned or identified as Residential (R1, R2, R3, R4, R5), Rural Village (RU5) and/or future growth areas in an environmental planning instrument be excised from the Yathong-Ivanhoe Trough release area to avoid amenity impacts including noise, dust and visual impacts on the town of Ivanhoe;
- an appropriate buffer is provided between any exploration or development and the Willandra Lakes Region World Heritage Area to avoid impacts to the curtilage and significance of this heritage item; and
- potential conflicts with the Mawonga Indigenous Protected Area are avoided or managed.

Appendix A – Previous Petroleum Exploration Licences

Table A-1: Previous Petroleum Exploration Licences over the Bancannia Trough

Title Reference	Tenement Holder	Approximate Year of Operation	Exploration Highlights	Area
PEL31	Clarence River Basin Oil Exploration Co NL	1960 - 1964	Two seismic surveys (both outside of the trough).	Northern margin of Bancannia Trough.
PEL35	Planet Exploration Company Pty Ltd	1960 - 1963	Aeromagnetic survey interpretation and seismic survey (outside of the trough).	Southern margin of Bancannia Trough.
PEL44	United Australian Oil Inc.	1961 - 1962	Desktop studies.	Central Bancannia Trough.
PEL52	Alliance Oil Development Australia NL	1961 - 1968	Gravity surveys, drilling, aeromagnetic survey interpretation and seismic surveys (outside of the trough).	Southern margin of Bancannia Trough.
PEL71	Lincoln Oil Ltd	1962	Desktop studies.	Central and southern Bancannia Trough.
PEL76	Australian Oil Corporation	1962 - 1966	Gravity survey.	Northern Bancannia Trough.
PEL78	Planet Exploration Company Pty Ltd	1962 - 1966	Aeromagnetic survey, gravity surveys and seismic survey.	South eastern Bancannia Trough.
PEL114	Planet Exploration Company Pty Ltd	1966 - 1970	Aeromagnetic survey, gravity survey, drilling, seismic survey.	Central and southern Bancannia Trough.
PEL125	Clarence River Basin Oil Exploration Co NL	1966 - 1970	Gravity survey.	Northern Bancannia Trough.
PEL155	Planet Exploration Company Pty Ltd	1969	Desktop studies and drilling (outside the trough).	South eastern Bancannia Trough.

PEL164	Planet Exploration Company Pty Ltd	1969 - 1971	Seismic survey.	North, central and south Bancannia Trough.
PEL193	Beaver Exploration Australia NL	1973 - 1977	Seismic survey.	Southern Bancannia Trough.
PEL240	Magnet Metals Ltd	1980 - 1981	Desktop studies.	Northern Bancannia Trough.
PEL241	Magnet Metals Ltd	1981 - 1990	Desktop studies.	Central and southern Bancannia Trough.
PEL265	Kells Investments Pty Ltd	1984	Desktop studies.	Northern Bancannia Trough.
PEL268	Base Resources Ltd	1984 - 1987	Seismic survey.	Central and southern Bancannia Trough.
PEL425	Otto Oil Pty Ltd	1998 - 2002	Desktop studies.	Central and southern Bancannia Trough.
PSPAUTH12	Hardie Infrastructure Pty Ltd	2006 - 2009	Desktop studies.	Northern and southern Bancannia Trough.

Source: NSW Geological Survey.

Table A-2: Previous Petroleum Exploration Licences over the Pondie Range Trough

Title Reference	Tenement Holder	Approximate Year of Operation	Exploration Highlights	Area
PEL15	Frome Broken Hill Co Pty Ltd	1958	Desktop studies.	Eastern Pondie Range Trough.
PEL35	Planet Exploration Company Pty Ltd; Oil Development NL	1959 - 1963	Airborne magnetometer survey, seismic (outside of trough) and desktop studies.	North western tip of Pondie Range Trough.

PEL38	Woodside Darling River Oil Co NL (title holder) & MidEastern Oil NL (operator)	1960 - 1967	Drilling (outside of the trough), seismic survey, core sampling, gravity survey and airborne magnetometer survey.	Eastern Pondie Range Trough.
PEL78	Planet Exploration Company Pty Ltd	1962 - 1968	Seismic survey, gravity survey and aeromagnetic survey and desktop studies.	Western Pondie Range Trough.
PEL142	Planet Exploration Company Pty Ltd	1968 - 1969	Drilling and gravity surveys.	Eastern Pondie Range Trough
PEL155	Planet Exploration Company Pty Ltd	1969 - 1970	Seismic survey and drilling (outside the trough).	Western Pondie Range Trough.
PEL250	Comserv (No. 779) Pty Ltd	1980 - 1991	Seismic surveys and gravity survey.	Pondie Range Trough.
PSPAUTH1	Department of Mineral Resources	1993 - 1994	Desktop studies.	Pondie Range Trough.
PEL424	Acer Energy Ltd	1998 - 2013	Seismic survey, soil gas sampling and desktop studies.	Pondie Range Trough.
PSPAUTH12	Hardie Infrastructure Pty Ltd	2006 - 2008	Desktop studies.	Pondie Range Trough.
Other Relevant Exploration (Non-Petroleum)				
EL9066	Secretary of Regional NSW	2013 - current	Drilling, geothermal potential and carbon capture and storage (CCS) assessments.	Pondie Range Trough.

Source: NSW Geological Survey.

Table A-3: Previous Petroleum Exploration Licences over the Neckarboo Trough

Title Reference	Tenement Holder	Approximate Year of Operation	Exploration Highlights	Area
PEL15	Frome Broken Hill Co. Pty Ltd	1956 - 1958	Field mapping.	All the Neckarboo Trough, except the most southern edge.

PEL51	Texam Oil Corporation	1960 - 1968	Aeromagnetic survey, gravity survey, interpretation of airborne magnetometer survey and drilling.	Southern Neckarboo Trough.
PEL56	Planet Exploration Company Pty Ltd	1960 - 1964	Interpretation of airborne magnetometer survey, gravity survey and seismic survey.	Central and northern Neckarboo Trough.
PEL115	Planet Exploration Company Pty Ltd	1963 - 1968	Drilling (outside of the trough).	Central and north western Neckarboo Trough.
PEL122	Texam Oil Corporation	1965 - 1967	Desktop studies.	Eastern Neckarboo Trough.
PEL138	Texam Oil Corporation	1967	Desktop studies.	Eastern Neckarboo Trough.
PEL163	Planet Exploration Company Pty Ltd	1968 - 1971	Gravity survey, seismic survey, drilling (all outside of the trough).	Central and north western Neckarboo Trough.
PEL166	North Star Oil of Australia Ltd (Energy Resource Corporation)	1969 - 1973	Desktop studies.	Eastern and southern Neckarboo Trough.
PEL193	Beaver Exploration Australia NL	1972 - 1977	Seismic survey (outside of the trough).	Western tip of Neckarboo Trough.
PEL248	Comserv (No. 779) Pty Ltd	1980 - 1985	Airborne hydrocarbon remote sensing.	Eastern Neckarboo Trough.
PEL251	Comserv (No. 779) Pty Ltd	1980 - 1991	Seismic surveys.	Northern margin of Neckarboo Trough.
PEL252	Comserv (No. 779) Pty Ltd	1980 - 1985	Seismic survey.	Northern margin of Neckarboo Trough.
PSPAUTH1	Department of Mineral Resources	1993 - 1994	No exploration reported.	All of the Neckarboo Trough, except the southeaster edge.
PSPAUTH4	Department of Mineral Resources	1995 - 1996	No exploration reported.	All of the Neckarboo Trough.

PEL420	Red Sky Energy Ltd	1997 - 2008	Ground interstitial hydrocarbon gas survey and interpretation of gravity and magnetic data.	Eastern and central Neckarboo Trough.
PEL422	Acer Energy Ltd	1998 - 2013	Seismic survey (outside of the trough).	Northern margin of Neckarboo Trough.
PEL448	Red Sky Energy Ltd	2006 - 2010	Airborne hydrocarbon micro seepage survey and interpretation of gravity and magnetic data.	Northern margin of Neckarboo Trough.
PEL451	Red Sky Energy Ltd	2006 - 2009	Airborne hydrocarbon micro seepage survey, seismic survey and interpretation of gravity and magnetic data.	Central and western Neckarboo Trough.
PSPAUTH32	Energetica Resources Pty Ltd	2009 - 2010	Desktop studies.	Southern, central-eastern Neckarboo Trough.
Other Relevant Exploration (Non-Petroleum)				
EL8065	Secretary of Regional NSW	2013 - current	Geothermal potential and CCS assessments.	1.5 km overlap with eastern Neckarboo Trough.

Source: NSW Geological Survey.

Table A-4: Previous Petroleum Exploration Licences over the Yathong-Ivanhoe Trough

Title Reference	Tenement Holder	Approximate Year of Operation	Exploration Highlights	Area
PEL15	Frome Broken Hill Co. Pty Ltd	1960 - 1963	Field mapping.	North western Yathong-Ivanhoe Trough
PEL51	Exploration Drilling of Australia, Texam Oil Corporation	1960 - 1968	Aeromagnetic survey, gravity and magnetic interpretation, gravity survey, seismic (outside of the trough) and drilling of 3 wells outside the trough.	North western Yathong-Ivanhoe Trough.

PEL56	Planet Exploration Company Pty Ltd	1962 - 1966	Interpretation of magnetic survey, gravity survey and seismic survey (outside of the trough).	Western margin of the Yathong-Ivanhoe Trough.
PEL68	Overland Australian Oil Ltd	1962 - 1962	Desktop studies.	Eastern Yathong-Ivanhoe Trough.
PEL107		1963 - 1966	No exploration reported.	Northern Yathong-Ivanhoe Trough.
PEL122	Texam Oil Corporation, Star Oil of Australia Ltd, Exploration Drilling of Australia Ltd	1965 - 1967	Desktop studies.	Northern margin of Yathong-Ivanhoe Trough.
PEL138	Texam Oil Corp, Star Oil of Australia Ltd (Exploration Drilling of Australia Ltd)	1966 - 1967	Desktop studies.	Northern margin of the Yathong-Ivanhoe Trough.
PEL166	North Star Oil of Australia Ltd (Energy Resource Corporation)	1969 - 1973	Desktop studies.	Central-eastern Yathong-Ivanhoe Trough.
PEL247	Comserv (No. 779) Pty Ltd (Claremont Petroleum NL), BHP Petroleum PL	1980 - 1991	Desktop studies.	Eastern Yathong-Ivanhoe Trough.
PEL248	Comserv (No. 779) Pty Ltd	1982	Desktop studies.	North western Yathong-Ivanhoe Trough.
PEL249	Comserv (No. 779) Pty Ltd	1982	Desktop studies.	North-eastern Yathong-Ivanhoe Trough.
PEL252	Comserv (No. 779) Pty Ltd	1982 - 1983	Seismic survey (outside of the trough).	Northern margin of the Yathong-Ivanhoe Trough.
PSPAUTH4	Department of Mineral Resources	1995 - 1996	Desktop studies.	Northern Yathong-Ivanhoe Trough.
PEL420	GO Resources (Aust. PL), Eastern Star Gas Ltd., Red Sky Exploration Pty. Ltd.	1997 - 2008	Seismic survey.	Northern Yathong-Ivanhoe Trough.

PEL421	First Sourcenergy Group Inc., Eastern Star Gas Ltd., Red Sky Exploration Pty. Ltd.	1998 - 2001	Desktop studies.	Northern Yathong-Ivanhoe Trough margin.
PEL448	Red Sky Energy Ltd	2006 - 2010	Desktop studies.	Northern Yathong-Ivanhoe margin Trough.
PEL451	Red Sky Energy Ltd	2006 - 2009	Desktop studies.	Central Yathong-Ivanhoe Trough.
PSPAUTH32	Energetica Resources Pty Ltd	2009 - 2010	Desktop studies.	Central Yathong-Ivanhoe Trough.
Other Relevant Exploration (Non-Petroleum)				
EL8065	Secretary of Regional NSW	2013 - present	Drilling (outside of the trough) and desktop studies.	Northern eastern Yathong-Ivanhoe Trough.

Source: NSW Geological Survey.

Appendix B – Groundwater Review by Mr George Gates PSM

V5

DARLING GEOLOGICAL BASIN – GROUNDWATER REVIEW FOR PRELIMINARY REGIONAL ISSUES ASSESSMENT

Professional Opinion prepared by George Gates PSM
Senior Hydrogeologist

January 2021

TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

This report is part of a Preliminary Regional Issues Assessment (PRIA) prepared for the Advisory Body for Strategic Release. For the purpose of this report, high value groundwater includes 'highly productive' aquifers as well as 'less productive aquifers' as defined in the Aquifer Interference Policy (DPI, 2012a). This approach recognises the importance of high yielding bores (for irrigation and town water supply), groundwater dependent ecosystems (springs and wetlands) and also stock bores, as they are often the only source of water in western NSW.

With minor localised exceptions, the Devonian rocks of the Darling Geological Basin (DGB) have not been studied for their groundwater potential. The available information indicates they contain brackish to saline groundwater suitable for limited stock use and industrial/mining purposes and that current groundwater usage is minimal.

All DGB rocks are saturated below the water table, the exact location of which is not known. From private bore records it is likely to be 25 to 70 m below ground surface. From limited petroleum drilling the rocks are known to be saturated to 3,000 m below ground surface, and may be saturated for the full stratigraphic thickness of the DGB sediments (greater than 8,000 m).

Bore yields between 2 - 5 L/sec are thought to be possible from the more fractured and permeable sandstone layers. It is more common however to find smaller yields, in the range of 0.1 to 0.5 L/sec. Water quality is often described as brackish to salty. Very occasionally fresh water has been recorded at depth.

Groundwater flow in the DGB is most likely to be from the north east to the south west. Recharge would occur around the basin margins, particularly where Devonian rocks outcrop or sub-crop. Paleo recharge is significant in the neighbouring Great Artesian Basin (GAB) and is also likely to be significant in the DGB. This is recharge that occurred thousands of years ago under wetter climatic conditions. The age of deep groundwater could be in excess of a million years old.

There are a number of discrete sedimentary troughs within the DGB which formed in areas of maximum subsidence. Current knowledge suggests the Bancannia Trough, Pondie Range Trough, Neckarboo Trough and Yathong-Ivanhoe Trough offer the best potential for gas exploration (see Figure 1 for location).

These four troughs are mainly prospective for tight gas but also have some potential for conventional gas. Irrespective of the mode of origin all natural gas is composed of methane (CH_4), with variable but usually only minor quantities of other hydrocarbons.

The petroleum/gas source rocks are marine deposits containing organic matter and potentially found in the Cambro-Ordovician and early Devonian units of the Winduck interval. The potential reservoir and seals are within the shallow marine and fluvial sediments of the Middle Devonian Wana Karnu Group and the Late Devonian Fluvial Ravendale Group (Geological Survey of NSW, 2017).

Tight gas is similar in some respects to conventional gas, in terms of geological setting, except that the reservoir sandstone has a low permeability, meaning that it more difficult to extract the gas than is the case for conventional high permeability sandstones.

Tight gas reservoirs require hydraulic fracturing (fracking) to increase the permeability of the rocks and allow the gas to flow. Fracking occurs under high pressure; it uses a large volume of water and involves the addition of chemicals to the fluid.

The large quantities of water required for hydraulic fracturing, will need to be sourced locally and the extraction and subsequent disposal will need to be managed within the New South Wales regulatory framework. This includes but is not limited to; obtaining water access entitlements, developing aquifer management plans, and obtaining drilling/fracking approvals. To obtain the necessary approvals, the impacts on existing groundwater users and any connected environment, would need to be “no more than minimal harm”. This applies for both the granting of water access licences and the granting of works approvals. Water licences are obtainable from all groundwater sources in the area, either through trading of water (limited market) or direct from NSW Government through a controlled allocation tender/auction process.

All four troughs of interest are overlain in part, or are in proximity, to shallower water sources (25 to 300m) that contain low salinity groundwater in places. Exploration drilling may penetrate these highly valued shallower water sources on the way to the deeper gas target zones. Appendix D shows the water sources that occur overlying the trough areas.

It should be noted that the ‘highly productive’ GAB sandstone aquifers overlie parts of the Bancannia Trough and Pondie Range Trough. The Pondie Range Trough is also in proximity to the alluvial aquifers of the Upper Darling, which are classified as ‘highly productive’. The ‘highly productive’ Lower Lachlan Alluvium extends over part of the Yathong-Ivanhoe Trough.

Any gas wells that are drilled through or in close proximity to highly productive aquifers (eg. Great Artesian Basin sandstones, Upper Darling Alluvium or the Lower Lachlan Alluvium) must be subject to the highest standard of well integrity regulation.

Some authors warn that there may be a risk of propagating fractures towards overlying aquifers if pre-existing transmissive faults exist. All four troughs are fault bound at their edges but it is unknown if groundwater is easily transmitted through these faults. More work is required to resolve this issue.

Unlike the coal seam gas developments in Queensland, both conventional gas and tight gas produce very little water during gas production. The water is in the form of condensate and is removed with the gas as it flows to the surface.

The pressure increase experienced during fracking will be temporary and will reverse when the fracking fluid is removed and gas begins to flow. Once operational the flow of gas in the fractured zone will cause the lowering of groundwater pressure in the fractured zone. The increased permeability and fracture porosity will allow more water to move into the fractured area than otherwise would be the case. As very little water is extracted in tight gas operations and because there are many aquitards (tens to hundreds) between the gas zone and any shallow bores, the hydraulic impact of a localised fall in water pressure, on any overlying shallow bores, or ecosystems is likely to be negligible and not measurable.

Springs in this arid area are very highly valued and are often sites of cultural significance. There are no listed springs in the potential release areas. Several groundwater dependent ecosystems including two karst systems are known to exist in proximity of the study areas.

A check should be made of local Aboriginal and landholder knowledge to make sure all known springs are recorded. Impacts on spring flows are also likely to be negligible for the reasons given above.

The potential water impacts of primary concern for gas exploration and possible future development include:

- The sourcing of large quantities of water required for fracking purposes and potential impacts on nearby water assets (bores, wetlands, springs, surface waters).
- The possibility of polluting aquifers, above the gas extraction zone, and surface waters. Contamination of high value aquifers could occur due to accidental leakage of saline groundwater or chemically-modified fluids during gas drilling or production. This may occur through well failure; leakage along transmissive faults; or by diffusion through over-pressured seals.

The argument has been made in Australian Council of Learned Academies (ACOLA) (2013) that there are no insurmountable technology barriers relating to shale gas production but there will be a need to adapt to particular geological features. It is reasonable to assume that the same logic would apply to tight gas extraction.

The collection of baseline groundwater data is essential during the drilling of any future gas wells so as to better understand regional and local groundwater flow conditions. The collection of the data outlined in Section 8 will provide baseline information against which to measure future changes and to compare natural change and change resulting from the gas industry activities.

A groundwater flow model should be developed as part of any environmental assessment into gas extraction. This would predict local changes in groundwater pressures as a consequence of gas extraction and the time it would take for a new water pressure equilibrium to be established.

1. INTRODUCTION

This report is part of a Preliminary Regional Issues Assessment (PRIA) prepared for the Advisory Body for Strategic Release. This body provides advice to the NSW Minister for Regional NSW on the allocation of new coal and petroleum exploration licenses.

The focus of this report is to gather relevant groundwater information from existing reports supplied by State and Commonwealth agencies together with published information, that would help define:

- the groundwater system in the Darling Geological Basin (DGB) including possible hydraulic connections to nearby high value groundwater sources; and
- the possible changes that may occur within the groundwater system should petroleum exploration activities and gas extraction, occur in the future.

A high value groundwater system can be considered one that is highly productive in supplying low salinity water to individuals or communities for agricultural or domestic purposes. It may also be critically important in supplying water to groundwater dependent ecosystems such as wetlands or springs. In arid areas where there are few alternative sources of water, groundwater that is brackish but suitable for stock use, is also highly valued.

The PRIA concentrates on four sub-basins within the broader DGB. These include:

- The Bancannia Trough, north of Broken Hill;
- The Pondie Range Trough, north west of Wilcannia;
- The Neckarboo Trough, south east of Wilcannia; and
- The Yathong – Ivanhoe Trough, located north of Hillston.

These areas are considered prospective for tight gas and have some potential for conventional gas, but not for coal seam gas. The Geological Survey of NSW (GSNSW) has recommended each trough for consideration by the Advisory Body, for release as new petroleum prospecting areas (**Figure 1**).

No new baseline data has been gathered for this report.

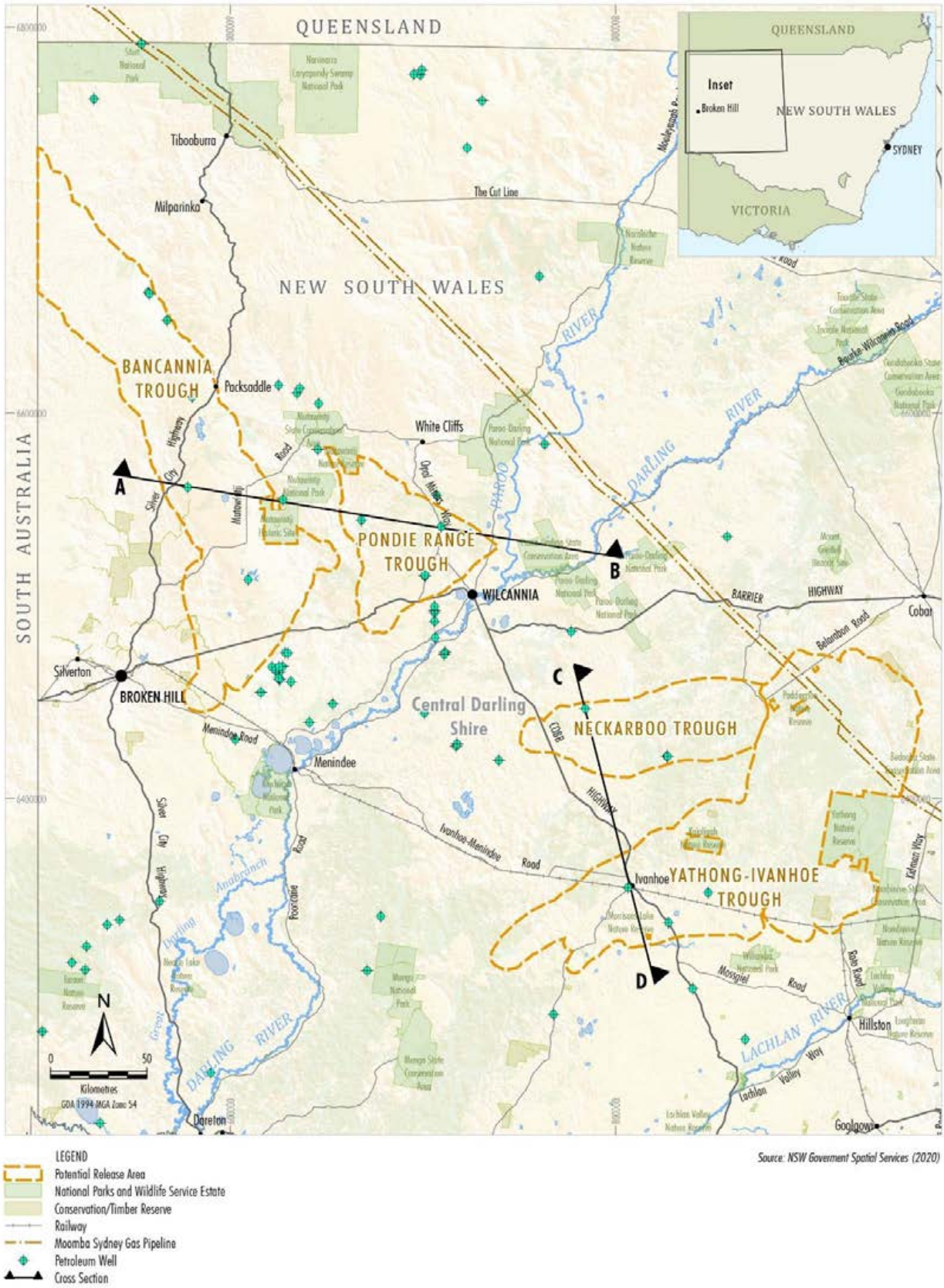


Figure 1 Location of Proposed Release Areas

2. GEOLOGIC SETTING

2.1 Regional

The DGB is a large on-shore sedimentary basin in western NSW (Figure 2). It is located in an area of low relief, broken by low ranges. The DGB strata have a relatively small outcrop area which is often obscured by a veneer of sandy soils and colluvium.

The DGB contains sedimentary formations deposited from the Late Silurian to the Early Carboniferous period (a geological time scale is provided at Appendix A for reference purposes). Of most interest for gas exploration is the thick sequence of Devonian sediments. The Basin is structurally complex and most of the geological understanding comes from limited petroleum exploration drilling and geophysical surveys. There is little evidence of the structural complexity in the present day eroded landscape because it is covered by dune sands or alluvium in parts.

The Basin is infilled with over 8,000 metres (m) of sedimentary rocks formed in a wide range of depositional environments, ranging from marine to fluvial modes of origin. The most common sedimentary rocks are Late Silurian to Early Devonian fossiliferous marine shales and Early Devonian to Early Carboniferous fluvial quartz-rich sandstones (GSNSW, 2017). The strata are unmetamorphosed and relatively undeformed. Seismic work has identified the location of some geological faults however many remain undetected.

There are a number of discrete sedimentary troughs within the DGB which formed in areas of maximum subsidence. Current knowledge suggests the Bancannia Trough, Pondie Range Trough, Neckarboo Trough and Yathong-Ivanhoe Trough offer the best potential for gas exploration. To date the region has been sparely explored with drilling results showing sporadic minor gas and petroleum shows.

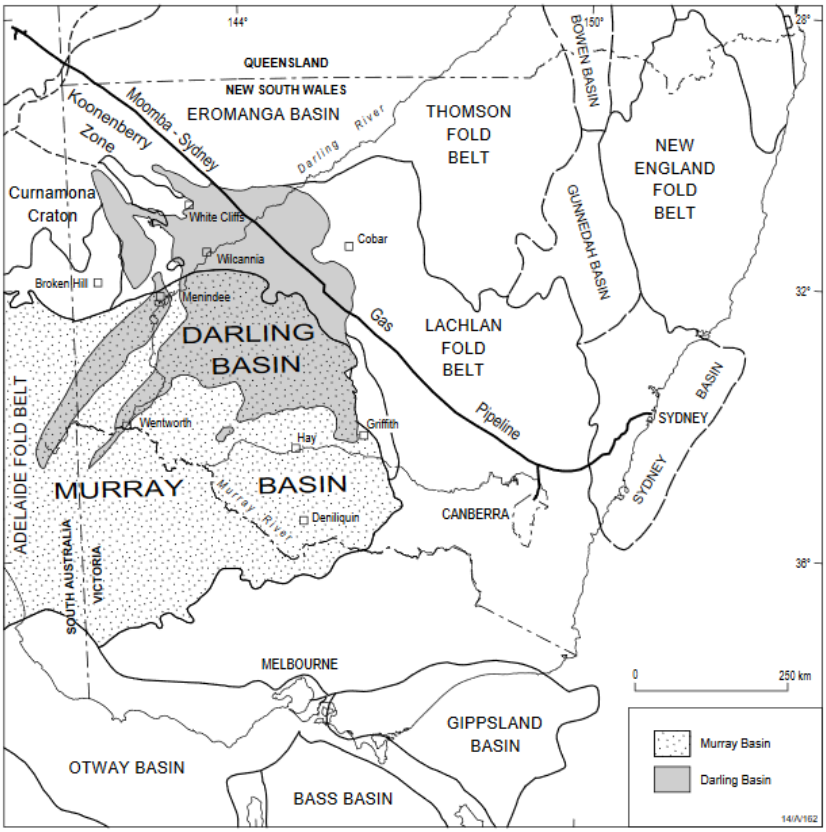
The general spatial variation in sedimentary facies across the DGB (fluvial sandstones in the western troughs to submarine fan facies in the eastern troughs) suggests to some geologists that many troughs of the greater DGB were probably interconnected during prolonged depositional periods. It is suggested in GSNSW (2017) that due to similarities in rock types the depositional connection may have extended to the gas producing Avondale Basin in Queensland.

The DGB is a deep sedimentary basin that underlies the southernmost part of the Jurassic-Cretaceous Eromanga Basin (a sub basin of the Great Artesian Basin [GAB]) in the north. The central and southern parts of the DGB underlie the unconsolidated Cenozoic sediments of Murray Geological Basin (MGB). The eastern and western boundaries are faulted against older Paleozoic rocks of the Lachlan Fold Belt and Precambrian rocks of the Adelaide Fold Belt respectively.

More recent geological events have seen the deposition of the Mid to Late Cenozoic Lower Lachlan Alluvium and the Recent Darling River alluvium, both of which contain useful supplies of low salinity water in places.

Erosion over geological time has resulted in low topographic relief with only a few relics of uplifted block rocks visible at ground surface.

Figure 2 shows the location of the DGB in relation to large geological basins and fold belts.



Source: Australian Government Geoscience Australia (AGGA) 2003

Figure 2 Darling Geological Basin and Surrounding Geological Provinces

Source: Geological Survey of NSW 2017

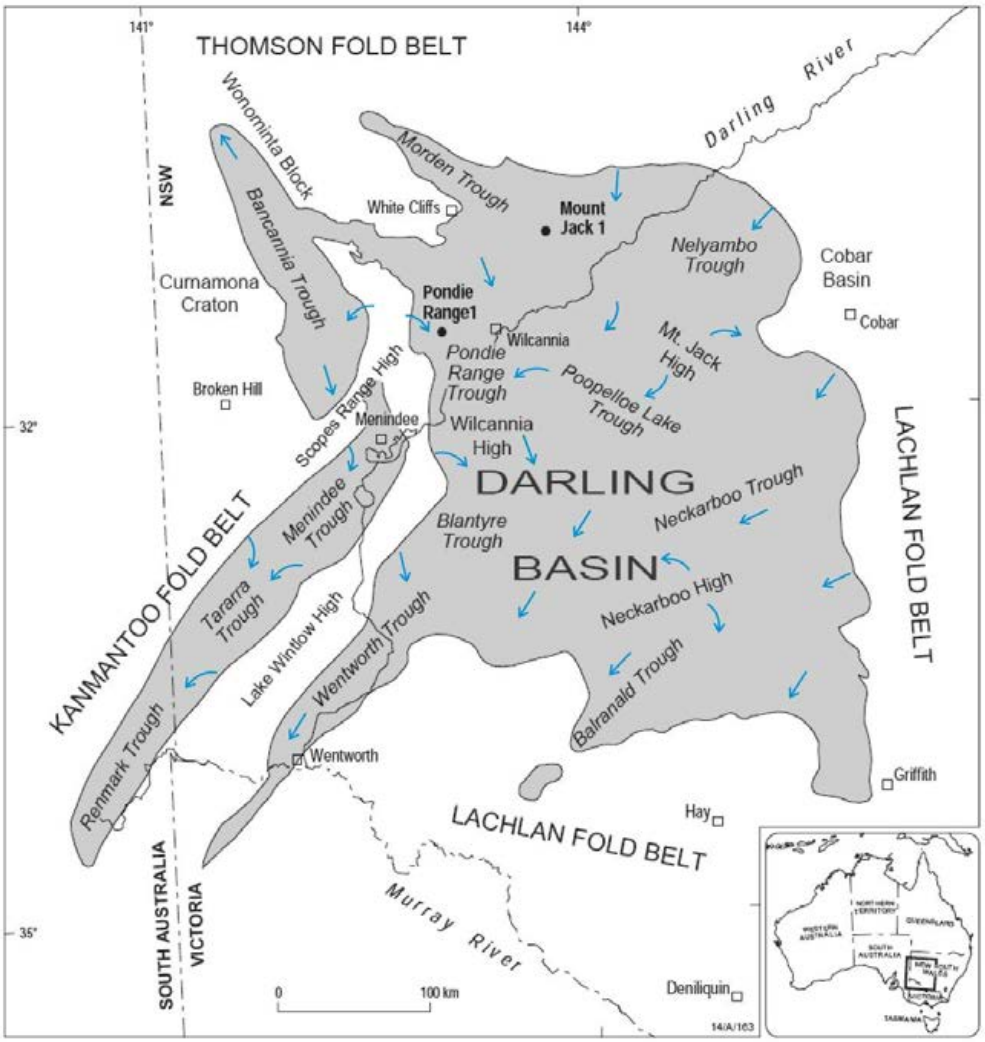
Figure 3 Structural Features of Eastern Australia

2.2 Structural Evolution

Figure 3 shows the DGB position with respect to regional fold belt structures such as the Adelaide, Lachlan and Thomson Fold Belts (GSNSW, 2017).

Based mostly on seismic information, the eastern and western boundaries of the DGB are faulted against metasediments of the Cobar Basin and Adelaide Fold Belt respectively. They represent a mineralized basement complex with numerous folds and faulting (AGGA, 2003).

In the north, the DGB extends to near White Cliffs and, as stated above, underlies the Eromanga Basin, a sub basin of the GAB. The location of some basin troughs and structural highs in the DGB can be seen in Figure 4.



Modified after AGGA 2003

Figure 4 Darling Basin Structural Elements and Inferred Groundwater flow

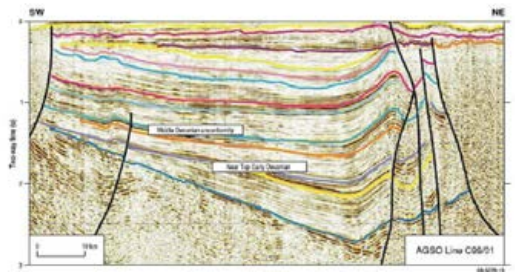
2.3 Local Geological Controls

Bancannia Trough

The Bancannia Trough is a fault-bounded trough 25 km-wide and about 100 km-long, trending northwest-southeast, and corresponds to a major regional gravity low. Gravity derived depth to basement estimates (confirmed by seismic data) suggest that the thickness of the sedimentary sequence exceeds 8,000 m (AGGA, 2003).

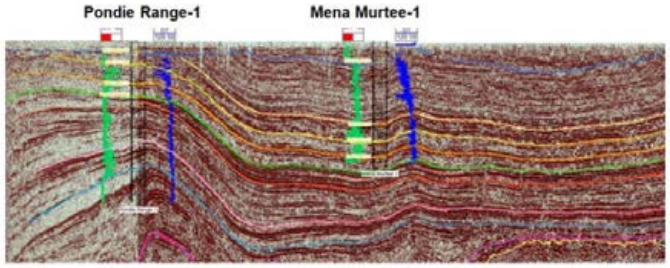
Three petroleum wells have been drilled in the Bancannia Trough: Bancannia North-1, Bancannia South-1 and Jupiter-1. Well completion reports and geophysical surveys have documented thick sequences of Palaeozoic sedimentary rocks. The basal unit is commonly a marine, fossiliferous Cambrian to Ordovician sequence, overlain by Devonian continental sandstones and 'red-bed' sequences. Basement rocks are of unknown age and consist of faulted and folded metasediments. Petroleum exploration drilling has shown that the porosity and permeability of the Devonian rocks in the Bancannia Trough range from poor to fair, with the highest porosities in the Upper Devonian sandstones and lowest porosities in Lower to Mid-Devonian strata down to basement (AGGA, 2008).

Figure 5a is an interpreted seismic reflection profile across the central part of the Bancannia Trough. It shows relatively flat lying Devonian sediments, with some compressional folding and faulting at the eastern and western edges.



Source: NSW Geological Survey 2017

Figure 5a Seismic Reflection Profile Bancannia Trough



Source: NSW Geological Survey 2017

Figure 5b Seismic Reflection Profile Pondie Range Trough

Pondie Range Trough

The Pondie Range Trough also has an estimated sedimentary thickness in excess of 8,000 m. Three wells have previously been drilled in the trough: Mena Murtee-1, Pondie Range-1 and Gnalta-1. Based on results of petroleum well drilling, the Pondie Range Trough contains shallow sub-cropping Devonian rocks which unconformably underlie GAB rocks at Mena Murtee-1 and Cenozoic sediments at the Pondie Range-1 site, before encountered Devonian rocks at 80 m. Gnalta-1 was sited at the western boundary of the trough in outcropping Devonian sandstones (GSNSW, 2017).

A seismic profile Figure 5b shows similar relatively flat bedded structure with anticlinal features and drape structures.

Neckarboo Trough

The Neckarboo Trough is an east-west trending sedimentary sub-basin the centre of which is approximately 80 km north of Ivanhoe and 150 km southwest of Cobar. It is approximately 30 km wide and 125 km long. The estimated maximum sediment thickness in the trough is approximately 5,500 m, comprising predominantly Devonian aged sandstone and siltstone. The western half of the trough is overlain by Cenozoic sediments of the MGB.

Three petroleum wells have previously been drilled along the flanks of the trough: Berangabah-1, BMR Ivanhoe-1 and Kewell-East-1. Berangabah-1 encountered Early Devonian shaley sandstone from 7 m to total depth 463.5m. Some water was encountered at 100m with increasing amounts thereafter. The inflow at 274 m was measured at 1.5 L/s. BMR Ivanhoe-1 has Early Devonian sediments from 4m to total depth at 305 m. It contained hard tight grey siltstone with interbedded black shale, more prominent near the base. Some open fractures were observed in cores and there is a suggestion of an aquifer from 56.6 to 59.3 m. Groundwater quality is reported as salty with a total salinity of 20,900 mg/L.

The third well, Kewell East-1, was spudded in red aeolian sand with coring commencing at 6 m. Tertiary to Recent light-grey to grey claystones and grey to light-grey quartzose sandstones of probable fluvial origin were intersected to 87.4 m. A significant lithological break at 87.4 m marked the unconformity between the overlying Cenozoic sediments and the Devonian Snake Cave (now Wana Karnu Interval) Sandstone. The Snake Cave Sandstone was present until 377.8 m where another major lithological break marked the top of the Winduck Group. The drill hole was terminated at 1,224 m within the Winduck Group. A fractured rock aquifer was reported at 336 m and subsequent water testing showed it to be unsuitable for stock, agriculture and domestic purposes because of high salinity.

Yathong-Ivanhoe Trough

The Yathong-Ivanhoe Trough is located southwest of Cobar. It is approximately 167 km from north to south, and 209 km east to west. The estimated maximum sediment thickness in the trough is approximately 6,000 m comprising predominantly Devonian aged sandstone and siltstone. It is overlain by Early Permian, Early Cretaceous and some Cenozoic sediments.

Three shallow stratigraphic wells have been drilled in the southwest part of the Yathong-Ivanhoe Trough: Conoble-1, North Star Ivanhoe-1 and Holey Box-1. Details include:

- Conoble-1 was drilled to 182.8 m. Strata encountered were 0-119 m Cenozoic sediments, 119-155 m Marine shales (of probable Early Cretaceous Period) and possible Devonian rocks at 182 m. No water flows were recorded.
- North Star Ivanhoe-1, was drilled to 667.7 m. Early Cretaceous and Early Permian fossils have been identified in the well. Possible reservoir sands are present in the Permian. The Early Devonian is shale rich with some potential as a source rock.
- Holey Box-1 was drilled to 666.7 m. The drillers log describes Cenozoic sediments from the surface to 164 m then Lower Cretaceous sediments to 203.6 m, then Lower Permian rocks to 488 m and Devonian non marine sediments down to 666.7 m. Whilst no estimates of porosity or permeability are provided, it is recorded that the shallow Quaternary-Tertiary sediments are loosely unconsolidated. The Permian rocks have fair porosity and the Devonian Shales lack Porosity.

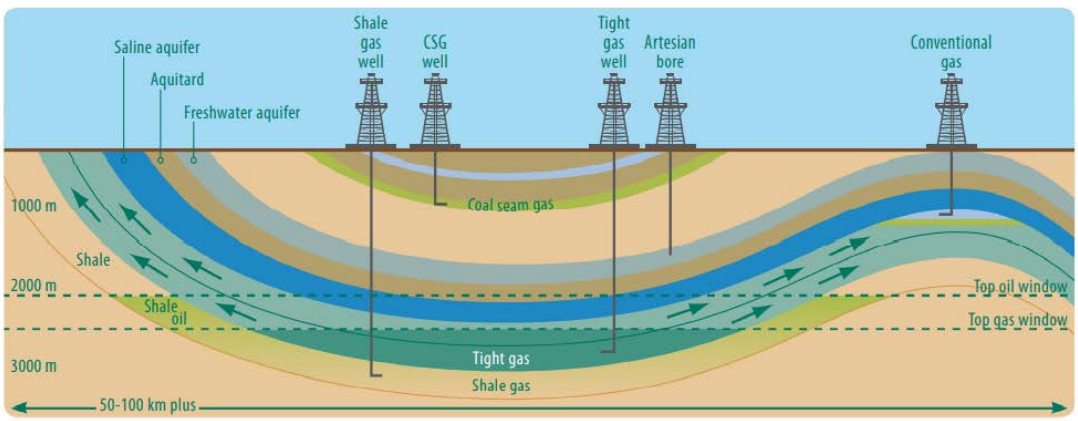
3. CONVENTIONAL AND UNCONVENTIONAL NATURAL GAS

The four geological troughs identified by GSNSW as having potential for exploration are mainly prospective for tight gas but also have some potential for conventional gas. Irrespective of the mode of origin all natural gas is composed of methane (CH_4), with variable but usually only minor quantities of other hydrocarbons.

A general discussion of conventional versus unconventional gas is warranted here as there are differences in hydrogeological impacts, should gas extraction occur.

Cooke et al. (ACOLA, 2013) state that it is the rock type and the trapping mechanism which defines whether a gas is regarded as “conventional” or “unconventional”. Conventional natural gas is trapped in porous and permeable reservoir rocks, sometimes in association with oil. There are several geological trapping mechanisms that prevent the buoyant gas from escaping. If conventional gas reservoirs can be found in the DGB then the gas can be brought to the surface through dedicated wells without the need to pump (CSIRO, 2020).

Unconventional gas reservoirs, can be found in more difficult to extract situations, such as from coal beds (coal seam gas), or from marine shales (shale gas), of from low permeability reservoirs (tight gas). Tight gas is discussed further below as it is a focus of this study.



Reproduced in ACOLA 2013

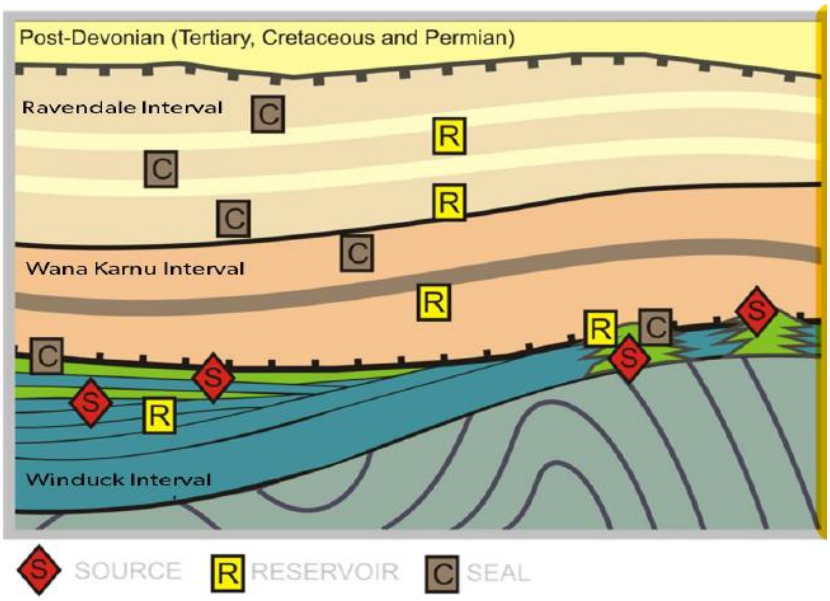
Figure 6 Diagram Showing Conventional Gas and Unconventional Gas Sources

Both coal seam gas and shale gas are examples where the natural gas is still within the source rock, having not migrated to a reservoir rock. Tight gas occurs within low permeability reservoir rocks, and has migrated from the underlying source rock. Tight gas can be regionally distributed rather than accumulated in a discrete structural closure as in a conventional gas field (Geoscience Australia, 2021). Figure 6 above is a diagram commonly used to explain the difference between conventional and unconventional gas.

4. GAS POTENTIAL IN THE DARLING GEOLOGICAL BASIN

For a detailed assessment of the gas potential in the DGB see GSNSW (2017) and GSNSW (2020a, 2020b, 2020c and 2020d). The following is a brief assessment only.

The potential for finding economic reserves of gas in the DGB depends on several key components: mature source rock, reservoir rock, and traps/seals for conventional gas. The GSNSW report (2017) considers the source rock distribution to be the greatest risk to successful identification of an economic gas reserve. Figure 7 shows an idealised petroleum system including three broad divisions of the Cambro-Devonian Strata (Winduck Interval, Wana Karnu Interval and Ravendale Interval).



Source: GSNSW 2017

Figure 7 Idealised Petroleum System

The depth, pressure and thermal history within a sedimentary basin defines whether oil or gas is likely to have been generated from the remains of ancient algal bacteria and plants, and then migrated within the basin; the structure of the basin determines whether generated oil or gas is likely to have been trapped (Cook, 2013).

The source rocks are marine deposits containing organic matter and potentially found in the Cambro-Ordovician and early Devonian units of the Winduck Interval. The potential reservoir and seals are within the shallow marine and fluvial sediments of the Middle Devonian Wana Karnu Group and the Late Devonian Fluvial Ravendale Interval (GSNSW, 2017).

Hydrocarbon traps may be caused by Early Devonian and Middle Devonian to Middle Carboniferous compressional events. There are several different structural and stratigraphic traps recognised in the troughs of the DGB.

Tight gas is similar in some respects to conventional gas, in terms of geological setting, except that the reservoir sandstone has a low permeability, meaning that it more difficult to extract the gas than is the case for conventional high permeability sandstones. It also has a number of similarities with shale gas in terms of production processes such as the use of hydraulic fracturing to create a permeable zone so the gas can be released.

Tight gas often occurs in close geological proximity to shale gas as reflected in Figure 6 above (ACOLA, 2013). Tight gas reservoirs may be present throughout all the stratigraphic intervals of the DGB.

The Bancannia Trough has had three petroleum wells drilled in it (Bancannia North-1, Bancannia South-1 and Jupiter -1). Thick Devonian sequences were intersected in these holes. Source rocks are expected in the Early Devonian, reservoirs in Late Devonian and seal rocks in the overlying Late Devonian. Some gas shows and live oil seeps were encountered, combined with porous and permeable reservoir sandstones (Robertson Research Australia, 2001). Porosity values up to 26% have been recorded in Devonian strata.

The Pondie Range Trough has had two deep petroleum wells drilled in it (Pondie Range-1 and Murtee 1). This trough is thought to be thermally mature for hydrocarbons in the Middle Devonian sequence. There are some porous and permeable reservoir type sandstones and seals in both the Mena Murtee-1 and Pondie Range-1 wells (GSNSW, 2017). Elevated background methane, ethane and propane values were obtained from soil gas surveys.

The Neckarboo Trough has had three exploration petroleum wells drilled in it (Berangabah-1 and BMR Ivanhoe-1 and Kewell East-1). A total of 21 seismic lines cross or partially cross the trough. Each of the wells intersected the Early Devonian sediments, which is known to be a potential source rock. Bitumen was detected in Berangabah-1. Wet and dry gas and liquid petroleum occur in fluid inclusions.

The Yathong-Ivanhoe Trough has had three exploration petroleum wells drilled in it (Conoble 1, North Star Ivanhoe-1, Holey Box-1). A soil gas survey undertaken by GSNSW in 2017 over parts of the Yathong–Ivanhoe Trough displayed elevated hydrocarbon signatures of thermogenic origin. Sandstones that could act as reservoirs outcrop on the eastern flank of the Yathong–Ivanhoe Trough. Potential seals are also present throughout the Devonian section.

A study by the NSW Department of Planning and Environment – Resources and Energy Division has revealed that most water bores in the GAB in NSW are flowing gas to the surface. The origin of this gas is not known.

5. REGIONAL GROUNDWATER SYSTEMS

The Darling Geological Basin (DGB) sits between and underlies in part, two important groundwater systems that have been extensively studied and contain highly productive aquifers, in some locations. They are the Great Artesian Basin (GAB) and the Murray Geological Basin (MGB) see Figure 2. The groundwater flow system for the DGB is considered to have some of the groundwater flow characteristics of these large sedimentary basins.

5.1 Darling Geological Basin

5.1.1 Hydrogeological Setting

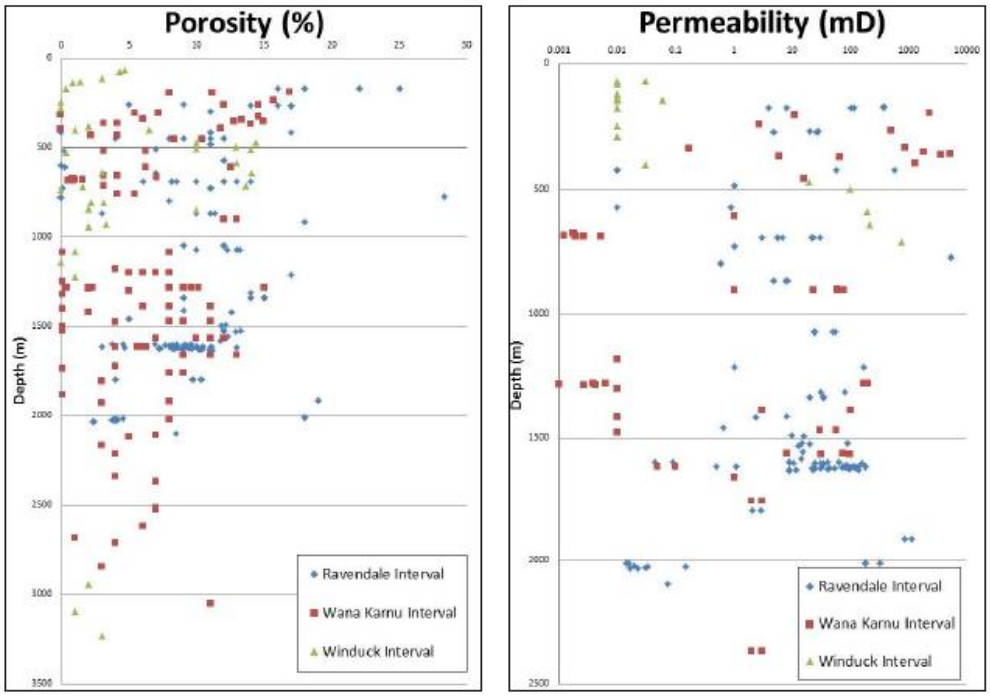
The potential for a significantly large volume of groundwater to exist within the Devonian sedimentary rocks of the DGB is substantial. This reflects the relatively deep nature of the sediments (5-8 km or more) and known sandstone porosity from hydrocarbon drilling (5 – 30%) together with fractures and faults in the low permeability strata. Whilst no detailed hydrogeological studies have previously been undertaken, some limited data exists from petroleum drilling records and information from private stock watering bores. Most of the stock bores are shallow, generally less than 150 m deep and obtain their water from several levels including shallow sands, sandstone and shale. The water is often described as brackish to salty, but fresh water is also recorded. Bore yields are generally in the range of 0.2 to 1.5 L/s.

The limited water data that was collected during petroleum exploration drilling shows that the Devonian strata is saturated to depths greater than 3 km, and it is considered possible that the full basin thickness of 8 km or more, may be saturated. Most records of water quality record the water as being salty, so the usefulness of this water source is limited. An occasional drillers log records fresh water but most refer to brackish or salty water.

At sites of higher permeability, bore yields from Devonian Sandstone aquifers between 2 and 5 L/s may be possible. This would need to be confirmed by drilling and testing. Fractures in the rock are mentioned in geologists' logs and this may account for the higher yield and better water quality. Fracture flow would predominate over intergranular flow in most strata however intergranular flow would occur in any porous and permeable sandstones.

Figure 8 shows the porosity and permeability for Devonian strata in the DGB. The Permeability units are in millidarcies (mD) which are the units used in the petroleum industry. These can be converted to the SI units used in the water industry, as 1 Darcy = 0.83 metres/day (hydraulic conductivity).

The most porous zones are found in the Upper Devonian sandstones in the Ravendale Interval. Commonly the permeability ranges from a few hundred millidarcies up to 8,000 millidarcies (equivalent hydraulic conductivity is 6.6 metres/day), but data coverage is scant.



Source: Geological Survey of NSW 2017

Figure 8 Porosity and Permeability data for Devonian Strata

Tables 1 to 4 in Appendix B show the water data obtained from petroleum wells drilled in the Bancannia, Pondie Range, Neckarboo and Yathong-Ivanhoe troughs respectively.

Because no detailed hydrogeological studies have been carried out, there is no water table information or pressure surface information for the various aquifer levels. The movement of groundwater both horizontally and vertically is unknown and can only be inferred. Also, the groundwater processes of recharge and discharge remain unknown in any detailed way.

5.1.2 Groundwater Flow

The following assessment of groundwater flow in the DGB is speculative and the conceptualisation is based on an understanding of the flow characteristics in the neighbouring geological basins (GAB and MGB).

Regional groundwater flow is likely to be in the direction of surface water flow. This is a common phenomenon with groundwater systems and occurs in the GAB and the MGB. In both of these basins the water table mimics the ground surface topography. Hence the groundwater flow in the DGB is most likely to be from the north east to the south west. Figure 4 shows the broad regional groundwater flow direction (blue arrows). Recharge would occur around the basin margins, particularly where Devonian rocks outcrop or sub-crop. Local recharge will occur through sandy soils that occur in alluvial/colluvial washout areas close to outcrop areas.

The DGB is located in arid western NSW which has low average rainfall (260 mm/year) of sporadic nature. Hence substantial recharge may not occur every year. Paleo recharge is significant in the GAB and is also likely to be significant in the DGB. This is recharge that occurred thousands of years ago under wetter climatic conditions. Most of the water contained in the DGB is likely to be old water. For example, water in the GAB has been dated as up to a million years old and the groundwaters in the DGB are likely to have a similarly long flow path, and could even be older.

The position of the water table or the piezometric surface for confined aquifers is unknown, so the gradient associated with each aquifer cannot be established. Given that many sandstones in the DGB are not highly permeable (from bore log descriptions) it is reasonable to assume that velocities will be less than in the GAB which has horizontal movement of water up to about 1 m per year in the most permeable sandstone aquifers. The saline nature of the groundwater supports this assertion.

Because of the deeply buried nature of the DGB sediments, most aquifers will be confined both above and below by aquitards consisting of finer grained sediments with much lower permeabilities eg. shales, siltstones. These are the seal rocks required to trap conventional gas.

The groundwater in confined aquifers is under pressure from the weight of overlying overburden rocks and contained water. In addition to the horizontal movement of groundwater there will be a component of vertical movement. The extent to which vertical leakage occurs is unknown but again can be likened to the GAB flow system, where vertical flow through aquitards is minimal but some flow occurs through fractures and faults that cut across the aquitards. Extensive faulting occurs in parts of the DGB, such as is shown in Figures 5a and 5b, and may interrupt groundwater flow in a horizontal direction and increase the vertical flow component. However not all faults are permeable and some can act as barriers to groundwater flow.

The petroleum drilling data has not indicated that artesian conditions exist in the DGB. It is likely however that the confined aquifers of the DGB are under considerable pressure and when penetrated by a bore, the water will rise to within tens of meters from the ground surface. From private bore records it is likely that the position of the water table will be 25 to 70m below ground surface.

It is also considered likely that some water is exchanged between the DGB and the overlying younger basin strata where they occur together. For example, where the DGB is overlain by the GAB (Eromanga sub-Basin) some small exchange of water is likely. The direction and volume of this exchange is not known, but water will move from higher pressure to lower pressure. Given the high water pressures in the Eromanga Basin it is suggested that some groundwater moves from the GAB down into the DGB. Some GAB water may also move upwards into the overlying Murray Basin alluvium where they occur together. This is shown diagrammatically in cross section A – B (Figure 9). Drilling and measuring groundwater pressures across stratigraphic boundaries would be needed to calculate the direction and quantity of water exchanged. Detailed water quality studies would also assist here.

The groundwater flow arrows in the cross sections Figures 9 and 10 should be viewed in conjunction with the inferred regional flow shown in Figure 4 to get a clearer picture of flow direction. Whilst flow is affected by basement highs and lows, it should be noted that most of the water flow is coming out of the page towards the reader.

V5

From a water budget point of view nothing is known about recharge and discharge volumes in the DGB. Because little groundwater is extracted from the system via bores the system is likely to be near equilibrium with recharge and discharge having a similar volume.

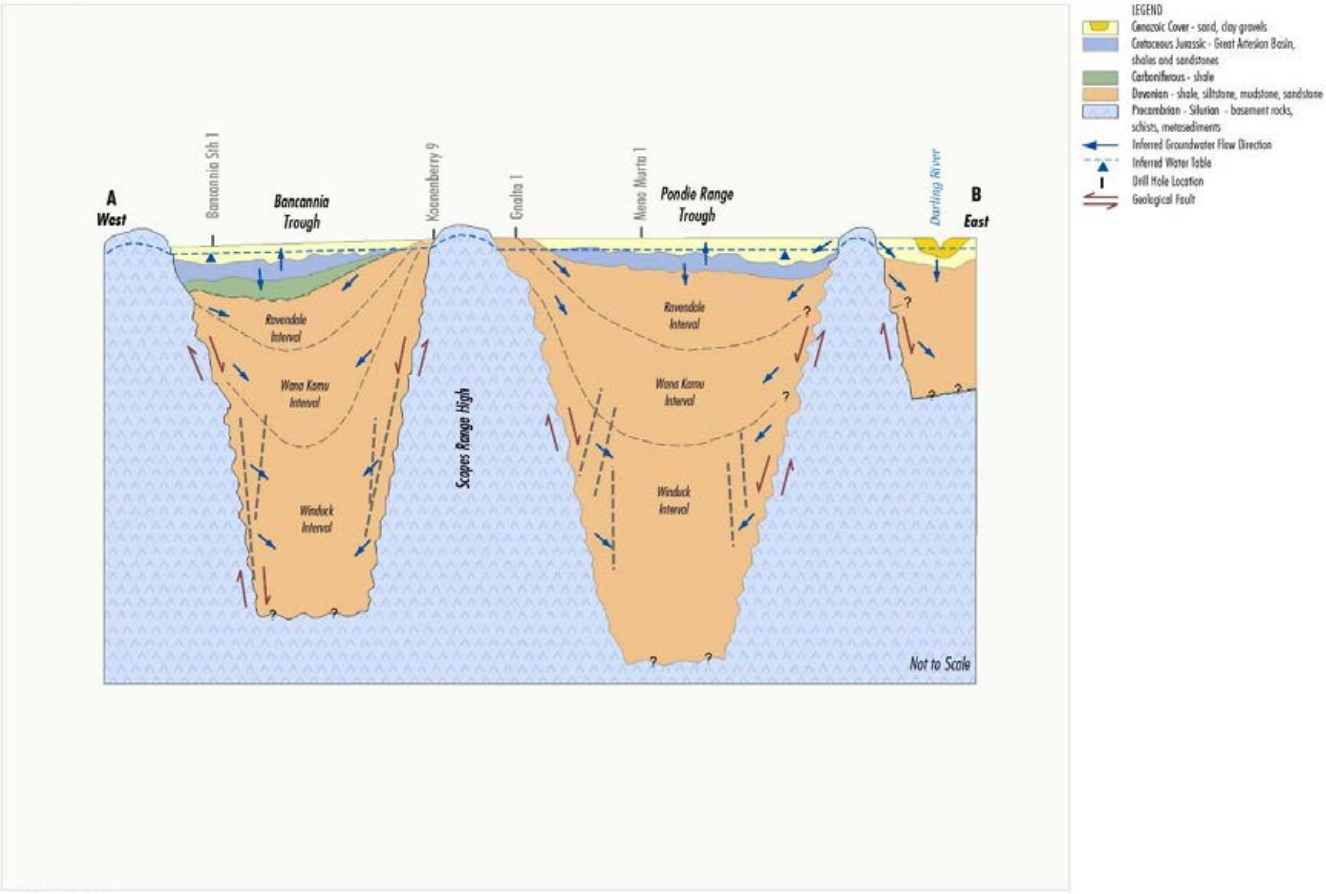


Figure 9 Diagrammatic Section Through Bancannia and Pondie Range Troughs

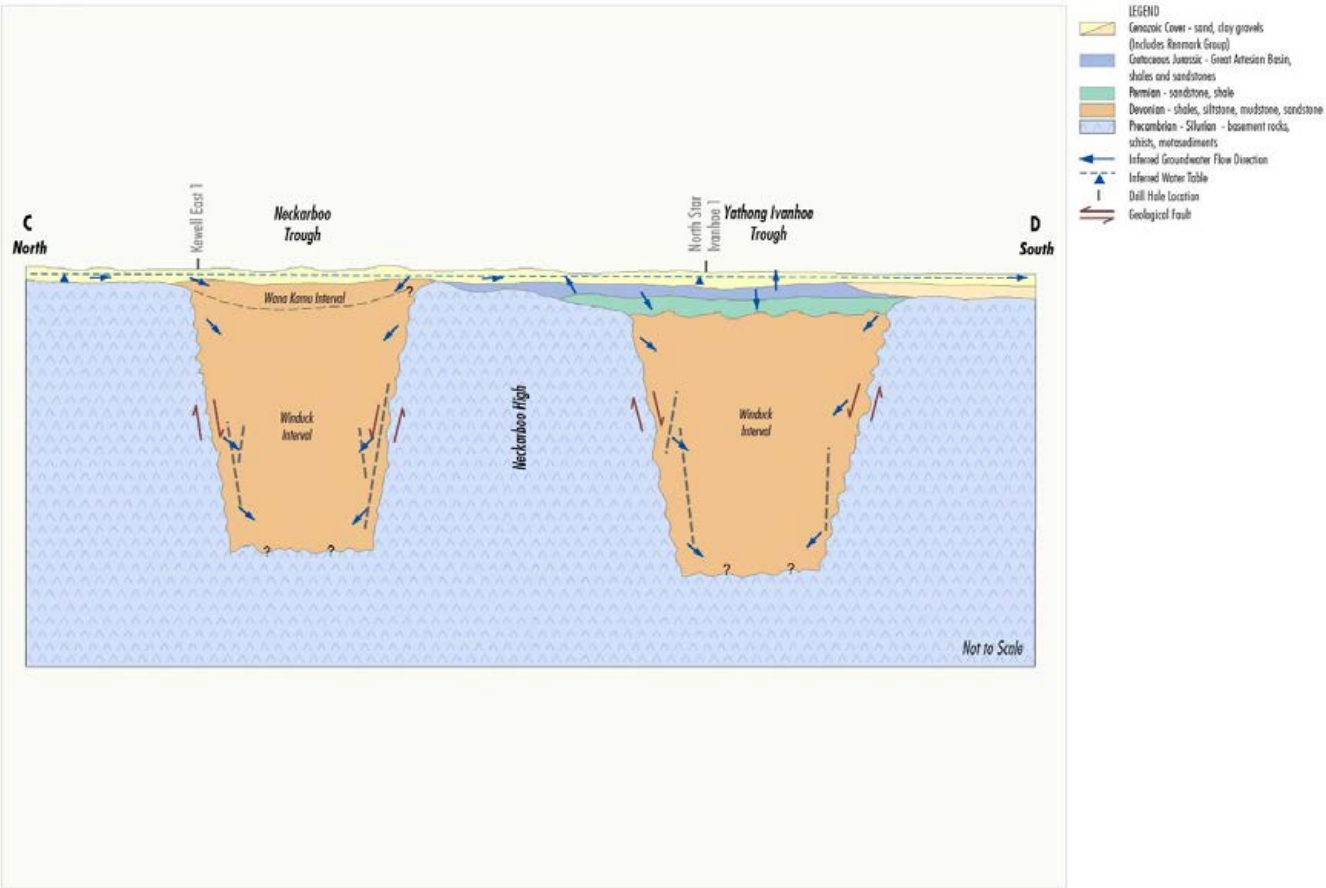


Figure 10 Diagrammatic Section Through Neckarboo and Yathong-Ivanhoe Troughs

5.2 The Great Artesian Basin

5.2.1 Hydrogeological setting

The GAB is Australia's largest artesian groundwater basin and contains an iconic aquifer system which underlies approximately a fifth of Australia's land mass. It is highly valued as it contains low salinity water under artesian pressure suitable for town water supplies, mining, stock and many farming uses but not always suitable for irrigation due to the high sodium content of the water. Irrigation is possible from bores constructed near the recharge areas in the north east of the GAB. It supports numerous spring complexes some containing endemic species of fauna and flora.

The GAB is an extensive and complex groundwater system that encompasses several geological sub-basins that were deposited, from 200 to 65 million years ago in the Jurassic and Cretaceous periods. These geological basins sit on top of deeper, older geological basins such as the DGB and in turn, have more geologically recent surface drainage divisions situated on top of them eg. the Lake Eyre and Murray-Darling river basins (CSIRO, 2012).

The aquifers of the GAB are composed of predominantly continental sandstones, confined by aquitards of both fluvial and marine mudstone and siltstone. The geological sub-basins within the GAB (Eromanga, Surat, Clarence-Moreton, and Carpentaria) have a similar depositional history with depocentres containing up to 3,000 m of a multi-layered lightly folded strata.

The geological formations that contain aquifers have average permeability values between 100 and 1,000 millidarcies. This is equivalent to approximately 0.1 to 1 m/year of horizontal groundwater movement. The geological formations known to contain aquitards have average permeability values between 10 and 100 md, which is equivalent to approximately 0.1 m/year of horizontal groundwater movement (CSIRO, 2012).

The regionally significant aquifers in the Eromanga Basin are the Cadna-owie – Hooray Aquifer and equivalents. Average thicknesses are 150–200 m for the main aquifers.

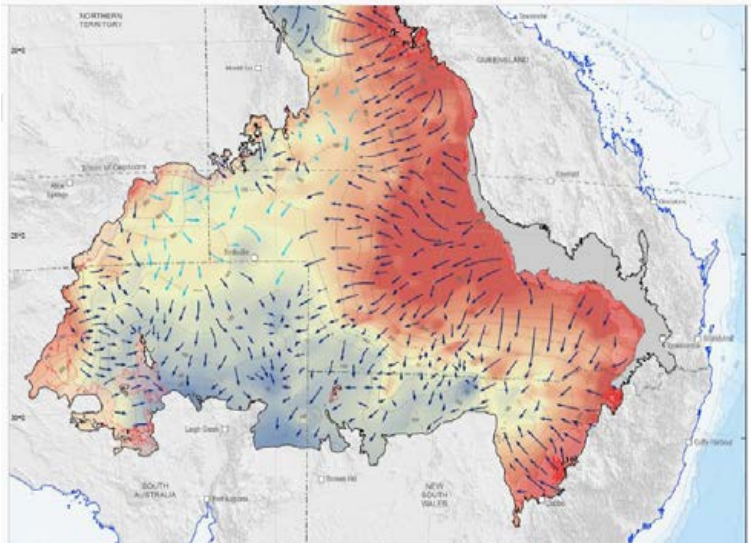
For the GAB, the current rate of recharge is significantly less than discharge for groundwater currently stored in the Cadna-owie – Hooray Aquifer and equivalents. This is a legacy from high groundwater extraction in recent times (100+ years) and also the lower recharge rates that have occurred since the wet periods in the early Holocene and Pleistocene age (CSIRO, 2012).

Artesian pressures in the GAB have been falling for over 100 years due to the large number of free-flowing bores wasting water through the use of open bore drains to distribute water. The Great Artesian Basin Sustainability Initiative was commenced in 1999 to renew old leaky bores and replace bore drains with piped reticulation. After 15 years, this initiative had saved 78,500 Megalitres per year of water in NSW alone. Thirty percent of this water is available as unassigned water in the NSW GAB Water Sharing Plan (WSP) and can be reallocated by the NSW Government through a controlled allocation (tender/auction) process.

5.2.2 Groundwater Flow

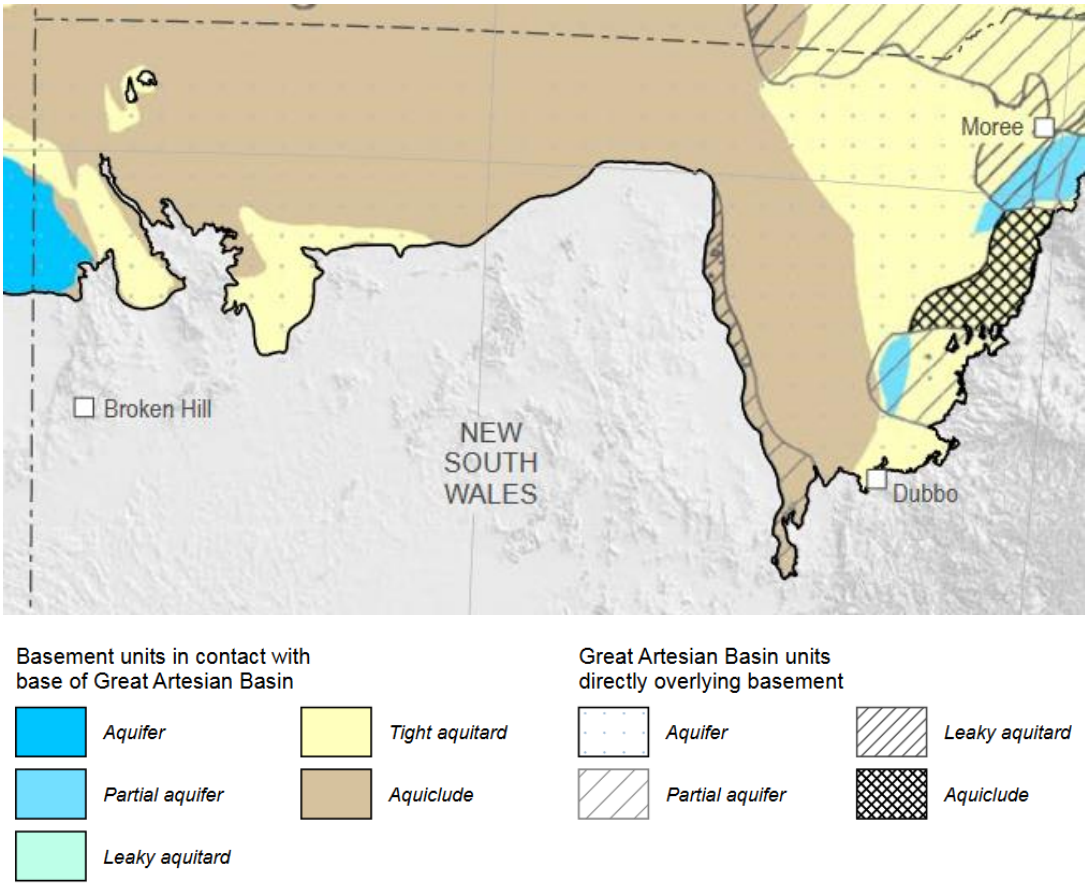
Groundwater flow in the GAB commences as recharge in the north east highland areas and flows in a south westerly direction (Figure 11). The flow is interrupted by faulting and by basement highs. Two of the potential release areas (Bancannia Trough and Pondie Range Trough) are located at the southern edge of the Eromanga Basin.

In the vicinity of these two troughs, the GAB strata are relatively thin and are reported to be 86 m thick in Bancannia South-1 and 271 m in Bancannia North-1 petroleum bores. In Section 5.1.2 above it was speculated that some minor flow across vertical boundaries is likely to occur. In the CSIRO (2012) report, the hydraulic connection with the Eromanga Basin and underlying DGB is reported to be very low as the water has to pass through tight aquitard material (Figure 12). So, the volume of water moving from one basin to another will be small per unit area.



Source: CSIRO, 2012

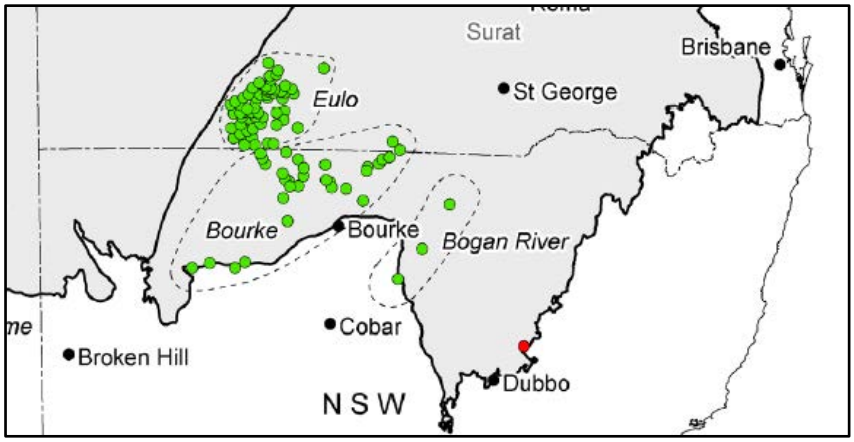
Figure 11 Groundwater Flow Direction in the Great Artesian Basin



Source: AGGA 2015

Figure 12 Connectivity of GAB with underlying Basins

In the arid parts of the GAB many ecosystems depend on groundwater from springs (discharge sites for groundwater). Spring complexes are generally structurally controlled. Figure 13 shows the GAB springs in NSW and southern Queensland. Figure 14 shows the Groundwater Dependent Ecosystem (GDE) locations in the vicinity of the potential release areas. Recent vegetation mapping shows the location of high priority groundwater dependent vegetation ecosystems. This vegetation gets at least some of its water from shallow groundwater.



Source: CSIRO 2012

Figure 13 Southern Springs of the Great Artesian Basin

Springs in arid areas are inextricably woven into the history of Aboriginal people. They also sustained early European settlement as permanent water sources.

In the GAB many native species which depend on the natural discharge of groundwater have been declared an endangered ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Fortunately, as both gas exploration activities and gas extraction involve very little water take, combined with the many low permeability confining layers between a gas reservoir and ground surface this set of circumstances means there should be no measurable hydraulic impacts on spring flows. Likewise, the hydraulic impact to any private bores obtaining water from GAB rocks should be very small and not noticeable.

The direct interaction between GAB groundwater and rivers is generally limited to the intake beds (recharge areas) in the north east (CSIRO, 2012). This is where the water table intersects the river and water exchange can occur. There is no direct connection in the study areas as the GAB rocks are vertically separated from surface waters.

Source: DPI Water Sharing Plans

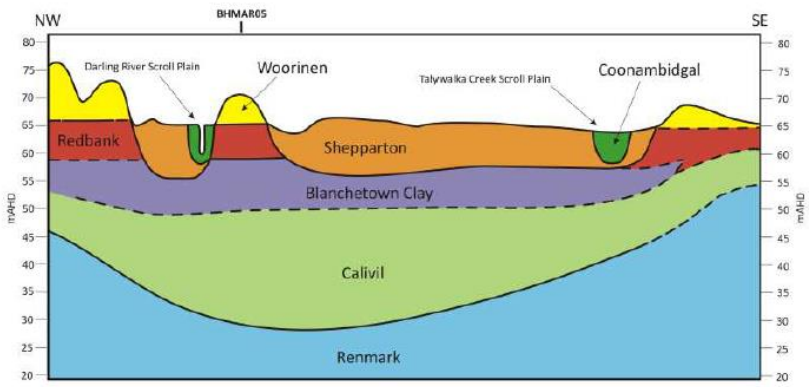
Figure 14 Known Groundwater Dependent Ecosystem Locations in Vicinity of Potential Release Areas

5.3 Murray Geological Basin and Equivalents

5.3.1 Hydrogeological Setting

Detailed studies of the groundwater in the MGB sediments were undertaken by AGGA (2008) within 100 km of Broken Hill to find alternative sources of town water for Broken Hill. More localised work in the Menindee Lakes area was carried out by AGGA (2010) for the Broken Hill Managed Aquifer Recharge Project. Much of the information below comes from these sources. Only a brief summary is provided here. All four troughs: Bancannia, Pondie Range, Neckarboo and Yathong-Ivanhoe are overlain in part by MGB sediments.

A simplified stratigraphy for a location in the vicinity of Menindee is shown in Figure 15.



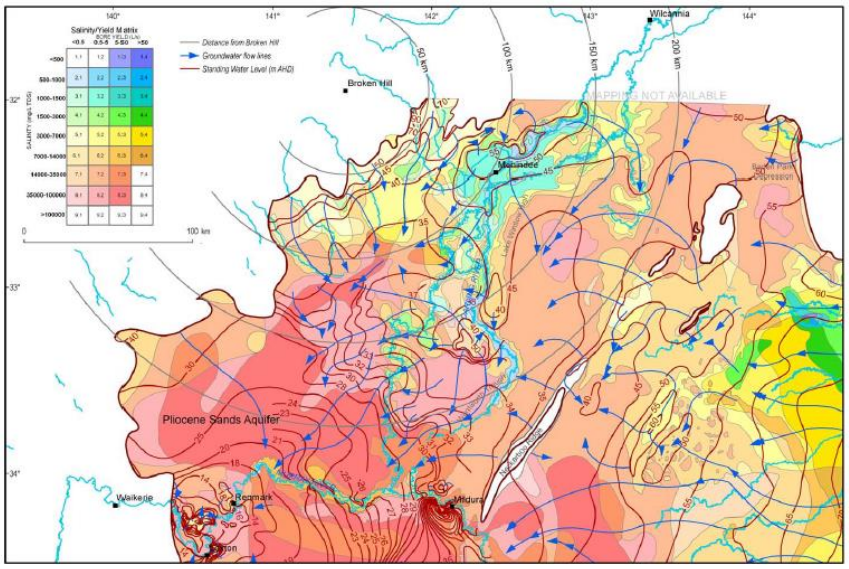
Source: AGGA 2010

Figure 15 Schematic Cross section near Menindee

The major aquifers of the Cenozoic MGB in NSW occur in the Renmark Group, Calivil Formation and to a lesser extent the Shepparton Formation.

Low salinity groundwater can occur in the Pliocene Calivil Formation sand aquifer in the vicinity of major rivers such as Lachlan and Darling Rivers in the study area. This is due to leakage through the sandy river bed. Away from these rivers, groundwater salinity may approach that of seawater. Low salinity groundwater also occurs in the shallow Coonambidgal sediments within the current Darling River flood plain, as a result of river leakage.

Regional flow directions can be seen in Figure 16. The flow lines are affected by basement structures and recharge is apparent from the Darling River (blue colour).



Source: AGGA 2008

Figure 16 Groundwater Flow Direction and Salinity for Pliocene Sands Aquifer

All four troughs have some Murray Basin sediments within their potential release area. They are located on the margin of the Basin away from major Rivers. This results in the underlying groundwater being salty and low yielding to a bore. The groundwater would generally be suitable for mining purposes and sometimes for stock and limited domestic use. The Yathong-Ivanhoe Trough has the Lower Lachlan alluvium within part of its boundary. The whole of this water source is designated ‘highly productive’ alluvium by the NSW government. However, the more remote parts of this water source away from the Lachlan River contain brackish to salty groundwater. Section 5.3.4 discusses this in more detail.

5.3.2 Lower Darling Alluvium

Regional studies of the shallow groundwater (less than 100 m) within 100 km of Broken Hill AGGA (2008) highlighted the possibilities of using the geologically Recent Lower Darling alluvial aquifers as an alternative water source, for Broken Hill. More localised work in the Menindee Lakes area was reported in AGGA (2010) for the Broken Hill Managed Aquifer Recharge Project. Here it was found that within the Quaternary alluvium a freshwater lens occurs which is recharged via flows in the Darling River.

A dilution aureole is found along most of the river, where shallow groundwater salinities range from 400–4,000 mg/L. This contrasts with typical salinities of about 20,000 mg/L in the shallow aquifer away from the lower reach of the river (AGGA, 2008).

The southern boundary of the Pondie Range Trough is in the vicinity of this water source which contains occasional low salinity groundwater when in close hydraulic connection with the Darling River.

5.3.3 Upper Darling Alluvium

The Quaternary Upper Darling alluvium (UDA) technically lies outside the Murray Geological Basin. It is geologically equivalent to the Lower Darling alluvium, so is discussed here. The Pondie Range Trough underlies a small part of the UDA, on its eastern boundary.

The alluvial deposits extend from upstream of Bourke to downstream of Wilcannia. It is comprised of basal sands and gravels and generally becomes finer closer to the surface. The thickness of the alluvial deposits is 40 to 50 m in places, with water levels 10 to 20 m below ground level (DPI, 2012b).

Water bore records show that away from Darling River floodplain, groundwater is mostly brackish to salty, whilst within the present day floodplain there are some areas of low salinity groundwater with bore yields up to 5-10 L/s. These aquifers are 'highly productive' aquifers under the Aquifer Interference Policy (2012) classification.

The Upper Darling alluvium is a gaining stream from Bourke to about 30 km upstream of Wilcannia below which it is a losing stream to groundwater. There is limited extraction from the groundwater source. Water is mainly used for domestic and stock purposes and also for Wilcannia town water supply during dry periods (DPI, 2012b).

5.3.4 Lower Lachlan Alluvium

The Lower Lachlan Groundwater Source is made up of unconsolidated alluvial sediments. These sediments form an extensive alluvial fan deposited by the Lachlan River and its distributaries, comprised of clay, silt, sand and gravel. The Yathong-Ivanhoe Trough underlies the north western part of the Lower Lachlan Groundwater Source.

The water-bearing sands and gravels of the alluvium are generally divided into two main aquifer systems: a shallow aquifer system up to approximately 70 m deep (Shepparton Formation equivalent), and a deep aquifer system up to a maximum of approximately 300 m deep (Calivil Formation and Renmark Group equivalents). Yields from the deep system vary with reported yield as high as 250 L/s. Recharge to the alluvium occurs through leakage from the Lachlan River and its distributaries, infiltration from rainfall and irrigation activity (DPI, 2017).

Groundwater salinity in both the shallow and deep aquifers of the Lower Lachlan Alluvium is lowest closest to Lachlan River near Hillston, generally less than 2,500 µS/cm. Away from the River, salinity increases, exceeding 40,000 µS/cm in places (DPI, 2020).

There are over 1,000 registered bores in the Lower Lachlan Alluvium, the majority used for stock and domestic purposes. There is significant reliance on groundwater for irrigation with approximately 178 production bores, the majority concentrated in the area surrounding Hillston. The town of Hillston uses groundwater for its water supply.

Water level decline (4-6 m) has been observed in both the aquifer systems (shallow and deep) of the Lower Lachlan Alluvium in the vicinity of Hillston, where irrigation development pressure has been the greatest.

In the vicinity of the Yathong-Ivanhoe Trough proposed release area, the groundwater salinity is elevated and generally unsuitable for irrigation purposes. Bores in this area are used for stock and limited domestic purposes. No water level decline has been observed in this area as the resource is lightly used in this location.

The sediments of the Lower Lachlan Groundwater Source grade into the Western Porous Rocks Groundwater Source on its western boundary resulting in a hydraulic connection across the boundary.

6. WATER ACCESS RIGHTS AND AQUIFER INTERFERENCE

6.1 Water Access Rights

Access to surface water and groundwater in NSW is provided through an access licence. Landholders have a basic right to take water for stock and domestic purposes on their own property without a licence. The rules for extracting and trading water are provided in Water Sharing Plans (WSP).

A water licence gives its holder a share of the water available for extraction. For groundwater, yearly allocations are announced on the 1st July each year.

For groundwater sources in western NSW both entitlement levels and annual water extraction volumes are below the sustainable diversion limits set under WSPs. Under this scenario the NSW Government can release additional entitlements through a controlled allocation order, via a tendering/auction process. The water access licence holder must have sufficient share component and water allocation to cover the take of water for their particular activity.

The Department of Planning, Industry and Environment (DPIE) - Water Group is currently converting WSPs to Water Resource Plans, a requirement of the *Commonwealth Murray Darling Basin Plan 2012*.

The four potential release areas are located where several WSPs overlap. In part, this is because of the vertically stacked nature of the aquifer systems (water sources). Major water sources often occur in separate WSP. Appendix D shows the water sources that occur in the potential release areas.

Appendix C shows the extraction limits and key rules for relevant Water Sharing Plans.

6.2 Aquifer Interference Activities

The NSW Aquifer Interference Policy (2012) explains the water licensing and impact assessment processes for aquifer interference activities under the *Water Management Act 2000*. There are three parts to the policy:

1. All water taken must be properly accounted for through an appropriate water license.
2. The activity must address minimal impact considerations for impacts on water table, water pressure and water quality.
3. Planning for measures in the event that the actual impacts are greater than predicted, including making sure that there is sufficient monitoring in place.

The *Water Management Act 2000* defines an aquifer interference activity as that which involves any of the following:

- the penetration of an aquifer;

- the interference with water in an aquifer;
- the obstruction of the flow of water in an aquifer;
- the taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- the disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The above definition is a very broad catch-all statement. The Policy is more generally used to address the following high risk activities:

- **mining activities** such as open cut voids, underground mine workings and the disposal of water taken from an aquifer including water taken as part of coal seam gas extraction;
- other **extractive industries**, such as sand and gravel extraction, as defined in the State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007;
- **coal seam gas activities**, including those related to both exploration and production;
- other large projects which require **dewatering** such as for the construction and maintenance of associated works, such as buildings, roads and other civil works;
- **injection works** used to transmit water into an aquifer; and
- activities with the potential to **contaminate** groundwater or result in unacceptable loss of storage or structural damage to an aquifer.

The *Water Management Act 2000* includes the concept of ensuring “no more than minimal harm” for both the granting of water access licences and the granting of works approvals. Minimal impact considerations are detailed in DPI (2012a) for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users.

Any future gas exploration or development within the DGB will need to hold appropriate water licences if any groundwater is to be extracted. During the exploration phase a groundwater licence is required if total groundwater extraction of 3 ML/year or more is expected.

The extent of any future exploration and development of gas fields in the DGB is unknown. If it includes substantial water extraction or injection works then the proposal would likely be assessed under the AIP minimal impact considerations. Note: the AIP does not regulate the process of hydraulic fracturing (also known as “fracking”). This is regulated under the *Petroleum (Onshore) Act 1991* and the *Environmental Planning and Assessment Act 1979*.

For significant aquifer interference activities, the impact of groundwater extraction or injection on each connected groundwater or surface water source as a result of the activity, will need to be predicted through the use of computer groundwater flow model.

Groundwater sources across NSW have been divided into “highly productive” and “less productive”. Highly productive groundwater is defined on the following criteria:

a) has total dissolved solids of less than 1,500 mg/L; and
b) contains water supply works that can yield water at a rate greater than 5 L/sec.

Less productive aquifers have higher salinities and or lower yields than the above.

In this context, it should be noted that the 'highly productive' GAB sandstone aquifers overlie parts of the Bancannia Trough and Pondie Range Trough. The Pondie Range Trough potential release area is also in proximity to the alluvial aquifers of the Upper Darling, which are classified as 'highly productive'. The 'highly productive' Lower Lachlan alluvium extends over part of the Yathong-Ivanhoe Trough potential release area.

All mining and petroleum projects and most exploration activities require approval under the *Environmental Planning and Assessment Act 1979* before they can start. For large projects, the proponent must submit an application for development consent with DPIE and prepare an Environmental Impact Statement (EIS). The proposal may be referred to the Water Division of DPIE for assessment of impacts under the AIP.

7. POTENTIAL WATER IMPACTS

7.1 Conventional Gas

Conventional gas is the most common form of gas extraction in Australia. In the DGB past gas exploration has been for conventional gas of thermogenic origin. As conventional gas is under high pressure it comes to the surface through a gas well under its own pressure and doesn't have to be pumped. A small amount of water may be removed with the gas as condensate (ACOLA, 2013).

While the gas is being removed, groundwater will move into the pore spaces previously occupied by the gas, causing a temporary localised redistribution of groundwater pressures. The groundwater flow direction will be towards the reservoir until the decrease in pressure caused by gas removal, is re-established. Over time, steady state groundwater conditions will gradually return and historic groundwater flow direction and pressures will be re-established. Because the volume of water to be removed is small to negligible the hydraulic impacts on nearby private bores, higher in the stratigraphic sequence, will be minimal and probably not measurable.

Exploration for gas resources involves extensive geophysical surveys, including aerial and ground surveys. Drilling is used to confirm or otherwise the geophysical interpretation. The drilling process is similar for exploration drilling as it is for the construction of a gas supply well. Drilling muds are used to cool the drill bit and bring rock cuttings to the surface for examination. Core samples may also be taken. Multiple strings of casing may be used to seal off shallow zones that are not gas prospective. After all testing is completed, the exploration bore is cemented back to ground surface and the drill pad area restored.

Environmental concerns regarding the potential impacts of conventional gas extraction on water assets include:

- Gas leakages in poorly constructed wells affecting overlying aquifers.
- Chemical contamination of high value aquifers due to the drilling and cementing of gas wells.
- Surface spills and pipe breakages causing contamination to surface waters.
- Obtaining sufficient water for the drilling process without causing excessive impacts on nearby surface waters and groundwater or water dependent ecosystems (eg. Wetlands or springs).
- Maintaining the integrity of abandoned bores, so that cross contamination, particularly of high value aquifers, does not occur in the long term.

All of the above potential impacts also apply to tight gas exploration and development and need to be addressed in an EIS before being considered by government for approval.

7.2 Tight Gas

As stated above, tight gas is an unconventional gas that has migrated to a low permeability reservoir from a deeper source rock. It is necessary to create permeability to allow the gas to flow from the rock. This is done by fracking the rock to create an artificial reservoir composed of fine fractures in an otherwise competent rock mass (ACOLA, 2013).

Large amounts of water are used in hydraulic fracturing operations. In general, brackish or salty water can be used; chemicals and sand are then added to the water to give it the right properties for the development of induced permeability. It is this increase in permeability which allows the gas to flow from the rock into gas wells (ACOLA, 2013). The chemicals that can be used in the fracking fluid are now highly regulated in Australia.

The fracking fluid must be removed from the well before any gas can flow. The water that flows back from the well can be re-used or it may be disposed of at an approved site. Contamination of aquifers and surface water can result from chemical spillage of this water (King, 2012).

The large quantities of water required for hydraulic fracturing, will need to be sourced locally and the extraction and subsequent disposal will need to be managed within the New South Wales regulatory framework. This includes but is not limited to; obtaining water access entitlements, developing aquifer management plans and obtaining drilling/fracking approvals. To obtain the necessary approvals the impacts on existing groundwater users and any connected environment, would need to be “no more than minimal harm”. This applies for both the granting of water access licences and the granting of works approvals.

Any gas wells that are drilled through or in close proximity to highly productive aquifers (eg. GAB sandstones, Upper Darling Alluvium and the Lower Lachlan Alluvium, must be subject to the highest standard of well integrity regulation.

Some authors warn that there may be a risk of propagating fractures towards overlying aquifers if pre-existing transmissive faults exist. All four troughs are fault bound at their edges but it is unknown if groundwater is easily transmitted through these faults. More work is required to resolve this issue.

As explained above, hydraulic fracturing occurs under very high pressure. It may occur at several stratigraphic levels in horizontally drilled wells. This localised pressure increase will propagate into the groundwater system both above and below the area of work. Tight gas however, is generally found at considerable depth (say 1000 m and deeper) with many hundreds, and sometimes thousands of metres, of sedimentary rocks, between the gas reservoir and the shallow privately used aquifers (50 to 250 m). Many aquitards exist in the intervening layers. The temporary increased in groundwater pressure will dissipate both horizontally and vertically, and its affect is likely to be small on any private bores that access water from the shallow overlying aquifers. If anything, a temporary rise in water level may occur in a bore.

The pressure increase experienced during fracking will be temporary and will reverse when the fracking fluid is removed and gas begins to flow. Once operational the flow of gas in the fractured zone will cause the opposite effect with some lowering of pressure occurring, and groundwater moving towards this low pressure area. The increased permeability and fracture porosity will allow more water to move into the fractured area than otherwise would be the case. Very little water is extracted in tight gas operations and the impact of a localised fall in pressure at depth, on shallow private bores, is likely the be very small to negligible.

Given that very little groundwater is removed either during the exploration phase or after development of a gas field, the potential impacts of primary concern fall into two areas:

- The sourcing of large quantities of water required for fracking purposes and potential impacts on nearby water assets (bores, wetlands, springs, surface waters).
- The possibility of polluting aquifers, above the gas extraction zone, and surface waters. Contamination of high value aquifers could occur due to accidental leakage of brines or chemically-modified fluids during gas drilling or production. This may occur through well failure; leakage along transmissive faults; or by diffusion through over-pressured seals.

ACOLA (2013) makes the argument that there are no insurmountable technology barriers relating to shale gas production but there will be a need to adapt to particular geological features. It is reasonable to assume that the same logic would apply to tight gas extraction.

In risk areas, such as in locations overlain by ‘highly productive’ groundwater or near groundwater dependent ecosystems, risk management and compliance reporting needs to be of a higher order.

8. DATA GAPS AND DATA ACQUISITION

Groundwater data on aquifer yields, water quality, pressure levels, direction of flow and the age of groundwater is scarce to non-existent across the DGB. With the exception of a report by AGGA (2008), the Devonian rocks of the DGB have not been studied for their groundwater potential. With minor exceptions the available information suggests they contain brackish to saline groundwater suitable for limited stock use and industrial/mining purposes and that current groundwater usage is minimal.

Both conventional gas and tight gas extraction does not involve large groundwater extraction, unlike some coal seam gas developments in Queensland. The development of tight gas reservoirs does however involve the injection of considerable volumes of fracking fluid, under high pressures.

The collection of baseline groundwater data is essential during the drilling of gas wells so as to better understand regional and local groundwater flow conditions. The collection of the data outlined below will provide baseline information against which to measure future changes and to compare natural change and change resulting from the gas industry activities.

The development of a three dimensional groundwater flow model with basic parameter distribution, would provide ball park estimates on the possible extent of groundwater impacts. Such a model could be refined as more groundwater data becomes available.

V5

Any gas exploration program should undertake studies and collect groundwater data to help fill knowledge gaps and answer questions raised as part of the environmental assessment process. Information to be collected during an exploration program should include, but not be limited to:

- Identifying all water sources from which water is to be taken for drilling purposes;
- Recording all water bearing zones during drilling and undertaking drill stem tests (DST) on significant aquifers for yield estimation and calculation of hydraulic parameters;
- Undertaking wire line geophysical logs to establish detailed lithology;
- Measuring the standing water level (pressure level) of all significant aquifers;
- Collecting water samples for chemical analysis and isotopic age dating to better understand the groundwater flow regime;
- Survey levelling the measuring points that water levels are taken from;
- Undertaking studies to better understand the location of major geological faults and how groundwater moves through these faults;
- Using sensing technology to closely monitor the hydraulic fracturing process, particularly any upward vertical growth of fractures into local transmissive faults; and
- Setting up a network or monitoring piezometers at various depths so the impacts of gas extraction can be directly measured and reported.

9. REFERENCES

ACOLA, 2013. Unconventional Gas Production. A study of shale gas in Australia. Funded by: Australian Council of Learned Academies. Authored by: Cook P. J., Beck V., Brereton D., Clark R., Fisher B., Kentish S., Toomey J., Williams J. May 2013.

AGGA, 2003. Structural Evolution and Potential Petroleum Plays in the Darling Geological Basin. Australian Government Geoscience Australia record 2003/05. Authors: Willcox J. B., Yeates A. N., Meixner A. J. and Shaw R. D.

AGGA, 2008. Assessment of Groundwater Resources in the Broken Hill Region.
Professional Opinion 2008/05 Prepared by Geoscience Australia for the Australian Government.

AGGA, 2010. Broken Hill Managed Aquifer Recharge Project, Phase 2
Interim Report Professional Opinion 2010/02. Prepared by Geoscience Australia for the Australian Government.

AGGA, 2015. Hydrogeological Atlas of the Great Artesian Basin. Geoscience Australia, Authors: Ransley T.R., Radke B.M., Feitz A.J., Kellett J.R., Owens R., Bell J., Stewart G. and Carey H.

Cook P. J., 2013. Life Cycle of Coal Seam Gas Projects: Technologies and Potential Impacts. Report for the New South Wales Office of the Chief Scientist and Engineer. June 2013.

CSE, 2013. Initial Report on the Independent Review of Coal Seam Gas Activities in NSW.
NSW Chief Scientist & Engineer. http://www.chiefscientist.nsw.gov.au/coal-seam-gas-review/initial-report-july-2013.

CSIRO, 2012. Water Resource Assessment for The Great Artesian Basin.
A report to the Australian Government from the CSIRO. Authors: Smerdon BD, Ransley TR, Radke BM and Kellett JR. Dec 2012.

CSIRO, 2020. Hydraulic fracturing - CSIRO, https://www.csiro.au/en/Research/Energy/Hydraulic-fracturing

DPI, 2012a. NSW Aquifer Interference Policy. Department of Primary Industries – Office of Water. Policy for licensing and assessment of aquifer interference activities.

DPI, 2012b. Water Sharing Plan for the Barwon - Darling Unregulated and Alluvial Water Sources. Department of Primary Industries – Office of Water.
www.water.nsw.gov.au/__data/assets/pdf_file/0006/549024/wsp_barwon_darling_background_document.pdf.

DPI, 2017. Lachlan Alluvium Water Resource Plan. Status and Issues Paper. Department of Primary Industries Feb 2017 www.industry.nsw.gov.au/__data/assets/pdf_file/0010/175969/Lachlan-alluvium-appendice-awater-resource-description.pdf

DPI, 2020. Groundwater Annual Report. Lower Lachlan Groundwater Source. Department of Primary Industries 2020

Geoscience Australia, 2021. Unconventional Petroleum Resources | Geoscience Australia (ga.gov.au).

GSNSW, 2017. Darling Basin Prospectivity Report. NSW Department of Planning and Environment, Division of Resources and Geoscience, Aug 2017. www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/nsw-geology-overview/sedimentary-basins/darling-basin

GSNSW, 2020a. Bancannia Trough Potential Strategic Release Area. Prepared by the Geological Survey of NSW. July 2020

GSNSW, 2020b. Pondie Range Trough Potential Strategic Release Area. Prepared by the Geological Survey of NSW. July 2020

GSNSW, 2020c. Neckarboo Trough Potential Strategic Release Area. Prepared by the Geological Survey of NSW. July 2020.

GSNSW, 2020d. Yathong-Ivanhoe Trough Potential Strategic Release Area. Prepared by the Geological Survey of NSW. July 2020.

Hughes K., Oliveira F. and Gilmore P., 2018. Updated Great Artesian Basin boundary outline in northwestern NSW. GS report GS2018/0194.

King G. E., 2012. Hydraulic Fracturing 101. Society of Petroleum Engineers.

Robertson Research Australia, 2001. Petroleum geology report of the Bancannia Trough, PEL 425. Geological Survey of NSW, File GS2002/381.

APPENDIX A

Geological Time Scale

Eon	Era	Period	Epoch	Date at Boundary (Ma = million years ago)
Phanerozoic	Cainozoic	Neogene (previously Quaternary)	Holocene	0.01
		Old Tertiary-Quaternary boundary	Pleistocene	1.5
			Pliocene	5
			Miocene	24
		Palaeogene (previously Tertiary)	Oligocene	35
			Eocene	55
			Palaeocene	65
	Mesozoic	Cretaceous		145
		Jurassic		210
		Triassic		250
	Palaeozoic	Permian		300
		Carboniferous		350
		Devonian		400
		Silurian		440
		Ordovician		500
		Cambrian		540
Proterozoic		Ediacaran		600
				2500

APPENDIX B

Water Information from Petroleum Boreholes

Table 1 Water Information for the Bancannia Trough

WELL NAME	DRILL STEM TEST (DST) RESULTS	SUMMARY LOG	TOTAL DEPTH	COMMENTS
Bancannia South-1	**3 DST recovered water:** a. from 874 to 914 m – fresh water; b. from 1,336 to 1,388 m - brackish water; c. from 1,458 to1,461 m – brackish water.	4-128 m – Cenozoic sediments (sand, clay) 128-214 m – Cretaceous shale and sand 214-237 m – Carboniferous shale 237-1,222 m – Late Devonian sandstone 1,222-2,609 m – Mid Devonian sandstone 2,609-3,257m – Mid Devonian sandstone and conglomerate 3,257-3,408 – Cambrian volcanic rocks	3,408 m	Porous Devonian sandstones occur from 830 to1,222 m; yielded fresh water during DST. Porosity and permeability of sandstone decreases down-hole, but rocks are generally tight.
Bancannia North-1	**3 DST recovered water:** a. 423.7 - 497.7 m muddy water; b. 563.6 - 576 m brackish water; c. 831.2 – 871.7 m muddy water.	4-128 m – Cenozoic sediments (sand, clay) 128- 399 m – Cretaceous siltstone, sandstone, shale 399-768 m – Late Devonian sandstone 768-1,478 m – Mid Devonian sandstone	1,478 m	Fair to good porosity in sandstones from 935 to1,137 m, but no DST conducted. Other porosities are mostly poor-fair.
Jupiter-1	**1 DST recovered water:** 1,085 to1,098 m – fresh water.	0-122 m – Cenozoic sediments 122-1173 m – Late Devonian sandstone, siltstone, shale 1173-1830 m – Mid Devonian sandstone	1,830 m	Variable sandstone porosity, mostly poor to fair but with excellent aquifer potential (high porosity and permeability in places).

Table 2 Water Information for the Pondie Range Trough

WELL NAME	DRILL STEM TEST (DST) RESULTS	SUMMARY LOG	TOTAL DEPTH	COMMENTS
Mena Murtee-1	1406.5-1407.5 md 24.5 md 1490.3-1491.9 m 573 md 1531.5-1532.5 m 554 md 1633-1634 m 247 md	5 – 75 m Claystone red brown 75 – 170 m Sandstone white 170 – 220 m Claystone red 220 – 1290 m Claystone grey 1290 – 1641 m Sandstone brown 1641 – 2008 m Claystone brown 2008 – 2270 m Sandstone lt grey	2270 m	0 – 214.5 m Post Devonian then older Late Devonian Ravendale Interval
Gnalta-1	Nil	0 – 99.1 m Sandstone grey 99.1 – 340.8 Sandstone Brown 340.8 – 451.1 m Sandstone 451.1 – 710 m Sandstone tan 710 m Quartzite basement	718.3 m	Middle Devonian Sandstones
Pondie Range-1	593 – 611 m muddy water 731 - 746 m muddy water @ 14,850 ppm	0 -84 m Sand, brown Tertiary 80.4 –1692.4 m Sandstone Late Devonian 1692.8 – 3053 m Siltstone, shale, conglomerate, Sandstone - Middle Devonian	3053.5 m	Porosity range 7-11% Permeability 97 md, greatest in 55-750 m Fractures visible

Table 3 Water Information for the Neckarboo Trough

WELL NAME	DRILL STEM TEST (DST) RESULTS	SUMMARY LOG	TOTAL DEPTH	COMMENTS
BMR-Ivanhoe 1	None found	0-4 m Quaternary sand 4-305 m Early Devonian siltstone and black shale	305 m	No significant aquifers found. Mud loss at 56.6 m which could be an aquifer. Siltstone core very tight. Some visible porosity in open fractures. Other fractures filled with calcite
Berangabah 1	None found	0-7.6 m Cenozoic sand, clay. 7.6-463.7 Siltstone, shales, trace limestone. (assigned to Devonian Amphitheatre Gp) Shaley siltstone from Lower to middle Devonian. Contains carbonaceous matter.	463.7 m	Water was encountered at 100.1 and 109.7 m, then steadily increased with depth. At 274.4 m a flow of 1.5L/s was measured. No intergranular porosity observed. Water quality salty, EC =20,900uS/cm
Kewell East 1	None found	0-87.4 m Tertiary to Recent clays, sands 87.4-377.8 m Snake Cave Sandstone 337.8-1224 m Winduck Group, Claystones, siltstone and minor sandstone	1224 m	None found

Table 4 Water Information for the Yathong - Ivanhoe Trough

WELL NAME	DRILL STEM TEST (DST) RESULTS	SUMMARY LOG	TOTAL DEPTH	COMMENTS
Conoble 1	None found	0-119 m Cenozoic sediments 119-155 m Marine shales, Early Cretaceous? No indications of Permian sediments. Possible Devonian at 182 m	182.8 m	No water inflows recorded
Holey Box 1	None found	0-166.2m U. Cenozoic sandy/clays 166.2-182.9 m Carbonaceous clays (Renmark Beds) 182.9-227 m L Cenozoic sandstone/conglomerate 227-335.4 m Devonian Shales/siltstone	355.2 m	No water inflows recorded
North Star Ivanhoe 1	None found	0-164 Quaternary/Tertiary Sediments 164-203.6 m L. Cretaceous shales 203.6-488 m L Permian 488-666.7 m Devonian, non marine shales	666.7 m	Sandy layer in L. Permian may have fair porosity. Devonian Shales -lack porosity

APPENDIX C

Groundwater Sharing Plans

Water Sharing Plan Name	Extraction Limit ML/yr	Comments	Boundaries
North Western Unregulated and Fractured Rock Water Sources 2011 • Kanmantoo Fold Belt • Adelaide Fold Belt	27,930 30,381	Unassigned water available Highly probable GDEs mapped Water trading available Carryover 10%	See map Appendix D
NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020 • Kanmantoo Fold Belt • Adelaide Fold Belt	18,700 6,900	Unassigned water available Highly probable GDEs mapped Water trading available Carryover 10% per year	See map Appendix D
NSW Great Artesian Basin Shallow Groundwater Sources 2020 • Central water source - north western • Central water source - MDB	33,220 8,830	Unassigned water available Highly probable GDEs mapped Water trading available Carryover permitted	See map Appendix D
NSW Great Artesian Basin Groundwater Sources 2008 • Central water source	5,193 +	Extraction limit based on a sustainable pressure surface Geo thermal springs listed 30% of water saving from C&P program available through controlled allocation Water trading available carryover permitted	See map Appendix D
Lachlan Alluvial Groundwater sources 2020	117,000	Carryover available Water trading available Highly probable GDEs mapped	See map Appendix D
Darling Alluvial Water sources 2020. • Upper Darling Alluvium • Lower Darling Alluvium • Paroo Alluvium	6,009 2,230 292	Unassigned water available High priority GDEs mapped Water trading available Some carryover permitted	See map Appendix D
NSW Murray Darling Basin Western Porous Rock Groundwater Source 2020	226,000	Unassigned water available Water trading available Highly probable GDEs mapped	See map Appendix D

+ Thirty percent of water savings under the Cap and Pipe Program may be made available by the Minister for Water.

APPENDIX D Water Sharing Plan Boundaries

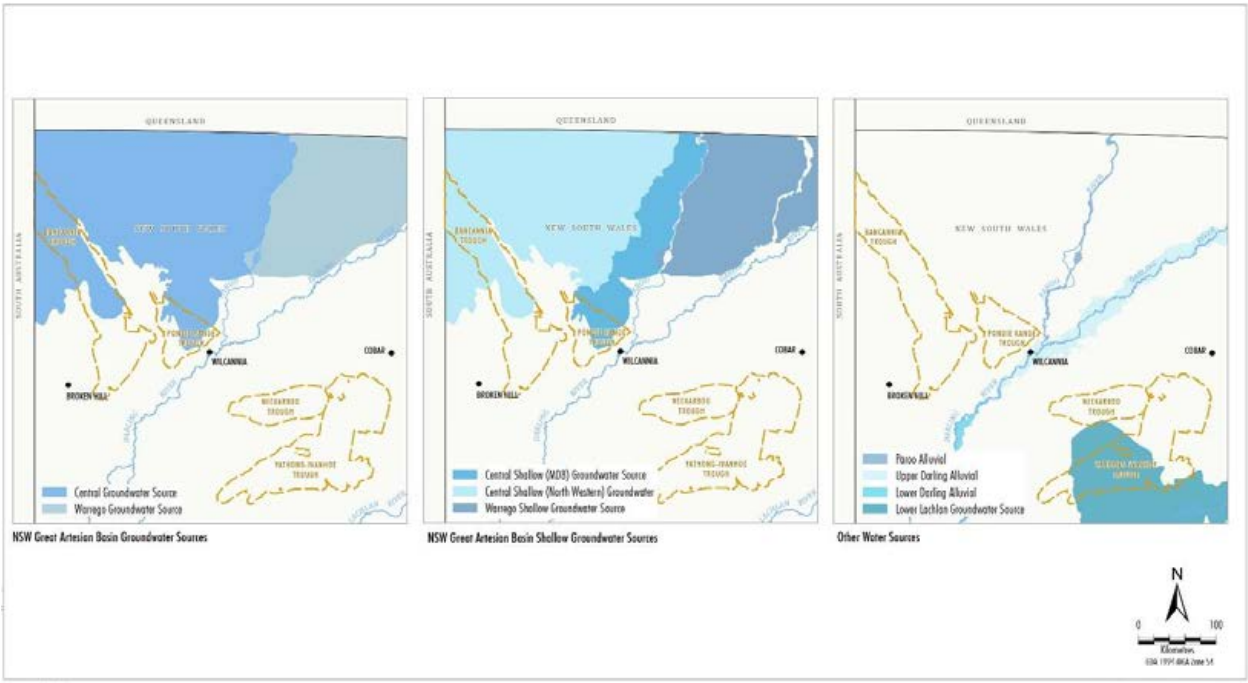
North Western Unregulated and Fractured Rock Water Sources

Murray Darling Basin Fractured Rock Water Sources

Murray Darling Basin Porous Rock Groundwater Sources

LEGEND
Potential Release Area

Source: Geoscience Australia (2006, 2017); NSW Office of Water (2017)



NSW Great Artesian Basin Groundwater Sources

NSW Great Artesian Basin Shallow Groundwater Sources

Other Water Sources

LEGEND
Potential Release Area

Source: Geoscience Australia (2006, 2017); NSW Office of Water (2017)