NSW MURRAY DARLING BASIN POROUS ROCK WATER RESOURCE PLAN

# Groundwater Resource Description Report

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**NSW Murray—Darling Basin Porous Rock Resource Description**

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NOTE: On 1 July 2019, NSW Department of Industry became part of NSW Department of Planning, Industry and Environment. Any references to Department of Industry in this document, except where made in a historical context, can be taken to refer to Department of Planning, Industry and Environment.

**More information**

Chris Rumpf, Department of Planning, Industry and Environment, Grafton

dpie.nsw.gov.au

**Acknowledgments**

# Glossary

Note: these terms are presented in the context that they are used for groundwater.

| Term | Explanation |
|---|---|
| **Alluvial aquifer** | A groundwater system whose geological matrix is composed of unconsolidated sediments consisting of gravel, sand, silt and clay transported and deposited by rivers and streams. |
| **Alluvium** | Unconsolidated sediments deposited by rivers or streams consisting of gravel, sand, silt and clay, and found in terraces, valleys, alluvial fans and floodplains. |
| **Aquifer** | Under the *Water Management Act 2000* an aquifer is a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water. More generally, the term aquifer is commonly understood to mean a groundwater system that can yield useful volumes of groundwater. For the purposes of groundwater management in NSW the term 'aquifer' has the same meaning as 'groundwater system' and includes low yielding and saline systems. |
| **Aquitard** | A confining low permeability layer that retards but does not completely stop the flow of water to or from an adjacent aquifer, and that can store groundwater but does not readily release it. |
| **Artesian** | Groundwater which rises above the surface of the ground under its own pressure by way of a spring or when accessed by a bore. |
| **Archean** | The Archean Era spanned 4.56 to 2.5 billion years ago. |
| **Australian Height Datum (AHD)** | Elevation in metres above mean sea level. |
| **Available water determination** | A determination referred to in section 59 of the *Water Management Act 2000* that defines a volume of water or the proportion of the share component (also known as an 'allocation) that will be credited to respective water accounts under specified categories of water access licence. Initial allocations are made on 1 July each year and, if not already fully allocated, may be incremented during the water year. |
| **Baseflow** | Discharge of groundwater into a surface water system. |
| **Basement (rock)** | See Bedrock |
| **Basic landholder rights (BLR)** | Domestic and stock rights, harvestable rights or native title rights. |
| **Bedding** | Discrete sedimentary layers that were deposited one on top of another. |
| **Bedrock** | A general term used for solid rock that underlies aquifers, soils or other unconsolidated material. . |
| **Beneficial use (category)** | [1]A general categorisation of groundwater uses based on water quality and the presence or absence of contaminants. Beneficial use is the equivalent to the 'environmental value' of water. |
| **Bore (or well)** | A hole or shaft drilled or dug into the ground. |
| **Brackish water** | Water with a salinity between 3,000 and 7,000 mg/L total dissolved solids. |

[1] As defined in '*Macro water sharing plans – the approach for groundwater*' (NSW Office of Water, 2011)

| Term | Explanation |
|---|---|
| **Cenozoic** | The Cenozoic Era spanned from 66 million years ago to present. |
| **Confined aquifer** | An aquifer which is bounded above and below by impermeable layers causing it to be under pressure so that when the aquifer is penetrated by a bore, the groundwater will rise above the top of the aquifer. |
| **Connected water sources** | Water sources that have some level of hydraulic connection. |
| **Development (of a groundwater resource)** | The commencement of extraction of significant volumes of water from a water source. |
| **Discharge** | Flow of groundwater from a groundwater source. |
| **Drawdown** | The difference between groundwater level/pressure before take and that during take. |
| **Dual porosity** | Where a groundwater system has two types of porosity; primary porosity resulting from the voids between the constituent particles forming the rock mass, and secondary porosity resulting from dissolution, faulting and jointing of the rock mass. |
| **Electrical conductivity (EC)** | Ability of a substance to conduct an electrical current. Used as a measure of the concentration of dissolved ions (salts) in water (i.e. water salinity). Measured in micro-Siemens per centimetre (µS/cm) or deci-Siemens per metre (dS/m) at 25$^{o}$ C. 1 dS/m = 1000 µS/cm |
| **Environmental Value** | [2]Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of contamination, waste discharges and deposits. |
| **Fractured rock** | Rocks with fractures, joints, bedding planes and cavities in the rock mass. |
| **Geological sequence** | A sequence of rocks or sediments occurring in chronological order. |
| **Groundwater** | Water that occurs beneath the ground surface in the saturated zone. |
| **Groundwater Dependent Ecosystem (GDE)** | [3]Ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. |
| **Geological formation** | A fundamental lithostratigraphic unit used in the local classification of strata and classified by the distinctive physical and chemical features of the rocks that distinguish it from other formations. |
| **Groundwater equilibrium** | A state where the forces driving groundwater flow have reached a balance in a groundwater system, for example where groundwater inflow equals groundwater outflow. |
| **Groundwater system** | Any type of saturated sequence of rocks or sediments that is in hydraulic connection. The characteristics can range from low yielding and high salinity water to high yielding and low salinity water. |

[2] As defined in '*Guidelines for Groundwater Quality Protection in Australia 2013'* published by the National Water Quality Management Strategy.

[3] Kuginis L., Dabovic, J., Byrne, G.,  Raine, A., and Hemakumara, H. 2016, *Methods for the identification of high probability groundwater dependent vegetation ecosystems.* DPI Water, Sydney, NSW.

| Term | Explanation |
|---|---|
| **Highly Productive Aquifer** | An aquifer system with potential bore yields of greater than 5 L/s and salinity concentration of less than 500 mg/L. |
| **Hydraulic conductivity** | The capacity of a porous medium to transmit water. Measured in meters/day. |
| **Hydraulic connection** | A path or conduit allowing fluids to be connected. The degree to which a groundwater system can respond hydraulically to changes in hydraulic head. |
| **Hydraulic head** | The height of a water column above a defined point, usually expressed in metres. |
| **Hydrogeology** | The branch of geology that relates to the occurrence, distribution and processes of groundwater. |
| **Hydrograph** | A plot of water data over time. |
| **Kriging** | A method of interpolation using a weighted average of neighbouring samples to estimate an 'unknown' value at a given location to create surfaces. |
| **Long term average annual extraction limit (LTAAEL)** | The long term average volume of water (expressed in megalitres per year) in a water source available to be lawfully extracted or otherwise taken. |
| **Igneous rock** | Rocks which have solidified from a molten mass. |
| **Infiltration** | The movement of water from the land surface into the ground. |
| **Ion** | Mineral species dissolved in groundwater. |
| **Make good provisions (in reference to a water supply work)** | The requirement to ensure third parties have access to an equivalent supply of water through enhanced infrastructure or other means for example deepening an existing bore, funding extra pumping costs or constructing a new pipeline or bore. |
| **Management zone** | A defined area within a water source where a particular set of water sharing rules applies. |
| **Mesozoic** | The Mesozoic Era spanned 252 to 66 million years ago |
| **Metamorphic rock** | Rocks that result from partial or complete recrystallisation in the solid state of pre-existing rocks under conditions of temperature and pressure. |
| **Minimal impact considerations** | Factors that need to be assessed to determine the potential effect of aquifer interference activities on groundwater and its dependent assets. |
| **Monitoring bore** | A specially constructed bore used to measure groundwater level or pressure and groundwater quality at a specific depth. Not intended to supply water. |
| **Ongoing take** | The take of groundwater that occurs after part or all of the principal activity has ceased. For example extraction of groundwater (active take) entering completed structures, groundwater filling abandoned underground workings (passive take) or the evaporation of water (passive take) from an abandoned excavation that has filled with groundwater. |
| **Outcrop** | Rocks which are exposed at the land surface. |
| **Piezometric or Potentiometric head** | The pressure or hydraulic head of the groundwater at a particular depth in the ground. In unconfined aquifers this is the same as the water table. |
| **Palaeozoic** | The Palaeozoic Era spanned 541 to 252 million years ago. |

| Term | Explanation |
|---|---|
| **Perched water table** | A local water table of very limited extent which is separated from the underlying groundwater by an unsaturated zone. |
| **Permeability** | The capacity of earth materials to transmit a fluid. |
| **Porous rock** | Consolidated sedimentary rock containing voids, pores or other openings in the rock (such as joints, cleats and/or fractures. |
| **Pre-development** | Prior to development of a groundwater resource. |
| **Proterozoic** | The Proterozoic Era spanned 2.5 billion to 541 million years ago. |
| **Recharge** | The addition of water into a groundwater system by infiltration, flow or injection from sources such as rainfall, overland flow, adjacent groundwater sources, irrigation, or surface water sources. |
| **Recovery** | The rise of groundwater levels or pressures after groundwater take has ceased. Where water is being added, recovery will be a fall. |
| **Recovery decline** | Where groundwater levels or pressures do not fully return to the previous level after a period of groundwater removal or addition. |
| **Reliable water supply** | [4]Rainfall of 350mm or more per annum (9 out of 10 years); or a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L. |
| **River Condition Index (RCI)** | This is a spatial tool used to measure and monitor the long term trend of river condition, but also reports on instream values and risk to instream values from extraction and geomorphic disturbance. |
| **Salinity** | The concentration of dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre. |
| **Salt** | A mineral which in a liquid will readily dissociate into its component ionic species for example NaCl into $Na^+$ and $Cl^-$ ions. |
| **Saturated zone** | Area below the water table where all soil spaces, pores, fractures and voids are filled with water. |
| **Sedimentary rock** | A rock formed by consolidation of sediments deposited in layers, for example sandstone, siltstone and limestone. |
| **Share component** | An entitlement to water specified on an access licence, expressed as a unit share or for specific purpose licences a volume in megalitres (e.g. local water utility, major water utility and domestic and stock). |
| **Sustainable Diversion Limits** | The volume of water that can be taken from a Sustainable Diversion Limit resource unit as defined under the Murray Darling *Basin Plan 2012*. |
| **Unassigned water** | Exists where current water requirements (including licensed volumes and water to meet basic landholder rights) are less than the extraction limit for a water source. |

[4] As defined by Strategic Regional Land Use Plans

| Term | Explanation |
|---|---|
| **Unconfined aquifer** | A groundwater system usually near the ground surface, which is in connection with atmospheric pressure and whose upper level is represented by the water table. |
| **Unconsolidated sediment** | Particles of gravel, sand, silt or clay that are not bound or hardened by mineral cement, pressure, or thermal alteration of the grains. |
| **Unsaturated zone** | Area above the water table where soil spaces, pores, fractures and voids are not completely filled with water. |
| **Water balance** | A calculation of all water entering and leaving a system. |
| **Water resource plan** | [5]A plan made under the *Commonwealth Water Act 2007* that outlines how a particular area of the Murray–Darling Basin's water resources will be managed to be consistent with the Murray–Darling Basin Plan. These plans set out the water sharing rules and arrangements relating to issues such as annual limits on water take, environmental water, managing water during extreme events and strategies to achieve water quality standards and manage risks. |
| **Water sharing plan** | [6]A plan made under the *Water Management Act 2000* which set out the rules for sharing water between the environment and water users within whole or part of a water management area or water source. |
| **Water source** | Defined under the *Water Management Act 2000* as 'The whole or any part of one or more rivers, lakes or estuaries, or one or more places where water occurs naturally on or below the surface of the ground and includes the coastal waters of the State. Individual water sources are more specifically defined in water sharing plans. |
| **Water table** | Upper surface of groundwater at atmospheric pressure, below which the ground is saturated. |
| **Yield** | The amount of water that can be supplied over a specific period. |

[5] https://www.mdba.gov.au/basin-plan-roll-out/water-resource-plans 21/03/17

[6] As defined in '*Macro water sharing plans – the approach for groundwater*' (NSW Office of Water, 2011)

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# 1 Introduction

The NSW Government is developing water resource plans as part of implementing the Murray-Darling Basin Plan 2012 (the Basin Plan). Water resource plans align Basin-wide and state-based water resource management in each water resource plan area. The water resource plans recognise and build on the existing water planning and management frameworks that have been established in NSW.

Under the Basin Plan, individual water resources are known as sustainable diversion limit (SDL) resource units and each water resource plan covers a number of SDL resource units within an area.

The NSW Murray Darling Basin Porous Rock Water Resource Plan (WRP) area is dispersed between four SDL locations within the NSW part of the Murray-Darling Basin (MDB). These SDL resource units correlate directly to groundwater sources (GS) currently covered by the Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources. These areas (shown in Figure 1) are:

- Gunnedah-Oxley Basin MDB (GS17); on the eastern side of the MDB between Narrabri, Gunnedah and Dubbo, and eastward to the MDB boundary.
- Sydney Basin MDB (GS41); on the eastern side of the MDB extending southward from the Gulgong area (east of Dubbo) along the MDB catchment boundary towards Lithgow.
- Western Porous Rock (GS50); in the far west of the state from south of Broken Hill and west of the Lachlan Alluvium and Murrumbidgee Alluvium water resource plan areas to the state borders with Victoria and South Australia.
- Oaklands Basin (GS38); in the south-central area of the state near Jerilderie and completely buried beneath the Murrumbidgee Alluvium and the Murray Alluvium.

This report describes the location, climate and physical attributes of the various groundwater resources, and explains their geological and hydrogeological context, environmental assets, groundwater quality and management. It also presents the current status of these groundwater resources including groundwater rights, accounts, dealings, take, and groundwater behaviour.

Being completely buried, information on some features are not included for the Oaklands Basin, such as overlying land use, connection with surface water and presence of water-dependent ecosystems. These surface features are presented in other reports for the overlying Murrumbidgee and Murray alluvium.

# 2 History of Groundwater Management

## 2.1 Early groundwater management

The *Water Act 1912* (WA 1912) was introduced at a time when the development of water resources for agriculture and regional development were the priority of government (DLWC, 1999). Under the WA 1912, water entitlement was linked to land rights and licences for bores and wells were granted for a fixed term with no restriction on the volume that could be extracted. Bore licences were initially required only for bores greater than 30 metres (m) depth in the western half of NSW.

After World War II, there was a drive to expand irrigation and promote economic development in inland NSW. In 1955, the WA 1912 was amended to require all bores to be licensed irrespective of depth or location.

By the 1970s, the rapid expansion of the irrigation industry, increasing competition for water resources and extended periods of drought were affecting the reliability of water supplies in inland NSW.

Acknowledging that groundwater was a finite resource, from 1972 to 1983 new irrigation licences were issued based on the size of the area being irrigated. These licences had to be renewed every five years, but still had no volumetric limit on extraction (Gates and O’Keefe, 1997).

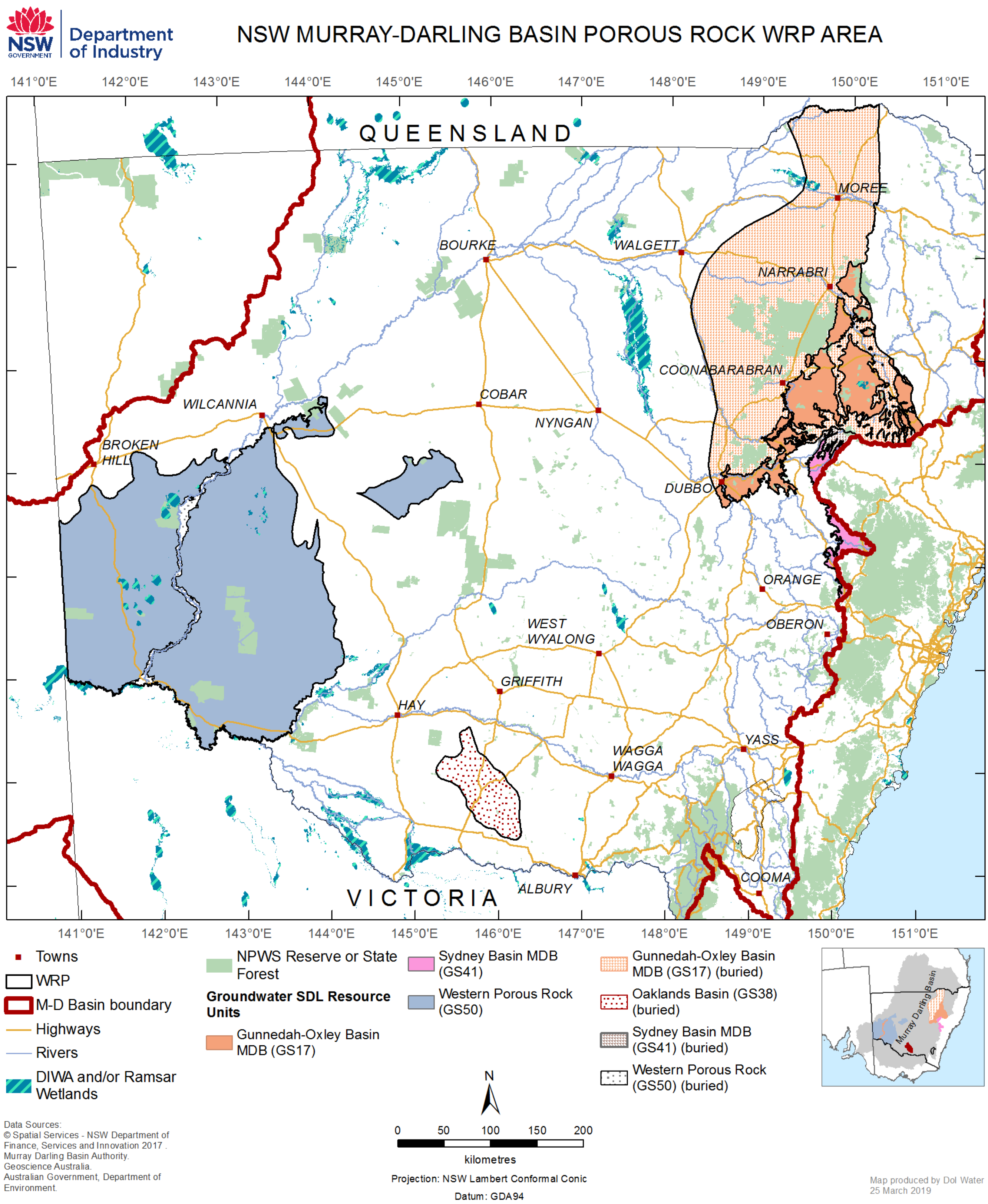


**Figure 1. Location of the NSW Murray Darling Basin Porous Rock Water Resource Plan Area and SDL Resource Units.**

From 1984, all new high yield bores and wells (greater than 20 megalitres (ML)) except those in the Great Artesian Basin, were given a volumetric entitlement and old area based licences were progressively converted. Volumetric entitlements were generally issued based on historical usage, property area or bore capacity.

From 1986, comprehensive volumetric groundwater allocation policies were introduced throughout the State.

The objectives were to more effectively manage development in those groundwater systems where the resource was fully committed and to encourage the use of groundwater where it was underutilised.

## 2.2 NSW water reforms

In 1994, the Council of Australian Governments (COAG) endorsed a strategic framework for reform of the Australian water industry. The framework included identifying and recovering the costs of water management and supply from beneficiaries, recognising the environment as a water user through formal allocations and ensuring that water rights could move by trade to where they would generate the highest value.

By the late 1990s, NSW had embarked on a major program of water policy reforms. This included the development of the NSW State Groundwater Policy Framework Document, the NSW Groundwater Quality Protection Policy, and an assessment of risk to the State's groundwater systems from over-extraction and/or contamination. The NSW State Groundwater Dependent Ecosystems Policy was subsequently released in 2002.

The 1990s policy reforms drove the development of the *Water Management Act 2000* (WMA 2000). The WMA 2000 establishes water for the environment as a priority while also providing licence holders with more security through perpetual licences and greater opportunities to trade through the separation of water access rights from the land.

The WMA 2000 considers other users of water such as groundwater dependent ecosystems, and aquifer interference activities; cumulative impacts; climate change; Aboriginal cultural rights and connectivity between groundwater and surface water. The WMA 2000 also sets up the framework for developing statutory plans to manage water.

Water sharing plans are the principle tool for managing the State's water resources including groundwater. These ten year plans manage groundwater resources at the 'water source' scale, define the long term average annual extraction limit (LTAAEL), establish rules for sharing groundwater between users and the environment, establish basic landholder rights and set rules for water trading.

Priority for developing water sharing plans was based on the groundwater systems identified by the risk assessment as being at highest risk. The first groundwater sharing plans in the Murray-Darling Basin commenced between 2006 and 2008 across six large alluvial groundwater systems in the Murray-Darling Basin. Access to groundwater was reduced to the extraction limit over the ten year plan using an approach that recognised historical extraction.

Since 2007, water sharing plans for unregulated rivers and groundwater systems in NSW have been completed using a 'macro' approach to cover most of the remaining water sources across NSW. Each groundwater macro plan covers a number of groundwater systems characterised by a particular type of occurrence (for example, fractured rock).

In 2008, two embargo orders covering the remaining inland groundwater resources were made under the WA 1912 on new applications for groundwater licences. These embargoes remained in effect until the commencement of water sharing plans for the groundwater sources that they covered.

In 2012, the 'NSW Aquifer Interference Policy' was released. The purpose of this Policy is to explain the water licensing and assessment requirements for aquifer interference activities under the WMA 2000 and other relevant legislative frameworks.

## 2.3 Gunnedah-Oxley Basin MDB

Groundwater development within the Gunnedah-Oxley Basin has historically been concentrated around the Spring Ridge area in the Upper Mooki River catchment where the younger sedimentary rocks of the Oxley Basin (that overlies the Gunnedah Basin) provide sufficient yields of low salinity groundwater to support irrigation. Volumetric entitlements were based on 6ML/ha of irrigation up to a maximum of 486 ML per property. In June 2006 an embargo on applications for new entitlements in the Oxley Basin was put in place.

Due to the high salinity of groundwater within the Gunnedah Basin, demand for groundwater entitlements was limited to mining and industrial uses.

The Gunnedah Basin was incorporated in the 2008 embargo orders that applied to all inland groundwater resources. These embargos also replaced the already existing embargo of the Oxley Basin.

These embargos remained in place until the commencement of the Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 on the 16 January 2012. This plan applies until the 30th June 2022.

## 2.4 Sydney Basin MDB

Due to the prevalence of high salinity groundwater within the coal measure sequences of the Sydney Basin there is minimal groundwater based development. An area of Jurassic sandstone that overlies the older coal measure sequences in the northern portion of the SDL resource unit does have potential for low salinity groundwater.

The Sydney Basin MDB was embargoed as part of the 2008 embargo orders that applied to all inland groundwater resources. This embargo remained in place until the commencement of the Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 on the 16 January 2012. This plan applies until the 30th June 2022.

## 2.5 Western Porous Rock

The groundwater resources of the Western Porous Rock were managed under the *Water Act 1912* until the implementation of the water sharing plan for NSW Murray-Darling Basin Porous Rock Groundwater Sources on 16 January 2012.

Groundwater in this water source is generally of poor quality and not suitable for most irrigation purposes. Prior to 2012 licences within the groundwater source were issued on a needs basis for particular purposes (i.e. stock, industrial, or mining). A state-wide embargo on the issue of new groundwater licences was introduced in July 2008. It included an exemption for licences where the salinity of groundwater to be used exceeded 14,000 milligrams per litre (mg/L) to encourage the extraction of high salinity groundwater and its removal from the system. The embargo was current until it was replaced by the water sharing plan in January 2012.

In August 2009 a state wide groundwater trading policy for the inland aquifers was introduced allowing trading within the groundwater source.

## 2.6 Oaklands Basin

The Oaklands Basin is not a target for groundwater supplies due to its depth and salinity of the groundwater. Consequently there have been no entitlements granted in this resource to date.

# 3 Regional Setting

## 3.1 Topography

### 3.1.1 Gunnedah-Oxley Basin MDB

Approximately 70% of the Gunnedah – Oxley Basin MDB is buried beneath SDL resource units consisting of alluvial sediments, basalt, and the Great Artesian Basin.

The topography of the outcropping Gunnedah – Oxley Basin MDB is typically flat to undulating (Figure 2). The surface elevation typically ranges from around 350m above sea level in the Quirindi area, to around 200m in the north of the basin around Narrabri. Steep sided hills are generally present in the east around the Liverpool Ranges where the elevation can be up to 700m or more above sea level.

The surface expression of the basin extends from south of Dubbo in the south west to north of Narrabri in the north, and is generally cut by three major river systems being the Namoi River in the north, Castlereagh River in the west, and the Macquarie River in the south (Figure 3).

The total outcropping area of the Gunnedah - Oxley Basin MDB is 11,280km².

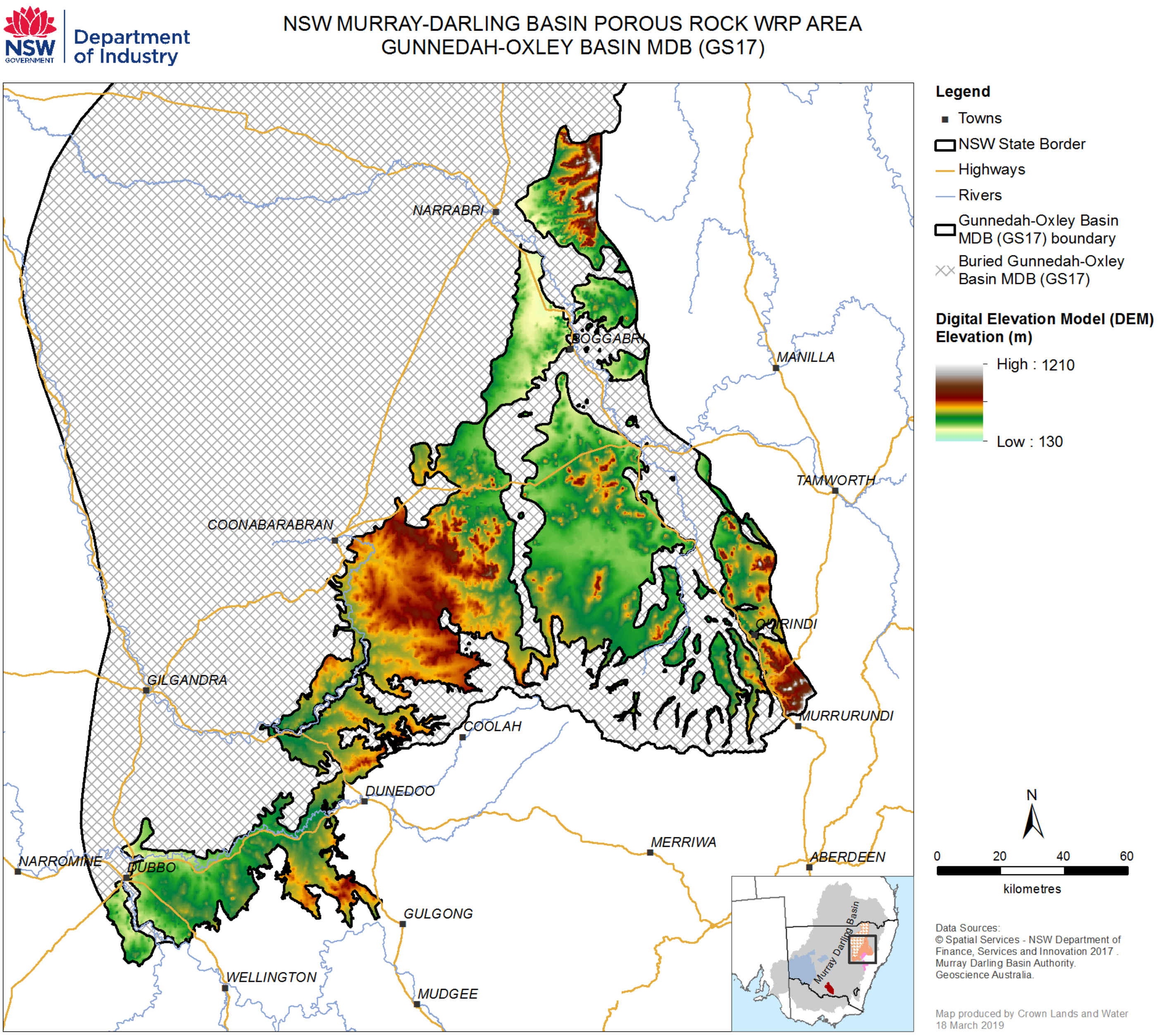


**Figure 2. Topography and elevation map of outcropping area of the Gunnedah-Oxley Basin MDB.**

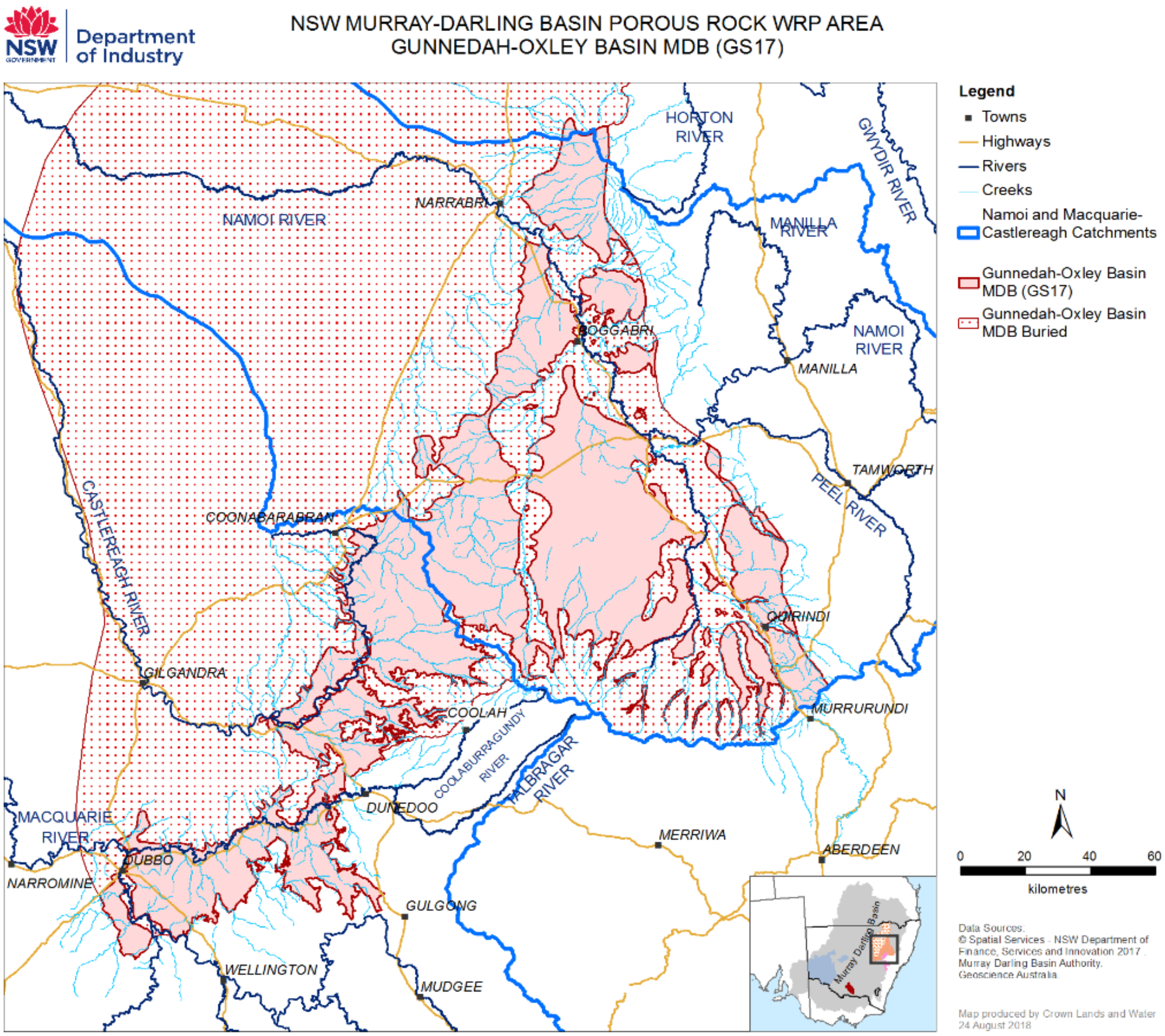


**Figure 3. Surface water map of the outcropping and surrounding areas of the Gunnedah-Oxley Basin MDB.**

### 3.1.2 Sydney Basin MDB

The Sydney Basin MDB outcropping area is approximately 2,120km² in size and is located in the general area as shown in Figure 4 being situated at the top of the Macquarie catchment. The topography of the Sydney Basin MDB is typically characterised by steep sided sandstone hills, gorges, and escarpments rising hundreds of metres above lower lying valleys at elevations around 450m above sea level. The main surface water features include the upper tributaries of the Talbragar River in the north, Cudgegong River in the central area, and the Turon / Crudine River system in the south (Figure 5)

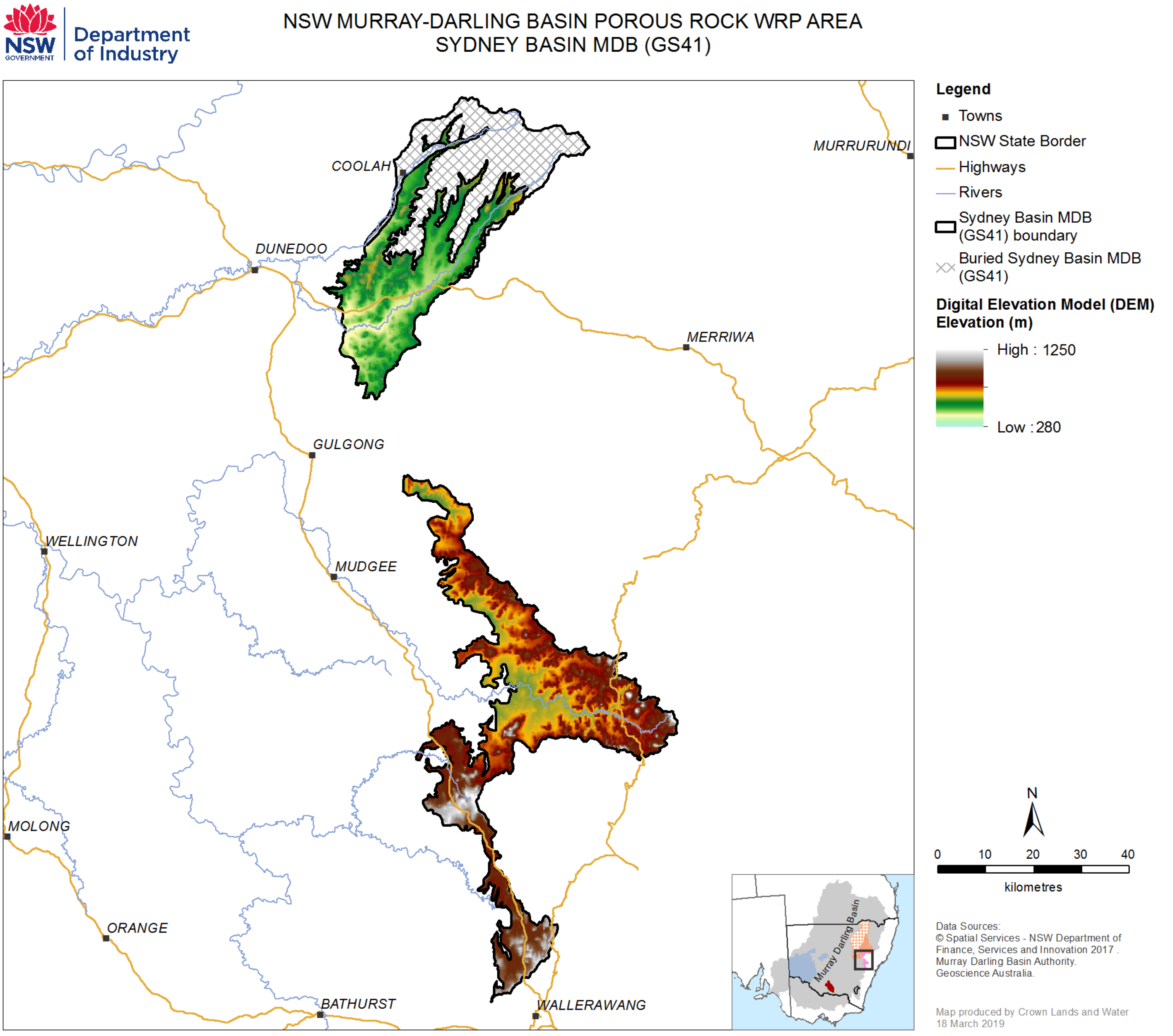


**Figure 4. Topography and elevation map of the outcropping area of the Sydney Basin MDB.**

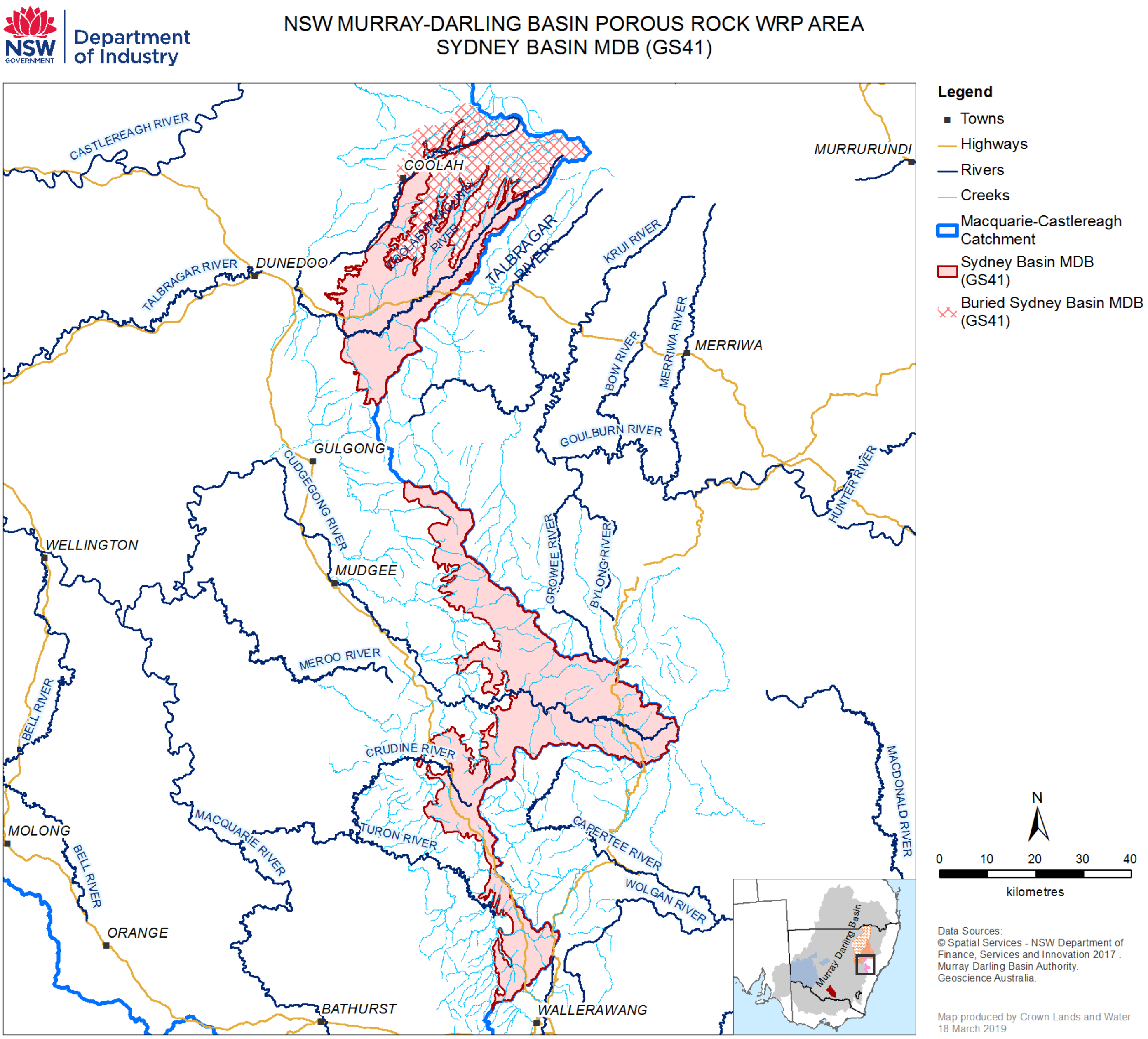


**Figure 5. Surface water map of the overlying and surrounding areas of the Sydney Basin MDB.**

### 3.1.3 Western Porous Rock

The surface expression of the Western Porous Rock covers a large area of the south west of NSW. The topography of this area is typically flat to undulating with towns including Menindee to the north and Wentworth to the south being both at low elevation above sea level as shown in Figure 6. The extent of the Western Porous Rock covers much of the Lower Darling catchment and ranges from Broken Hill and Wilcannia in the north, to the NSW / Victoria border in the south and the NSW / SA border in the west. The surface outcrop of the Western Porous Rock covers approximately 73,020km². Surface water drainage is dominated by the 2 main river systems being the Murray and Darling rivers as shown in Figure 7. Due to the dry climatic conditions experienced in the area, the majority of the smaller streams only provide ephemeral discontinuous flows.

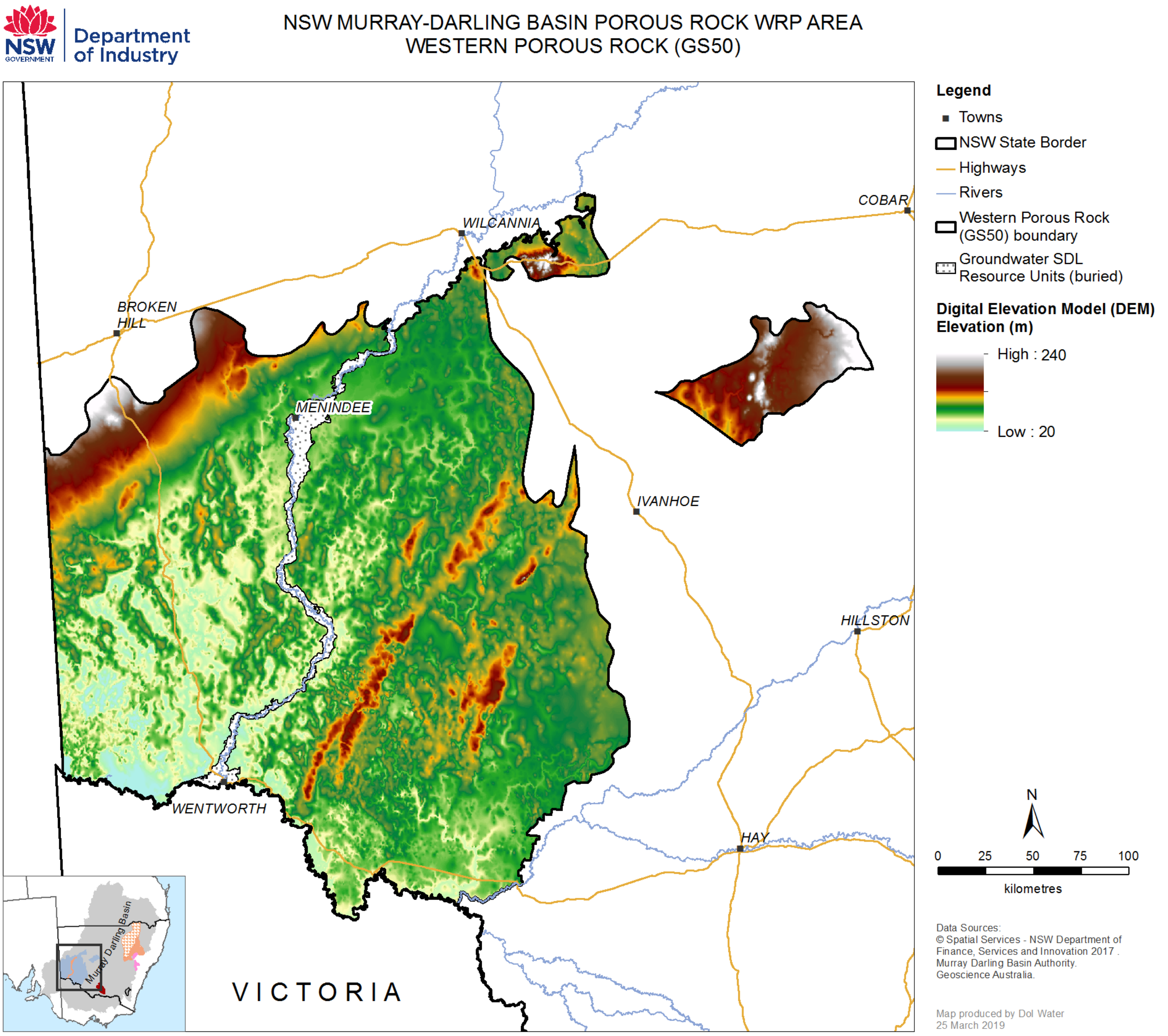


**Figure 6. Topography and elevation map of the Western Porous Rock.**

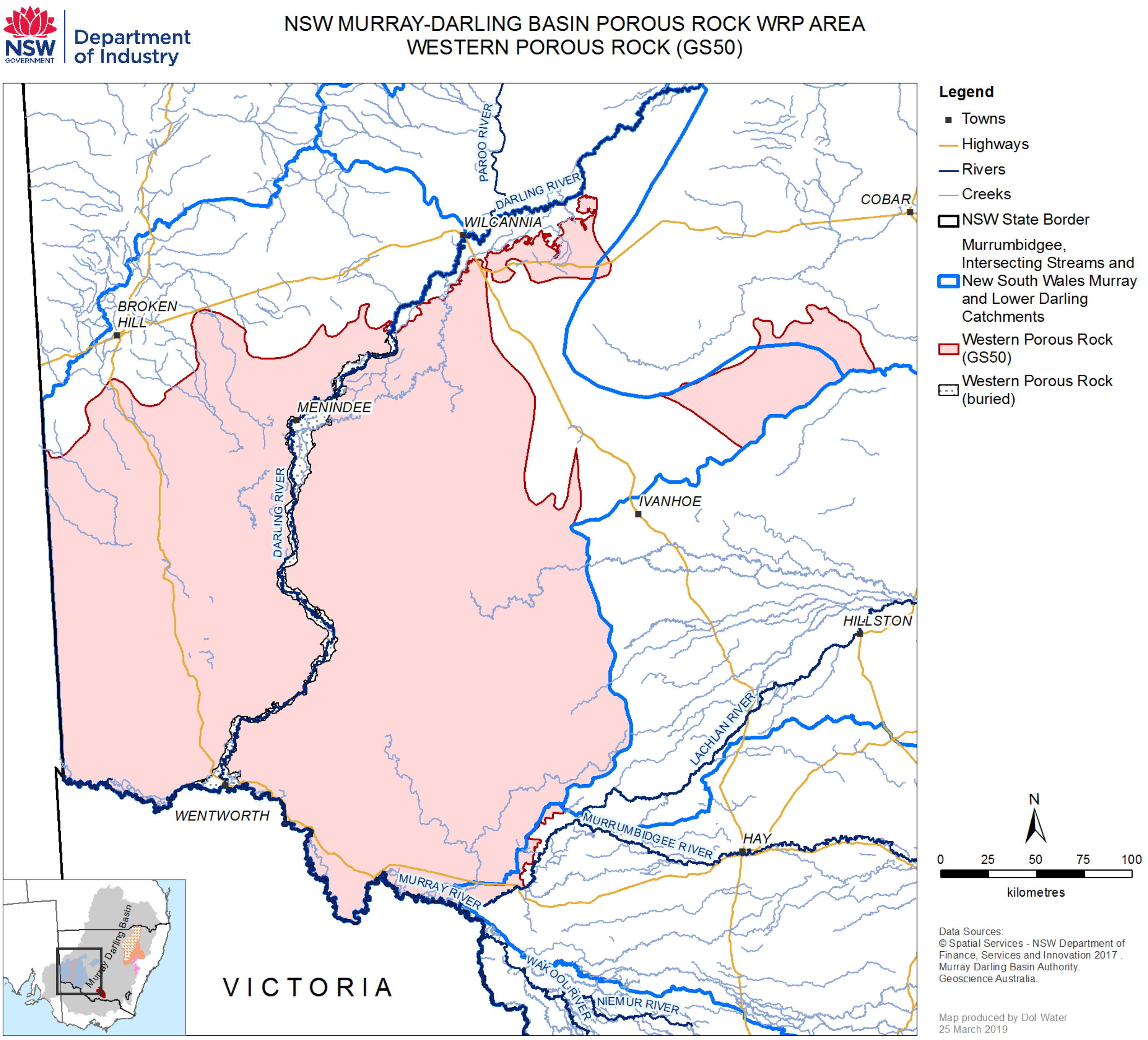


**Figure 7. Surface water map of the overlying and surrounding areas of the Western Porous Rock.**

### 3.1.4 Oaklands Basin

The Oaklands Basin is buried under the alluvium associated with the Murray and Murrumbidgee alluvial areas, and as such has no surface topographical features.

## 3.2 Climate

The WRP area has a varied climate, with a considerable gradient from east (wetter) to west (drier).

The temperature extremes across the WRP area vary greatest in the Gunnedah Oxley Basin MDB and at Gunnedah can range from -8.7 C in the winter to 48.7 C in the summer. The average maximum temperature is 25.9°C and average minimum 11°C.

Average annual rainfall varies from over 680mm near Rylstone in the Sydney Basin MDB to around 310mm in the Western Porous Rock.

Figure 8 presents a spatial map of the average annual rainfall showing the general steady decline in rainfall from east to west, whilst monthly rainfall averages for three larger population centres are presented in Figure 9 depicting seasonal rainfall variability.

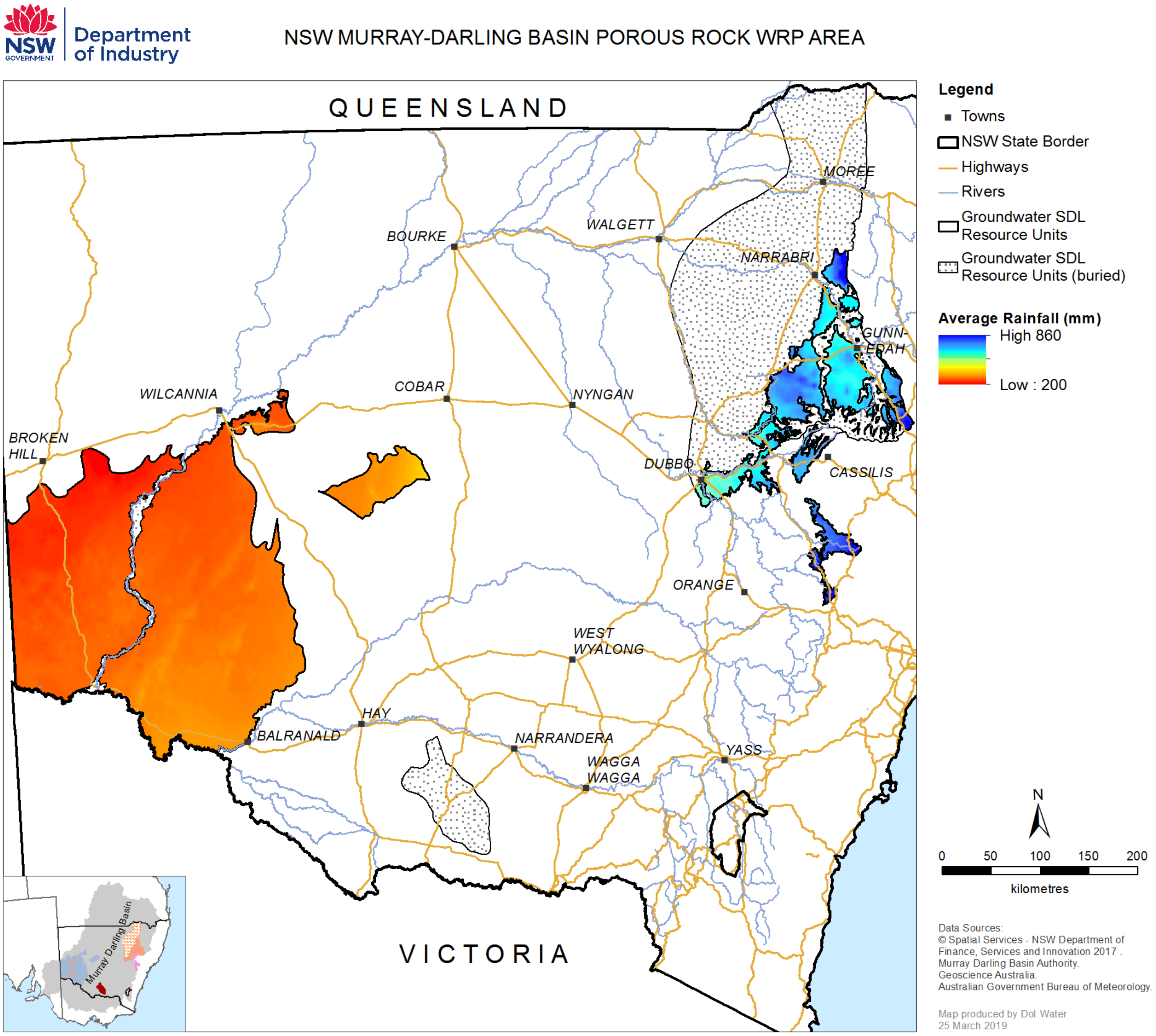


**Figure 8. Average annual rainfall map of the outcropping areas within the WRP area (BOM, 2017).**

Annual rainfall across the WRP area decreases westward. Sydney Basin MDB in the east receives an average yearly rainfall of 680mm while population centres in the Western Porous Rock in the west has an average of 270mm. Rainfall patterns vary across the WRP area with eastern areas being generally summer dominant with the heaviest rainfall occurring from December to January (Figure 8). Western areas are typically winter rainfall dominant with the heaviest occurring from May to June with 80-90mm per month at Gunnedah, and around 30mm per month at Balranald (BOM 2017). Summer rainfall is typically 60-70mm per month at Gunnedah, and 20mm per month at Balranald (BOM 2017).

Cumulative residual rainfall plots have been constructed for the WRP area using monthly data sourced from the Scientific Information for Land Owners (SILO) database. The cumulative rainfall residual mass graph plots the cumulative difference from the monthly average rainfall and provides a visual representation of the rainfall history in an area. A falling trend indicates a period of lower than average rainfall, a rising trend showing periods of above average rainfall.

Figure 10 shows the residual mass graph of average monthly rainfall from 1974 to 2016 at Gunnedah (Gunnedah Oxley Basin MDB), Casillis (Sydney Basin MDB), and Balranald (Western Porous Rock). This figure displays a below average rainfall trend during the millennium drought from 2002 to 2010, followed by an above average spike over the 2011 to 2013 period and then a below average trend to present.

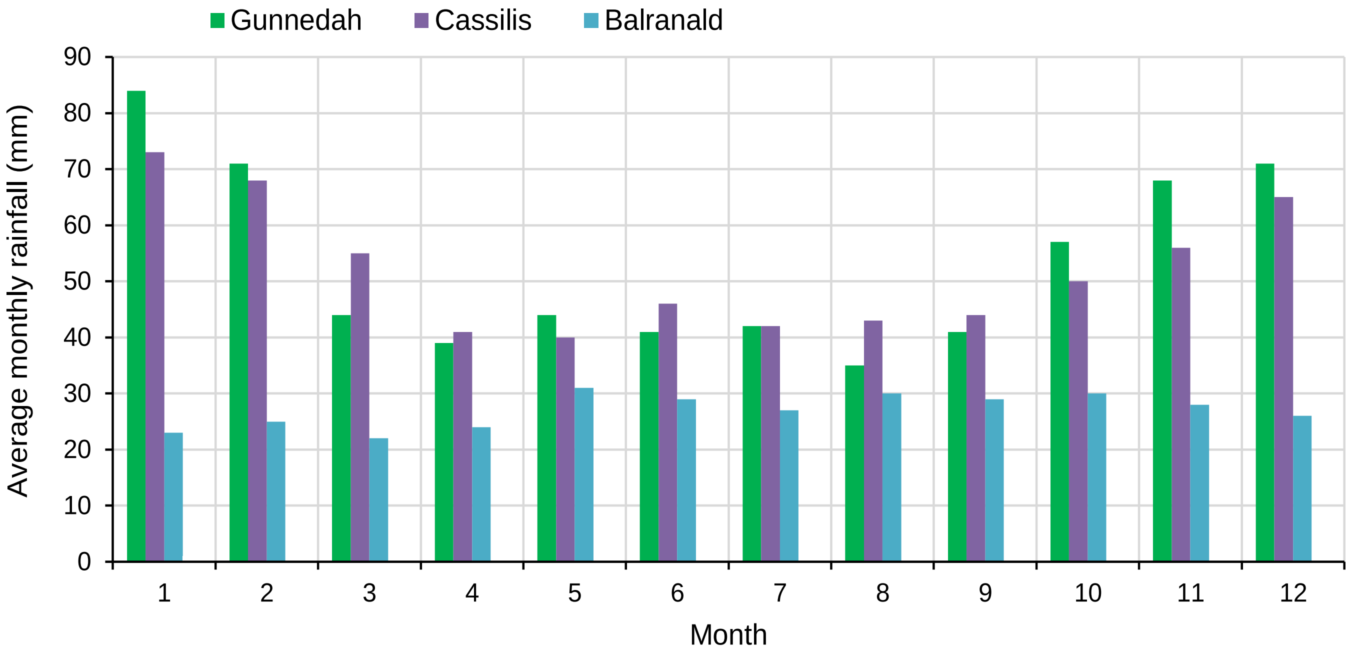


**Figure 9. Average monthly rainfall 1974 – 2016 for the towns of Gunnedah, Cassilis and Balranald within the WRP area (BOM, 2017).**

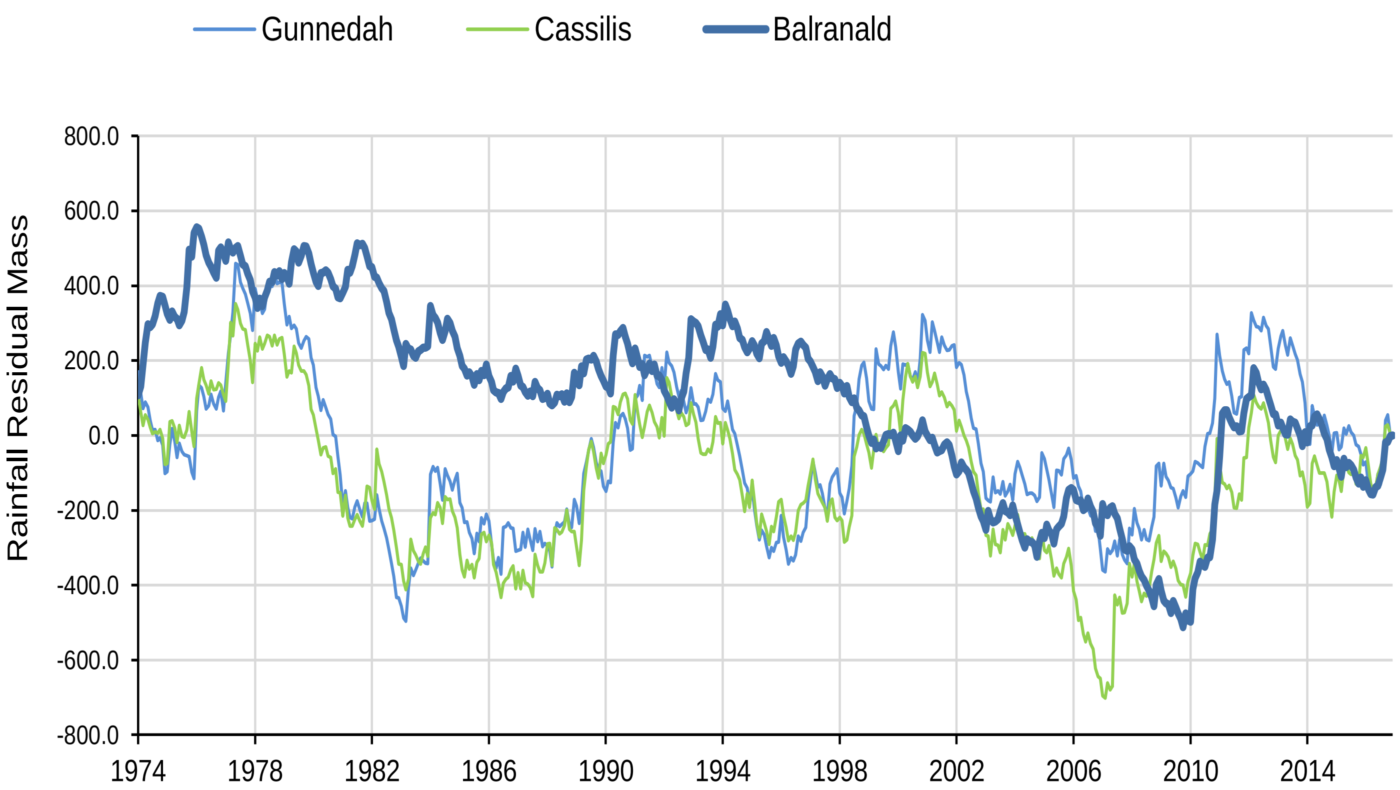


**Figure 10. Rainfall residual mass graph 1974 – 2016 for the towns of Gunnedah, Cassilis and Balranald within the WRP area (BOM, 2017).**

Evaporation (Class A pan evaporation) in the WRP Rock area has a strong east to west gradient (Figure 11). Yearly evaporation varies from around 1,600 mm in the east to over 2,300 mm in the west.

Evaporation is strongly seasonal (Figure 12) varying from 50 - 60 mm a month over winter (June/July). Evaporation significantly exceeds average monthly rainfall over the year. The greatest exceedance occurs over the summer months (December/January), when up to 350 mm of evaporation occurs per month compared to up to 30 mm of rainfall per month for the same period.

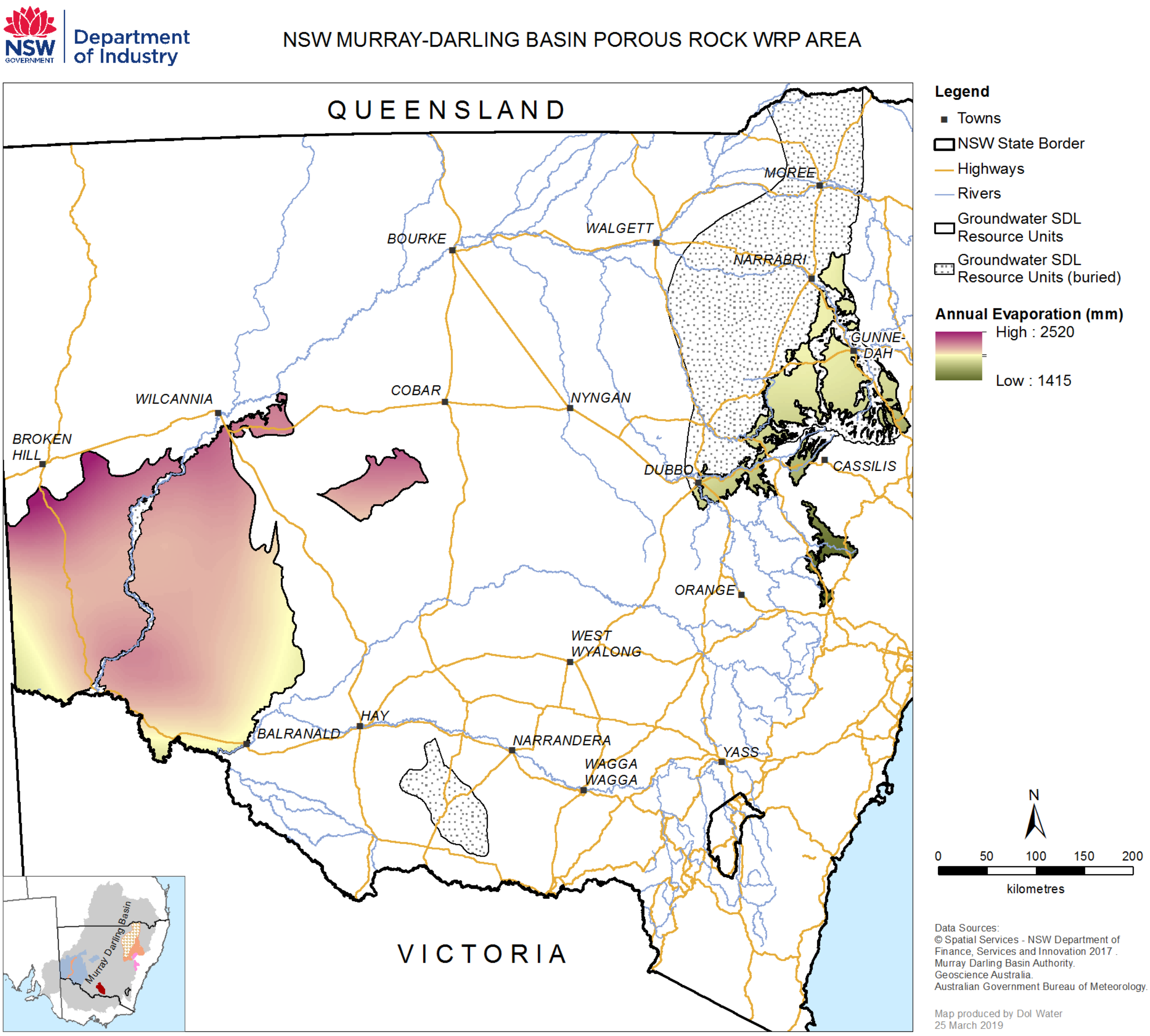


**Figure 11. Average annual evaporation map of the outcropping areas within the WRP area (BOM, 2017).**

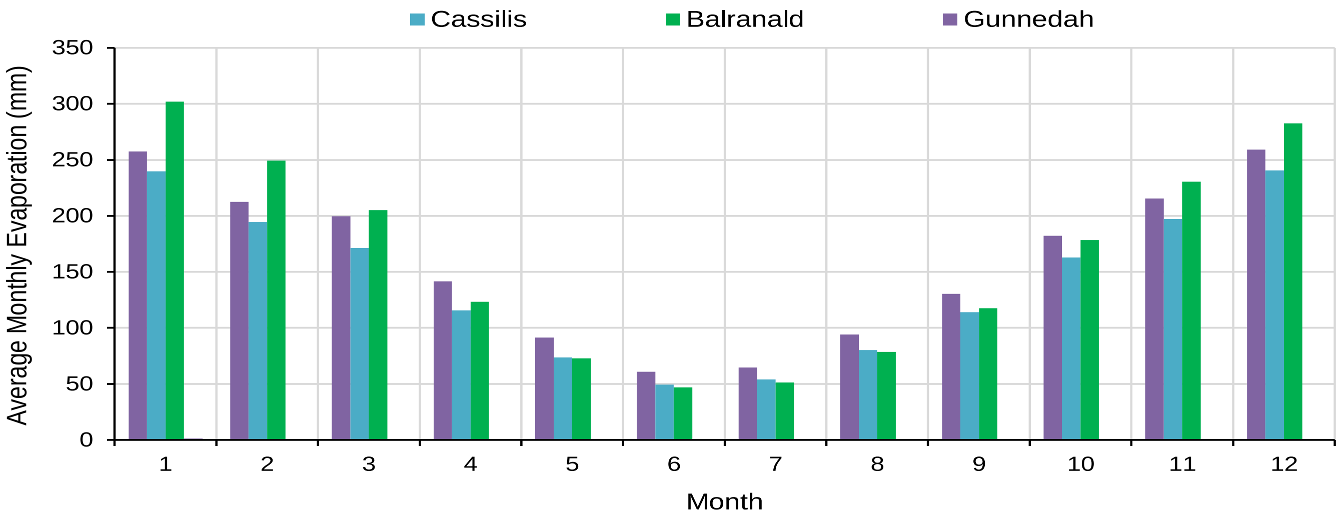


**Figure 12. Average monthly evaporation 1974 – 2016 – for the towns of Gunnedah, Cassilis and Balranald within the WRP area (BOM, 2017).**

## 3.3 Land use

The areas covered by the WRP area, typically have urban centres providing population hubs for the extensive surrounding rural areas. The largest towns are Gunnedah in the north (approximately 7,800 people), and Balranald Shire (2,500 people) in the south west of the state. These are the main commercial centres for the surrounding agricultural areas.

The outcropped area covered by this WRP makes up 14.5% of the NSW portion of the MDB. Given the extent of the plan, land use history is wide and varied. Due to the low rainfall environment, lack of soil nutrients, and the limited surface and groundwater availability within these porous rock environments, the options for land use are also limited. The dominant land use in the area is livestock grazing. However, there are a number of existing and proposed coal and coal-associated extractive industries situated within the Gunnedah-Oxley Basin and the MDB Sydney Basin areas. As well, there are also 2 mineral sand mines existing within the Western Porous Rock with a number of additional mines approved and proposed.

Land use in the WRP area, as shown in Figure 13, is classified as grazing (84%), conservation (6%), followed by dryland cropping (4%), and other (6%) (Department of Planning, Industry and Environment, Enterprise Data Base Production).

There is only minor development of groundwater resources for irrigated agriculture across the WRP, being within the Spring Ridge area of the Gunnedah-Oxley Basin.  This is primarily due to the low yields and variable salinity levels elsewhere.  In contrast to this, the surface water systems of the Western Porous Rock, primarily being the Darling and Murray Rivers, support irrigated agriculture as well as numerous wetlands and nature conservation areas such as the Menindee Lakes system.

There are varying levels of community dependence on access to groundwater across the plan area. Within the Sydney and Gunnedah Basins, the coal mining industry utilises groundwater for dust suppression and processing, but the largest volumes are associated with groundwater extracted to dewater the mines or the incidental take caused by groundwater ingress into voids created by the mines. The overall volumes extracted are still small in comparison to the available water in each of the resource units.

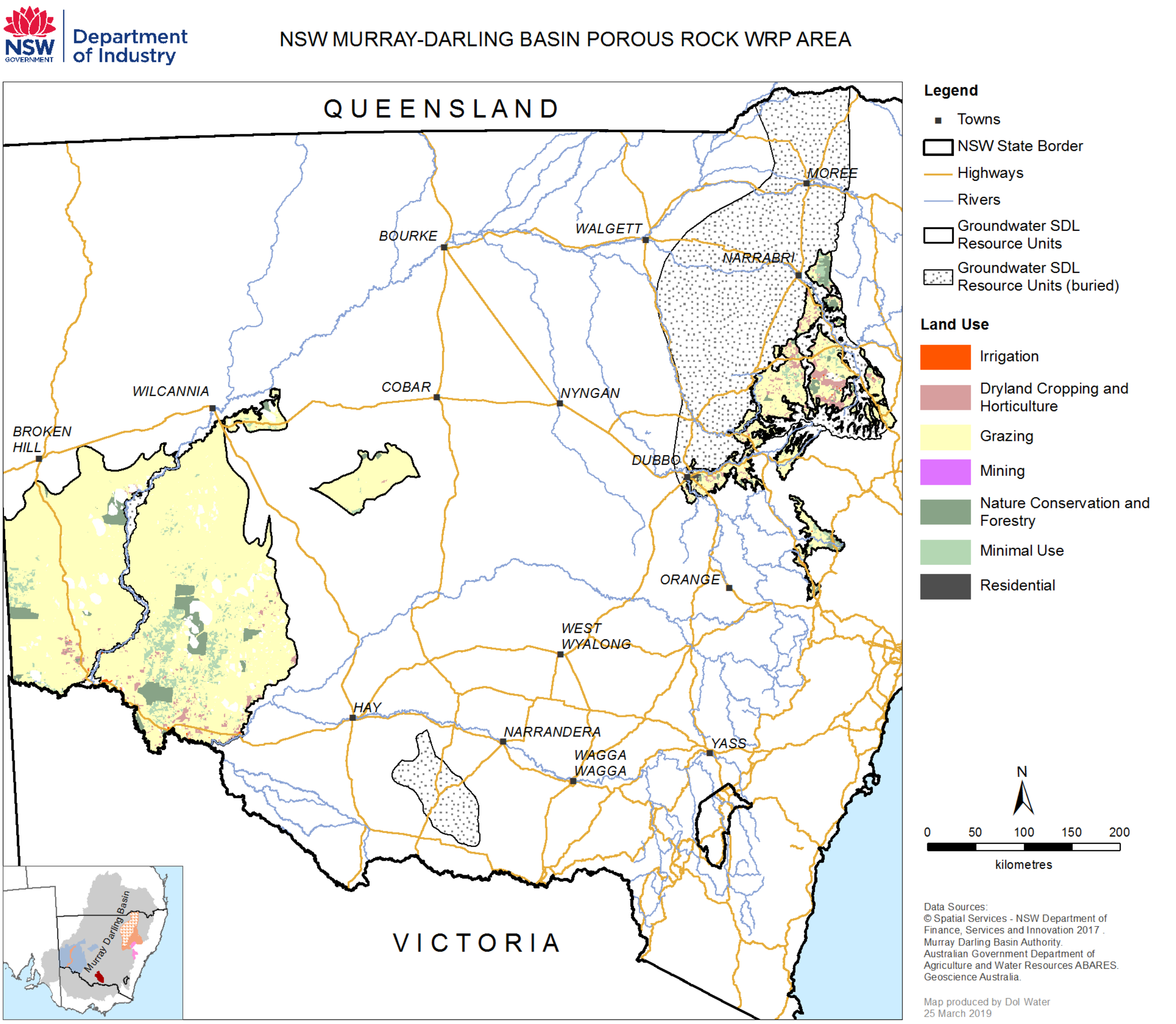


**Figure 13. Landuse within the outcropping areas of the WRP area.**

# 4 Geology

## 4.1 Gunnedah-Oxley Basin MDB

The north to south oriented Gunnedah Basin contains a more than 1,200 m thick sequence of marine and non-marine Permian and Triassic sedimentary rock strata, which is part of an essentially continuous depositional system from the Sydney Basin in the south to the Queensland portion of the Bowen Basin in the north (Ward and Kelly, 2013). These strata unconformably overly the basement rocks of the Lachlan Fold Belt on the western side of the basin, and have a faulted contact along the Mooki Thrust against the New England Fold Belt to the east.

The overall sequence is thicker in the eastern part of the basin than in the west (Tadros, 1995a), reflecting greater subsidence associated with loading of the basement from overthrust of the New England Fold Belt on the eastern side.

North of the Liverpool Range the Permian and Triassic strata are unconformably overlain by Jurassic volcanic and sedimentary rocks. These Jurassic sediments have been hydraulically isolated from the Surat Basin, a sub basin of the Great Artesian Basin, via erosion and are informally referred to as the Oxley Basin. The older Permian and Triassic beds crop out along a north-north west trending zone from south of Quirindi to north of Narrabri. West of Narrabri the Gunnedah Basin is buried by the Surat Basin and to the east much of its sedimentary sequence is eroded, or is overlain by a thick accumulation of Quaternary sediments.  The geology of the Gunnedah-Oxley Basin is shown in Figure 14.

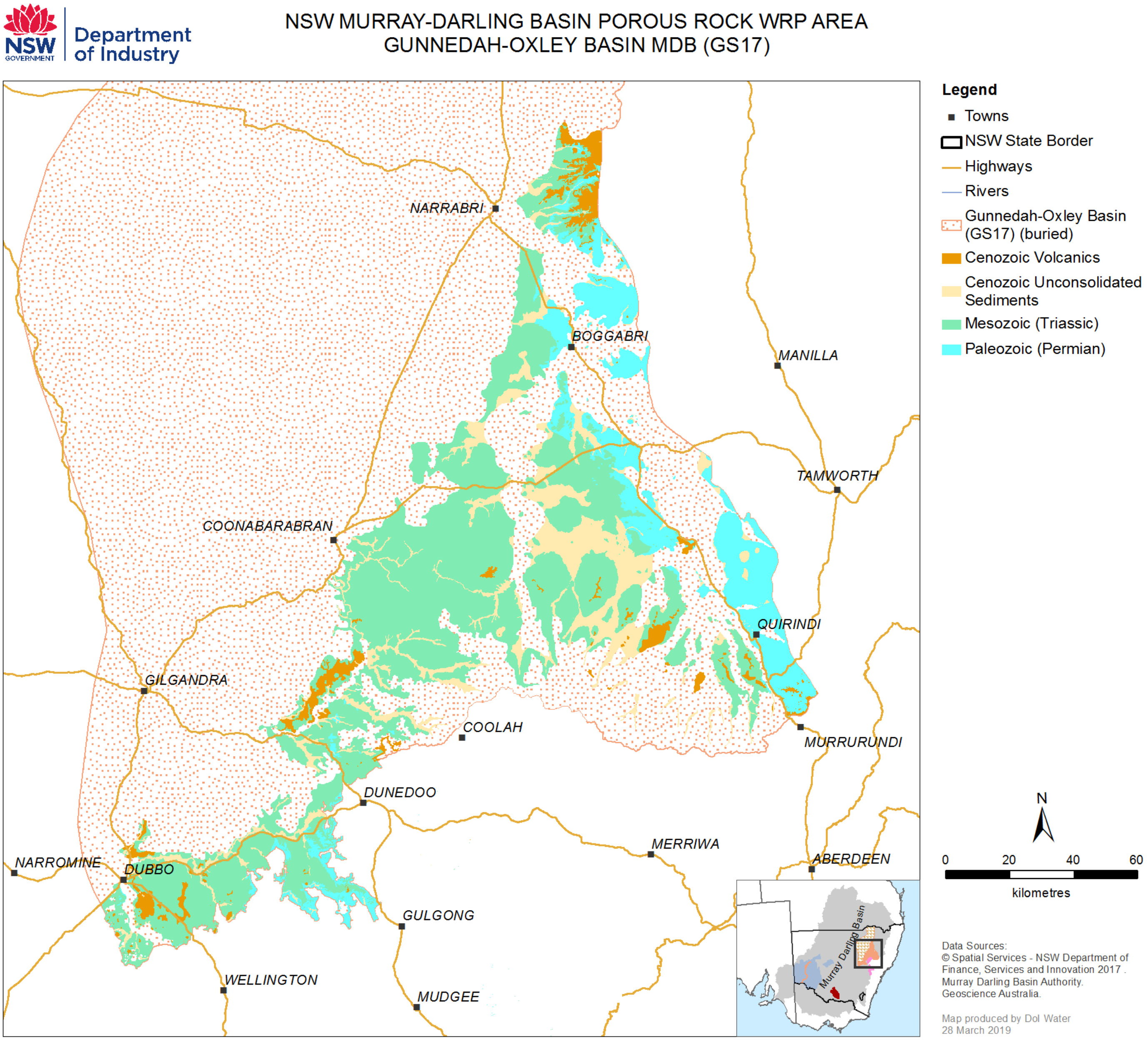


**Figure 14. Geology of the outcropping areas of the Gunnedah-Oxley Basin MDB.**

## 4.2 Sydney Basin MDB

The Sydney Basin is part of the Sydney - Gunnedah - Bowen Basin as outlined above. As such, much of the geology is similar between basins being of Early Permian to Mid Triassic age.

The entire Sydney Basin extends for approximately 350 km north to south and an average of 60km east to west. It occupies an area of approximately 44,000 $km^2$ onshore, centred on the city of Sydney, and an additional 5,000 $km^2$ between the coastline and the outer edge of the continental shelf (Stewart and Alder, 1995). Only the western edge of the Sydney Basin is within the MDB as shown in Figure 15 and represents just 6% of the larger geological basin.

In broad terms the lower part of the sequence is mainly represented by sedimentary strata deposited in a series of marine environments with some volcanic rocks also occurring in different areas. The marine strata are interbedded, especially in north of the basin, with locally-developed coal-bearing sequences of Early Permian age, and those coal measures are in turn overlain by younger additional marine deposits. Extensive coal-bearing sequences of Late Permian age overlie these marine strata, formed in more terrestrial environments and covering the whole of the basin.

Above the Late Permian coal measures is a succession of terrestrial strata typically being the Narrabeen Group of Early Triassic age, although some of the lower beds in the sequence may in fact have been deposited during the latter part of the Permian Period. The Permo-Triassic sedimentary succession is intruded in places by igneous bodies, ranging from Jurassic and Cretaceous to Tertiary in age, and overlain in places by unconsolidated Cenozoic river deposits and coastal sediments.

Jurassic sediments, which are equivalent to the Oxley Basin as described in Section 4.1 in the neighbouring Namoi catchment to the north, overlie the Permo-Triassic sediments in the Coolah area as shown in Figure 15. These are also included in the Sydney Basin SDL resource unit.

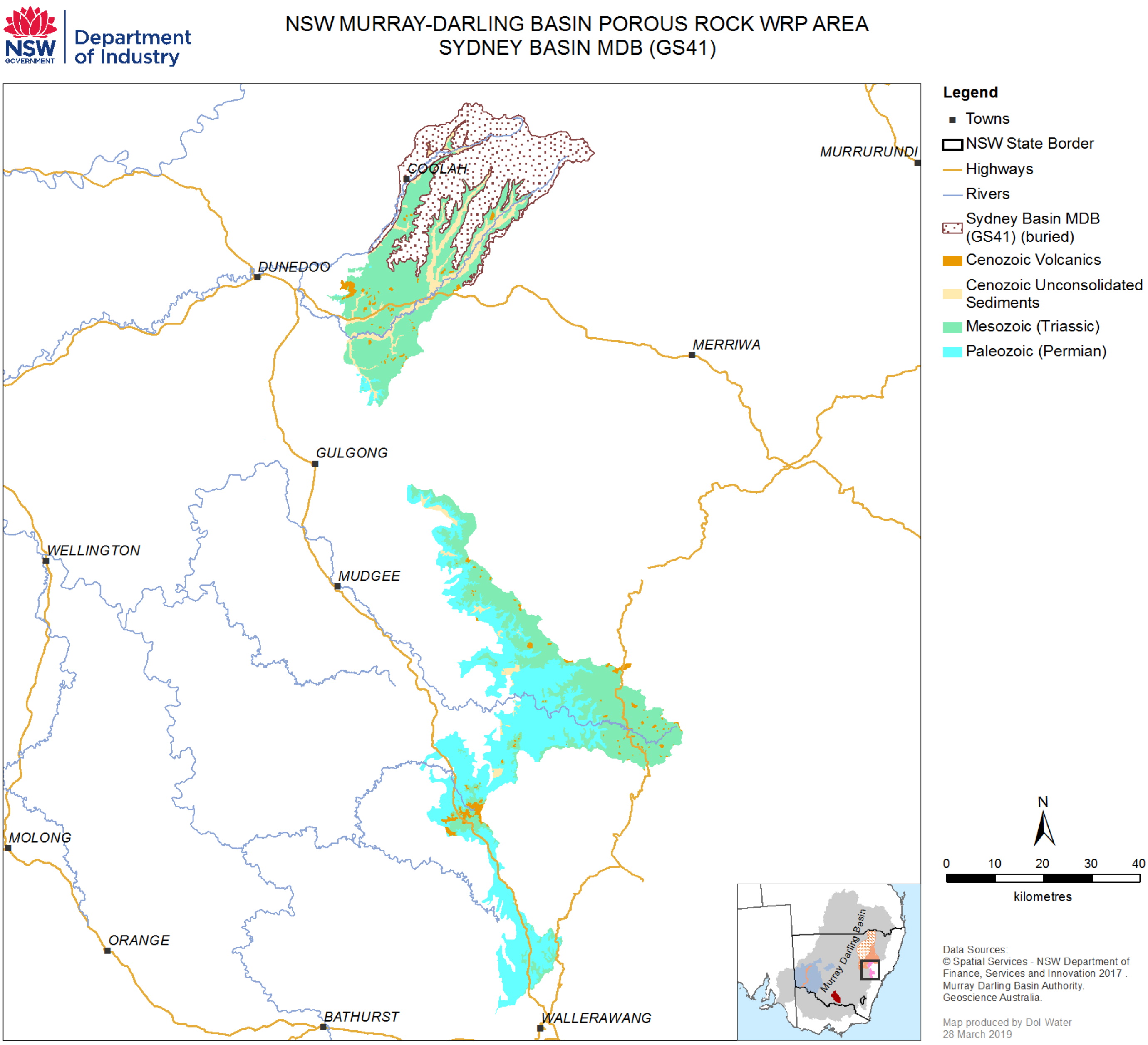


**Figure 15. Geology of the Sydney Basin within the MDB and surrounds.**

## 4.3 Western Porous Rock

The Western Porous Rock lies within the Murray Geologic Basin, a low-lying saucer shaped depression located in the south western part of the MDB. It is a relatively shallow sedimentary basin extending over 300,000 km² of south-eastern Australia. Thicknesses range from less than 200 m in the north and east to about 600 m in the south west near Wentworth. The Murray Geologic Basin is bounded on three sides by older fractured rocks of the Adelaide, Kanmantoo and Lachlan Fold Belts which also form the underlying basement rocks.

The basal sequence of the Murray Geologic Basin in NSW is the Renmark Group, an accumulation of riverine sediments (sands, silts, and clays) deposited in a tropical environment 30 to 50 million years ago.

Overlying the Renmark Group in the west are the limestones of the Murray Group, deposited in a marine environment 12 to 32 million years ago.

Overlying both the Renmark and Murray Groups are deposits of marine quartz sands in the west (Parilla Sand), grading into fluvio – lacustrine and fluvial quartz sand and gravel deposits in the east (Calivil Formation) including silts and clays, deposited between 2 and 6 million years ago.

Uplift along the western margin of the basin led to the damming of the Murry River and the formation of Lake Bungunnia resulting in the deposition of the Blanchetown Clay. To the east and north the Calivil Formation is overlain by finer grained sands, silts and clays of the Shepparton Formation.

Figure 16 shows the area is completely covered by the Cenozoic unconsolidated sediments (NSW DPI Water 2011).

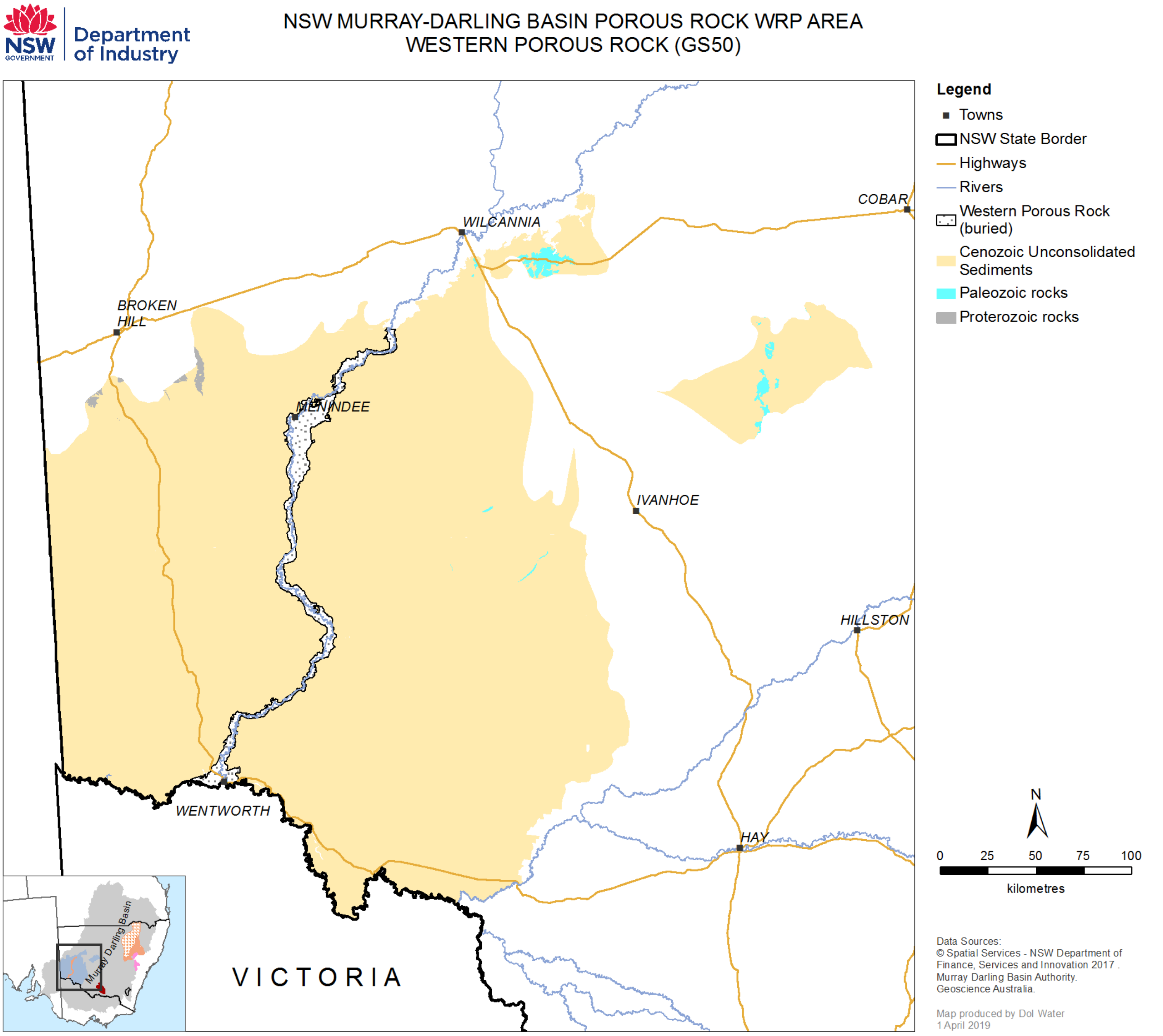


**Figure 16. Geology of the Western Porous Rock and surrounds.**

## 4.4 Oaklands Basin

The Oaklands Basin underlies approximately 3,800km$^2$ in the Riverina District of southern NSW, approximately between the towns of Jerilderie, Coleambally, and Urana. This Permo-Triassic basin trends from north-north west to south-south east and is concealed beneath the south-eastern portion of the Murray Geologic Basin. It is approximately 25 km wide in its mid-southern section and approximately 15 km wide at its northern extent. The Oaklands Basin hosts sediments more than 1,000 m thick and incorporates the Late Carboniferous to Triassic sediments, with most notably a thick Permian Coorabin Coal Measures sequence. The basin was first discovered in 1916 when water drillers discovered coal near Coorabin to the east of Jerilderie. Coal has been the main focus for exploration within the basin since this time (NSW Department of Resources and Energy Miners and Explorers Website).

# 5 Hydrogeology

## 5.1 Regional context

Each porous rock SDL resource unit is part of a sedimentary basin system. Most of these systems are larger than the porous rock SDL units boundaries of this water resource plan and consequently are expected to have hydraulic connections across the WRP border with Queensland, South Australia and Victoria and other groundwater sources outside the Murray Darling Basin in NSW.

For these SDL resource units, the flow of groundwater is largely governed by both primary porosity with water movement around the rock grains, as well as secondary porosity with water movement through fractures made up of a combination of joints, bedding plane separation, faults and cavities within the rock mass. The ability to transmit usable quantities of water depends on the continuous interconnection of these higher permeability features. Groundwater flow is highest where fractures are both continuous, and interconnected. Groundwater flow is also often strongly influenced by the degree of weathering of the rock mass.

Recharge to these systems is primarily through infiltration from rainfall, runoff and surface water within the outcropping areas. However, inflow can also occur from downward percolation of groundwater from overlying permeable strata that coincides with layers of the sedimentary sequences that have sufficient permeability for groundwater exchange to occur.

Large sedimentary basins such as these typically exhibit groundwater flow systems at various scales, ranging from regional (100 km or more in length), intermediate (up to 50 km in length) and local (usually less than 10 km length). Groundwater occurring as deep regional flow from recharge locations to discharge areas commonly increases in salinity (total dissolved solids) along the flow path (Freeze and Cherry, 1979). Along the shorter flow paths changes in salinity may not be as apparent. Each of these flow systems are modified by topography and geology, so that elevated areas of outcropping strata tend to be recharge zones and lower lying locations are commonly discharge sites (provided conduits for the emergence of groundwater exist).

As described in Section 4, the Permo – Triassic sediments of the Gunnedah and Sydney Basin are part of a larger depositional system that extends outside of the Murray Darling Basin to the south east and into Queensland north of the NSW border. Consequently, groundwater flow across these boundaries would occur where sufficient permeability and appropriate hydraulic head conditions prevailed. The low economic potential of this groundwater, due to the low permeability of the strata and high salinity of the groundwater, has resulted in little being known of regional groundwater flow systems between these sedimentary basins however groundwater flows at the intermediate to local scale within them have been studied associated with coal and gas resource exploitation.

The Jurassic sediments identified as the Oxley Basin that overlie the Permo – Triassic sediments of the Gunnedah and Sydney Basin were deposited contemporaneously with the Surat Basin located further west. However removal of the Pilliga Sandstone by erosion, which is the main groundwater target of these sequences, has hydraulically isolated the Oxley Basin from the Surat Basin. Groundwater throughflow in the Pilliga Sandstone outside of the outcropping catchments is expected to occur in response to the prevailing hydraulic heads. Given the magnitude and spatial location of current extraction from the sandstone, induced changes to the natural groundwater flow conditions between the surface water catchments is not anticipated.

The Murray Geological Basin within NSW includes the Lower Lachlan, Lower Murrumbidgee, Lower Murray Alluvium and the Western Porous Rocks SDL resource units. The alluvial SDL units grade into the Western Porous Rocks SDL resource unit on their western boundary and groundwater through flow is uninterrupted across contiguous boundaries between the Western Porous Rock and the other management units of the Murray Geological Basin sediments. The Lower Darling Alluvium (and the southern extent of the Upper Darling Alluvium) overlies and adjoins the sediments of the Murray Geologic Basin. These younger sediments are hydraulically connected to the Western Porous Rocks SDL resource units to varying degrees dependent on the juxtaposition of sediments of sufficient permeability.

## 5.2 Gunnedah-Oxley Basin MDB

The Gunnedah-Oxley Basin SDL resource unit incorporates an outcrop area of 1,128,000 hectares and a buried area of 2,860,000 hectares. The overlying systems include a number of alluvial resource units, the Liverpool Ranges Basalt and the Great Artesian Basin. There is limited information on the degree of connection between the Gunnedah-Oxley Basin MDB and the overlying strata however in areas where the permeable Jurassic Pilliga Sandstone of the Oxley Basin underlie or adjoin the basalt and alluvial systems there is expected to be potential for groundwater exchange to occur dependent on the relative hydraulic heads in that locality. The basal units of the Great Artesian Basin that overlie the Gunnedah-Oxley Basin are typically low permeability shales or volcanics and unlikely to facilitate significant exchange of groundwater.

There has been minimal demand for groundwater from the Gunnedah-Oxley Basin MDB due to the limited yields generally achievable, the exceptions being locations in the irrigation areas around Spring Ridge. Here, the target Jurassic sandstones provide average yields of 5-10L/s of irrigation quality water. Yields of 20- 30L/s are not uncommon however the depth can vary due to the depth of the target formations.

## 5.3 Sydney Basin

Regional groundwater flow within the Sydney Basin is typically to the east away from the MDB and toward the coast. The portion within the MDB represents the western edge of the Sydney Basin.

Due to the high variation in relief and incised nature of the Sydney Basin strata, conceptually local groundwater flow may provide a degree of baseflow to streams and creeks although there is limited information within the MDB catchment. The bore yields from rocks of the Sydney Basin are typically in the order of 1L/s and of variable salinity dependent on the strata being intercepted by the bore.

## 5.4 Western Porous Rock

The Adelaide, Kanmantoo and Lachlan Fold Belt rocks form a variable relief surface beneath the Cenozoic sediments of the Western Porous Rock SDL resource unit. The fold belt basement structures influence the flow of groundwater within the overlying sediments particularly in the western part of the area. It has been described as the major cause of outflow of saline groundwater to the rivers and land surface within the area (NSW DPI 2011).

The two main regional aquifers within the SDL resource unit occur within the Pliocene sands and the Renmark Group sediments.

The Renmark Group sediments are at the base of the sequence and form a major confined aquifer over the entire water source area. Data from departmental monitoring bores indicates the thickness of these Cenozoic sediments to range 90-500 m (NSW DPI 2011). There are no outcrops of this formation as it is overlain by the Calivil Formation in the east and the sediments of the Murray Group in the west. It consists of layers of lignite, peat, carbonaceous clay and medium to coarse grained quartz sand. The thickness of the group is variable and ranges from 10 to 330 m with its maximum in the eastern part of the water source near Balranald. Bore yields are variable and range 0.5-50 L/s and occasionally greater than 50 L/s.

The aquifers within the Pliocene sands consist of the Parilla Sand (unconfined/semi-confined) and the Calivil Formation (semi confined). Within the Western Porous Rock SDL resource unit the Calivil Formation occurs mainly in the eastern parts along the margins of the Murray Geologic Basin. The Parilla Sand interfingers with the Calivil and Shepparton Formations and overlie the Upper Renmark Group in the northern, central and eastern parts of the SDL resource unit area. Towards the west it overlies a low permeability barrier (mainly clay). The thickness of this aquifer is variable and ranges 10-80 m (NSW DPI 2011). Bore yields are highly variable and range 0.5-100 L/s and are commonly greater than 10 L/s.

The recent alluvial deposits form a continuous aquifer along the present Murray River overlying the regional aquifer (Parilla Sand) and are hydraulically connected.

Recent aeolian sand dunes cover almost the entire surface of the SDL.

## 5.5 Oaklands Basin

There is little known with regard to the regional movement of groundwater within this basin. Due to the depth, high salinity and expected low yields, the Oaklands Basin is not a target for groundwater supply and, as such, there is no recorded groundwater extraction from this basin. Recharge is expected to be through vertical seepage from the overlying unconsolidated sediments.

## 5.6 Connection with surface water

Within the Western Porous Rock SDL resource unit area, water tables are generally below surface water systems and these circumstances represent a “losing system” for streams or rivers. That is, water is lost from the surface water flow to the groundwater system. An exception to this generalisation is the lower Murray River prior to reaching the South Australian border which alternates from losing to gaining conditions.

The interaction between the Murray River and the aquifers is complex and dynamic. During periods of high flows fresh river water recharges the shallow alluvial aquifer whereas saline groundwater flows into the river during low flow conditions. Groundwater and surface water level data indicate that the river reach between Euston and the South Australian border alternates from losing to gaining conditions. This depends on river levels, groundwater heads in the alluvial aquifers and the underlying Parilla Sand. Groundwater recharge or discharge to the river is controlled by the presence or absence of aquitards separating the local and regional aquifers, as well as the locations of locks and weirs and the influence of underlying basement structures. Although the Murray River is considered to be hydraulically connected to the recent alluvium confined to the floodplain groundwater pumping impacts from the regional aquifer (Parilla Sand) at the river are subdued or delayed. This lag time of groundwater pumping impacts is acknowledged in setting the extraction limit of the resource and the WPR is managed independently from the river.

The higher elevated areas associated with the Sydney Basin, along with the higher rainfall, and more incised nature of the sediments would facilitate groundwater to discharge as baseflow into creeks along the upper catchments. As such, streamflows may be reliant on groundwater discharge during drought times.

Within much of the Gunnedah-Oxley Basin, with the exception of some of the more elevated fringe areas, it is not considered that groundwater has a direct connection with surface water systems. Typically the surface water systems overlying the Gunnedah-Oxley Basin are considered to be in low hydraulic connection. This lag time of groundwater pumping impacts is acknowledged in setting the extraction limit of the resource and groundwater is managed independently from the river

Being totally buried, groundwater in the Oaklands Basin is not connected to surface water.

# 6 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined as 'ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services' (modified from Richardson et al. 2011).

The department has developed a method for the identification of high probability groundwater dependent vegetation ecosystems (Kuginis et al. 2016) and associated ecological value (Dabovic et al. in draft).

This process has the Western Porous Rock, Gunnedah – Oxley Basin and Sydney Basin SDL resource units supporting significant GDEs of high probability ecological value including wetlands, springs and vegetation ecosystems.

The determined ecological value of vegetation GDEs are shown in Figure 17 and Figure 18.

The Sydney Basin area is dominated by Black Tea Tree-River Oak-Wilga riparian, Red Gum-Yellow Box woodlands, Narrow-Leaved Ironbark-White Cypress Pine-Buloke woodlands, Poplar Box-Yellow Box-Western Grey Box woodlands, River Red Gum woodlands, shallow freshwater wetlands, White Bloodwood-Red Ironbark-Black Cypress Pine woodlands, White Box woodlands, Rough-Barked Apple-Red Gum-Yellow Box woodlands, Western Grey Box-Cyprus Pine woodlands, Yellow Box woodlands, and Fuzzy Box woodlands. These include endangered ecological communities, basin target vegetation species (MDBA 2014) of River Red Gums and DIWA/Ramsar wetlands (associated with Lake Goran). The communities provide vital habitat to nesting species. Generally the GDE communities with high ecological value have large vegetation patches, are highly connected and have a high number of threatened species.

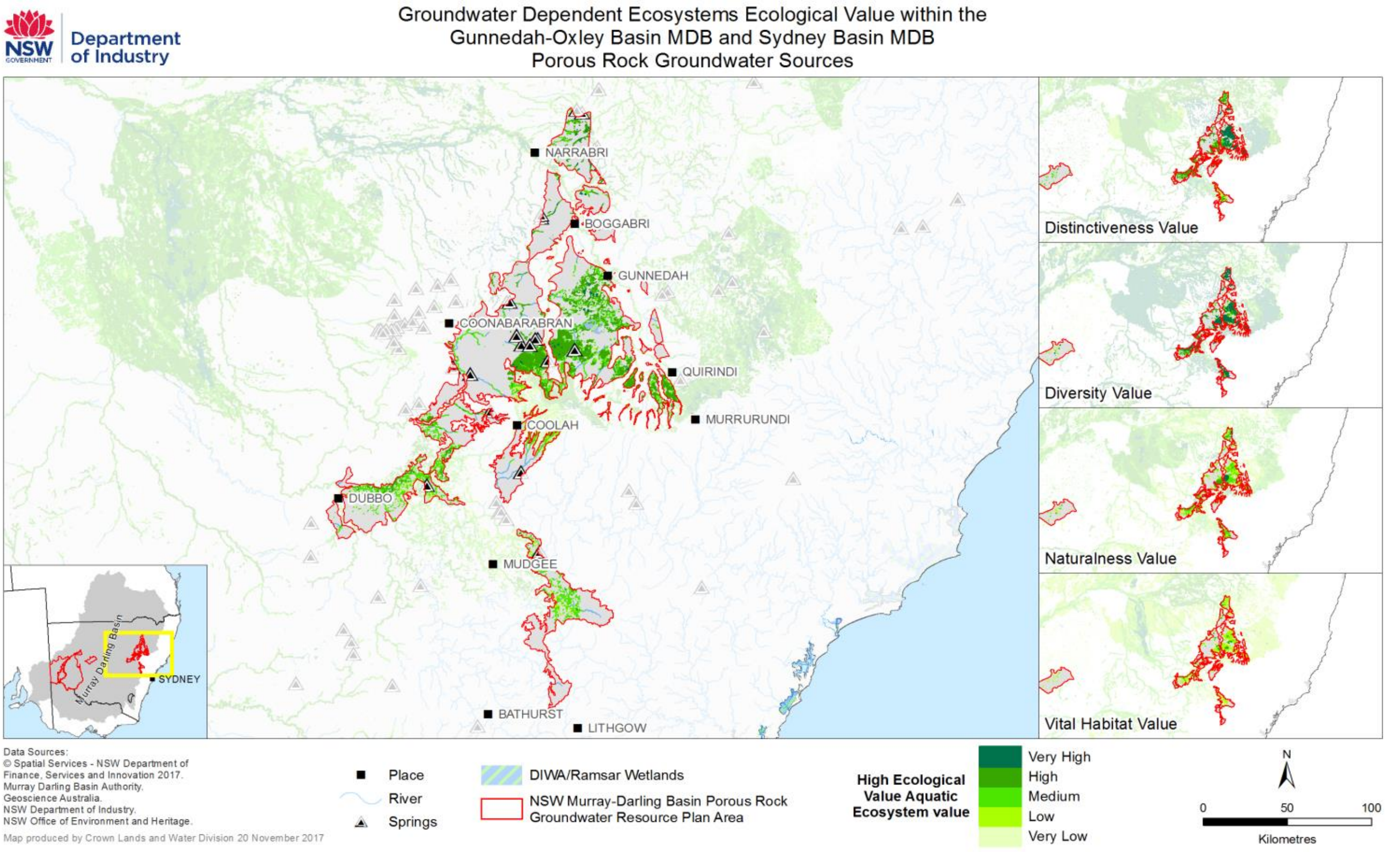


**Figure 17. GDE Ecological value within the Gunnedah – Oxley Basin and Sydney Basin MDB Porous Rock Groundwater Sources.**

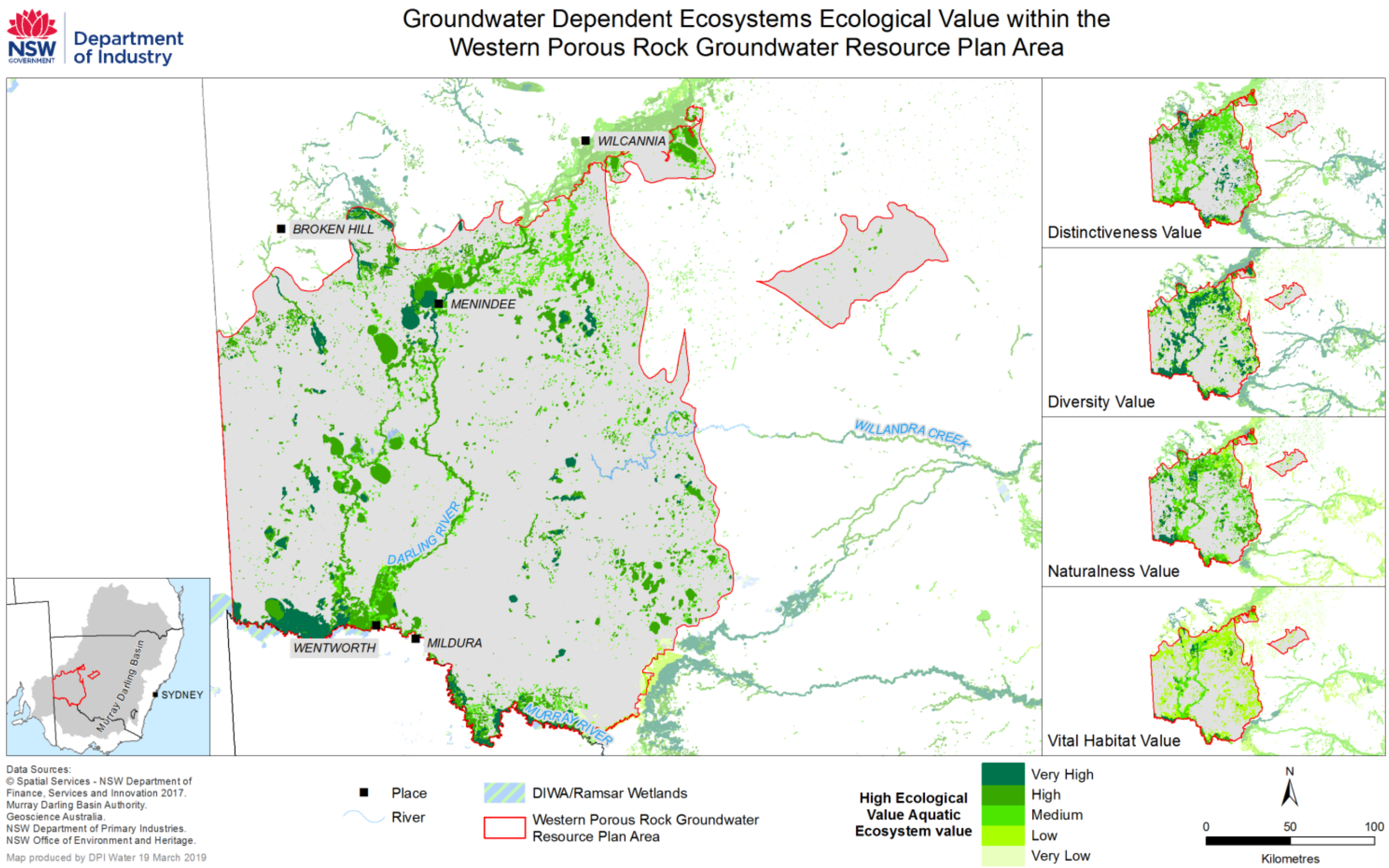


**Figure 18. GDE Ecological value within the Western Murray Porous Rock Groundwater Sources.**

The Western Porous Rock WRP area (Figure 19) is dominated by the vegetation GDE communities of Black Blue Bush shrublands, Black Box-Lignum wetlands, Black Box woodland wetlands, Canegrass swamps, Lignum shrubland wetlands, Nitre Goosefoot shrubland wetlands, permanent and semi-permanent wetlands, River Red Gum-Lignum woodland wetlands and River Red Gum woodland wetlands. These include endangered ecological communities, DIWA/Ramsar wetlands (associated with Menindee Lakes), extensive connected riparian corridors and basin target vegetation species (MDBA 2014) of River Red Gums. The riparian communities provide vital habitat to nesting species and contributes to ecosystem function of instream ecosystems. Generally the GDE communities with high ecological value have large vegetation patches, are highly connected (along riparian corridors) and have a moderate number of threatened species present especially in the wetland areas.

Being completely buried, the Oakland Basin has no identified groundwater dependent ecosystems.

# 7 Groundwater Quality

Water quality describes the condition of water within a water source and its related suitability for different purposes. The water quality characteristics of a groundwater system influence how that water is used by humans (e.g. for town water or stock and domestic supply, or for commercial purposes such as farming and irrigation). If water quality is not maintained, it can impact on the environment as well as the commercial and recreational value of a groundwater resource.

One measure of quality most relevant to the end use is the level of salt present in groundwater, or groundwater salinity. This is determined by measuring electrical conductivity (EC) and is generally reported in microsiemens per centimetre (µS/cm).

In NSW, groundwater salinity levels can range from that of rainwater (<250 µS/cm) to greater than that of sea water (~60,000 µS/cm). Groundwater with salinity suitable for a range of productive uses is generally found in the large unconsolidated alluvial systems associated with the major westward draining rivers.

Groundwater suitability can be changed by contaminants infiltrating into the groundwater system. This can be from spills or leaks onto the land surface but it can also occur more broadly from the overlying land use. Seasonal variations and longer-term changes in climate as well as groundwater extraction can all affect groundwater quality.

Specific water quality information for the WRP areas is limited but indications are that it is extremely variable depending on location.

In the Western Porous Rock SDL resource unit, groundwater quality ranges from fresh, supplying domestic users, through to highly saline (the target of the salt interception schemes, i.e. greater than 50,000 µS/cm). Typically, the high salinity of the groundwater within this SDL resource unit makes is unsuitable for drinking.

In the Gunnedah-Oxley Basin and the Sydney Basin the ambient salinity levels are generally unsuitable for potable or irrigation supplies, but may be suitable for stock supply. The exception is the low salinity groundwater within the Jurassic sandstone in the Spring Ridge area of the Gunnedah-Oxley Basin that supports irrigated agriculture and also the Coolah area of the Sydney Basin although high yields have not been obtained sufficient for irrigation supplies.

There is no information on water quality within the Oaklands Basin SDL resource unit area.

# 8 Groundwater Management

Groundwater in these resource units are currently managed under the Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011. The Gunnedah-Oxley Basin MDB, Sydney Basin MDB, Western Murray Porous Rock and Oaklands Basin groundwater sources in this water sharing plan correlate directly with the four SDL resource units in the WRP.

Table 1 summarises the spatial relationship of the numerous contiguous SDL resource units and non Murray-Darling Basin resources to the porous rock SDL resource units.

**Table 1: Relationship of contiguous SDL resource units with the porous rock resource units.**

| Porous SDL resource unit | spatial relationship | contiguous SDL resource unit |
|---|---|---|
| Gunnedah-Oxley Basin MDB | Overlies and adjacent to | Lachlan Fold Belt and New England Fold Belt |
| | Underlies and adjacent to | Liverpool Ranges Basalt, Upper Namoi Alluvium |
| | Underlies and adjacent to | Great Artesian Basin (non Basin resource) |
| | adjacent to | Sydney Basin |
| | adjacent to | Sydney Basin (non Basin resource in coastal NSW) |
| Sydney Basin MDB | Overlies and adjacent to | Lachlan Fold Belt |
| | Underlies and adjacent to | Liverpool Ranges Basalt ,Talbragar and Upper Macquarie Alluviums |
| | Adjacent to | Gunnedah-Oxley Basin MDB |
| | Adjacent to | Sydney Basin (non Basin resource in coastal NSW) |
| Western Porous Rock | Adjacent to | Lower Lachlan, Lower Murrumbidgee Deep, Lower Murrumbidgee Shallow, Lower Murray Deep and Lower Murray Shallow Alluviums |
| | Overlies and adjacent to | Adelaide Fold Belt, Kanmantoo Fold Belt and Lachlan Fold Belt |

| Porous SDL resource unit | spatial relationship | contiguous SDL resource unit |
|---|---|---|
| | Underlies and adjacent to | Upper Darling and Lower Darling Alluvium |
| Oaklands Basin | Overlies | Lachlan Fold Belt |
| | Underlies | Lower Murrumbidgee and Lower Murray Alluviums |

The fractured rocks of the regional fold belts have very different hydrogeological characteristics to the overlying porous rock SDL resource units and are not hydraulically connected. Overlying fractured basalts are expected to have sufficient permeability to allow groundwater drainage from them into any underlying permeable units of the porous rock sequences, such as sandstone. There is no information on the level of hydraulic connection with the basalt and any underlying permeable sandstone layers. In estimating the SDL of these respective units this contribution to the water balance was not considered so that there is no reliance on these volumes to ensure sustainability of the respective groundwater resources.

With the exception of the Western Porous Rock SDL resource unit, the permeability of the alluvial resource units is many times greater than the underlying porous rock systems and consequently in a resource management sense they are not linked.

In contrast, the sediments of the Lower Lachlan, Lower Murrumbidgee and Murray alluvium grade into the Western Porous Rocks SDL resource unit on their western boundaries resulting in a hydraulic connection across their contiguous boundaries with the Western Porous Rock. Whilst there is hydraulic connection across these boundaries they are independently managed as there is minimal pumping in these areas due to the high salinity of the groundwater. Consequently the hydraulic relationship of the aquifer systems in these areas is essentially unchanged from natural conditions.

The Lower Darling Alluvium (and the southern extent of the Upper Darling Alluvium) overlie the Western Porous Rock SDL resource unit and may be hydraulically connected were permeability is sufficient for groundwater exchange.  However, for management purposes these overlying shallow systems are managed separately as local systems overlying the much larger regional groundwater flows of the Western Porous Rock SDL resource unit.

The Oaklands Basin underlies in part the Lower Murray and Murrumbidgee alluvium. With respect to management of the resource, the groundwater contained within the Oaklands Basin is managed separately as an isolated buried resource.

In the following sections, data is not available for presentation on all groundwater sources.  There are no groundwater supply bores in the Oaklands Basin, and extraction from groundwater supply bores in the Sydney Basin is not metered (NSW DPI Water, 2017).

## 8.1 Access rights

Groundwater access licenses for the four groundwater sources are shown in Table 2.

The local water utility access licences are held by local government for town water supply purposes and the share component is for a specified volume of groundwater. The share components of aquifer access licences are issued for a specified number of unit shares Table 2.

**Table 2. Access licence share components in the NSW Murray Darling Basin Porous Rock Water Resource Plan area (at February 2019).**

| Access Licence Category | Gunnedah-Oxley Basin MDB | Sydney Basin | Western Porous Rock | Oaklands Basin |
|---|---|---|---|---|
| Local Water Utility (ML/yr) | 480 | 0 | 390 | 0 |
| Aquifer (unit shares) | 23,109 | 5,443 | 21,529 | 0 |
| Salinity and Watertable Management (ML/yr) | 0 | 0 | 13,985 | 0 |

## 8.2 Extraction limits

Extraction in a groundwater source is managed to the long term average annual extraction limit (LTAAEL) set by a water sharing plan.

Water resource plans will set limits, in the same way as water sharing plans, on the quantities of water that can be taken from MDB water resources. These limits are known as sustainable diversion limits (SDLs). Under the water resource plans, NSW will manage extraction to ensure compliance with the SDLs.

Table 3 lists the LTAAEL and the SDL for each area. The estimated requirements for basic landholder rights are included in both the LTAAEL and the SDL.

**Table 3. LTAAEL for the groundwater sources covered by the NSW Murray Darling Basin Porous Rock Water Resource Plan compared to the SDL.**

| Water Source | LTAAEL ML/yr (WSP 2012) | SDL ML/yr |
|---|---|---|
| Gunnedah-Oxley Basin MDB | 205,640 | 127,500 |
| Sydney Basin MDB | 60,443 | 19,100 |
| Western Murray Porous Rock | 530,486 | 226,000 |
| Oaklands Basin | 0 | 2,500 |

To manage any growth in extraction in excess of the LTAAEL, water sharing plans set a trigger for complying with the extraction limit.

Table 4 presents the average annual extraction since commencement of the water sharing plan for each water source where metered extraction has been collected. It also shows the LTAAEL and the trigger set by the water sharing plan to initiate a management response to ensure there is no growth in extraction above the LTAAEL in the long-term.

**Table 4. Average measured extraction under access licence in the resource units of the WRP area.**

| SDL Resource Unit | Groundwater Source | SDL volume (ML/yr) | Access Licence volume (unit shares) | Average annual Usage (ML/yr) |
|---|---|---|---|---|
| Gunnedah-Oxley Basin MDB | Gunnedah-Oxley Basin MDB | 127,500 | 23,104 | 5,106 |
| Sydney Basin | Sydney Basin MDB | 19,100 | 3,228 | Not monitored |
| Western Porous Rock | Western Murray Porous Rock | 226,000 | 21,529 | 4,988 |
| Oaklands Basin | Oaklands Basin | 2,500 | 0 | Not monitored |
| Total | | 372,100 | 47,861 | 10,094 |

The risk of over extraction in each water source exceeding the LTAAEL is low as there is very little groundwater development.

## 8.3 Available water determinations

An available water determination is made at the start of each water year which sets the allocation of groundwater for the different categories of access licence. Since the commencement of the water sharing plans available water determinations have been 100 per cent for all water sources, i.e. 1ML per share.

## 8.4 Groundwater accounts

Under a water sharing plan a water allocation account is established for each water access licence. Water is credited to the account when an available water determination is made or water is traded in, and debited from the account when water is physically taken or traded out.

The water sharing plan allows for the accrual of unused allocation in aquifer access licence accounts. This includes the yearly allocations for the aquifer access licences made through available water determinations plus any carryover of unused allocation up to a maximum of 0.25 ML per unit of share component.

The maximum amount of water that can be debited from an account in any one water year (i.e. account take limit) in these groundwater sources cannot exceed 1.25ML per unit share component plus any allocation transferred in, minus any allocation transferred out. The water sharing plan also permits allocations to be re-credited under water return flow rules should they be established in the future.

Local water utility, domestic and stock and salinity and water table management access licences do not have any provisions for carryover.

## 8.5 Groundwater take

Groundwater is taken and used in the WRP area for productive purposes such as irrigation and industry as well as for water supply for local water utilities and stock and domestic use. Figure 19. Registered bores in the Western Porous Rock SDL area. Figure 20 and Figure 21 show the distribution of water supply bores across the SDL resource units.

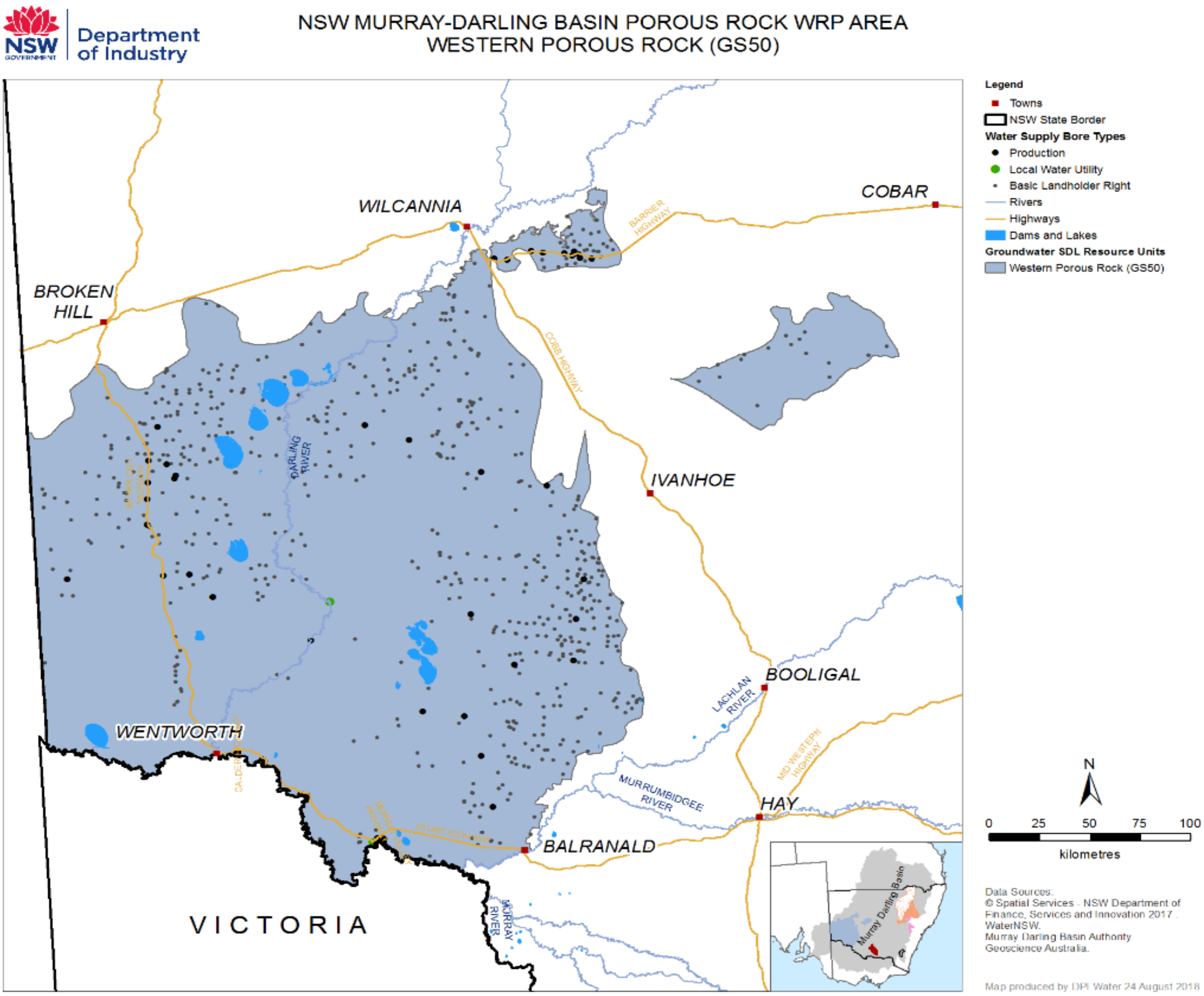


**Figure 19. Registered bores in the Western Porous Rock SDL area.**

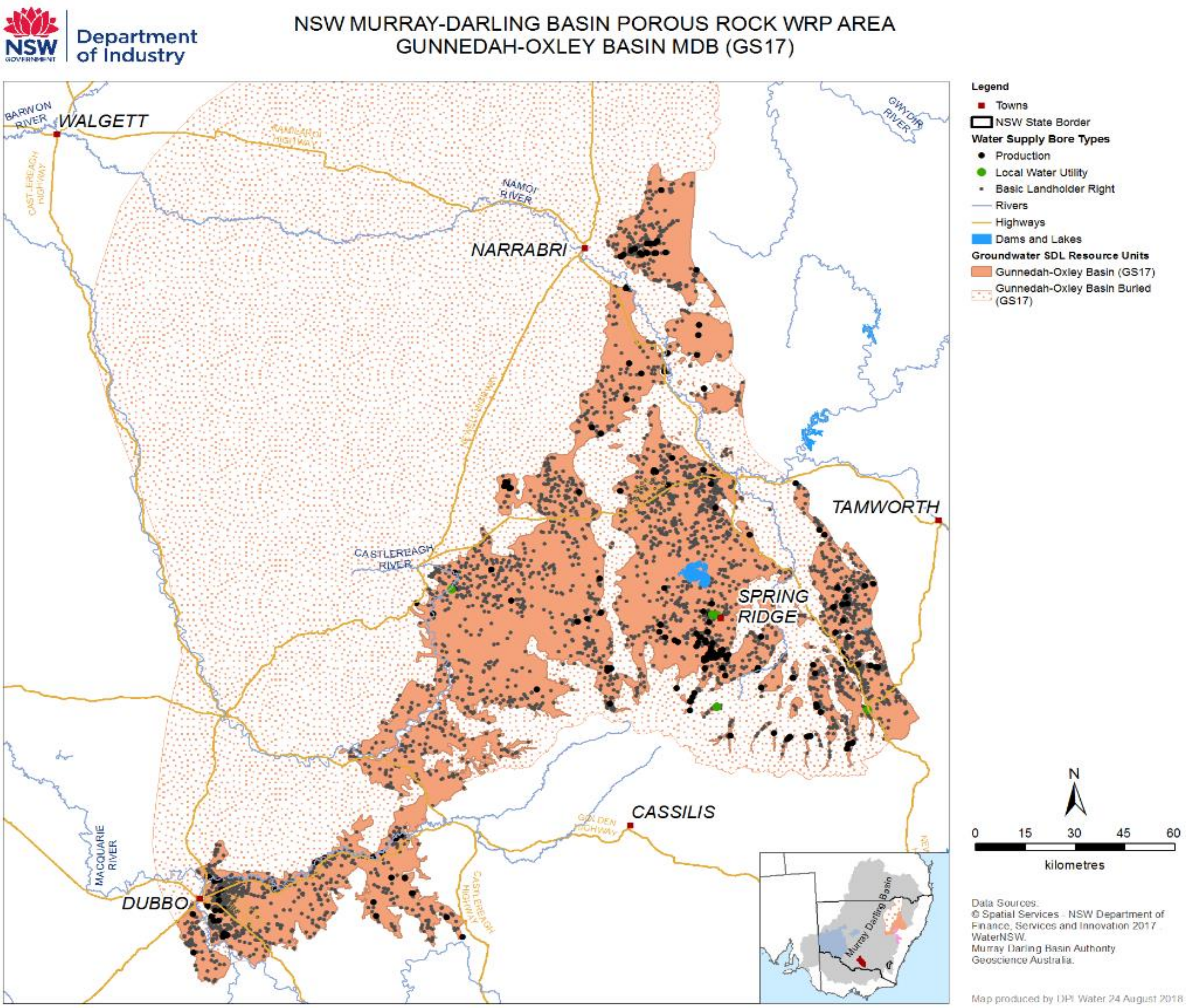


**Figure 20. Registered bores in the Gunnedah Oxley Basin MDB SDL area.**

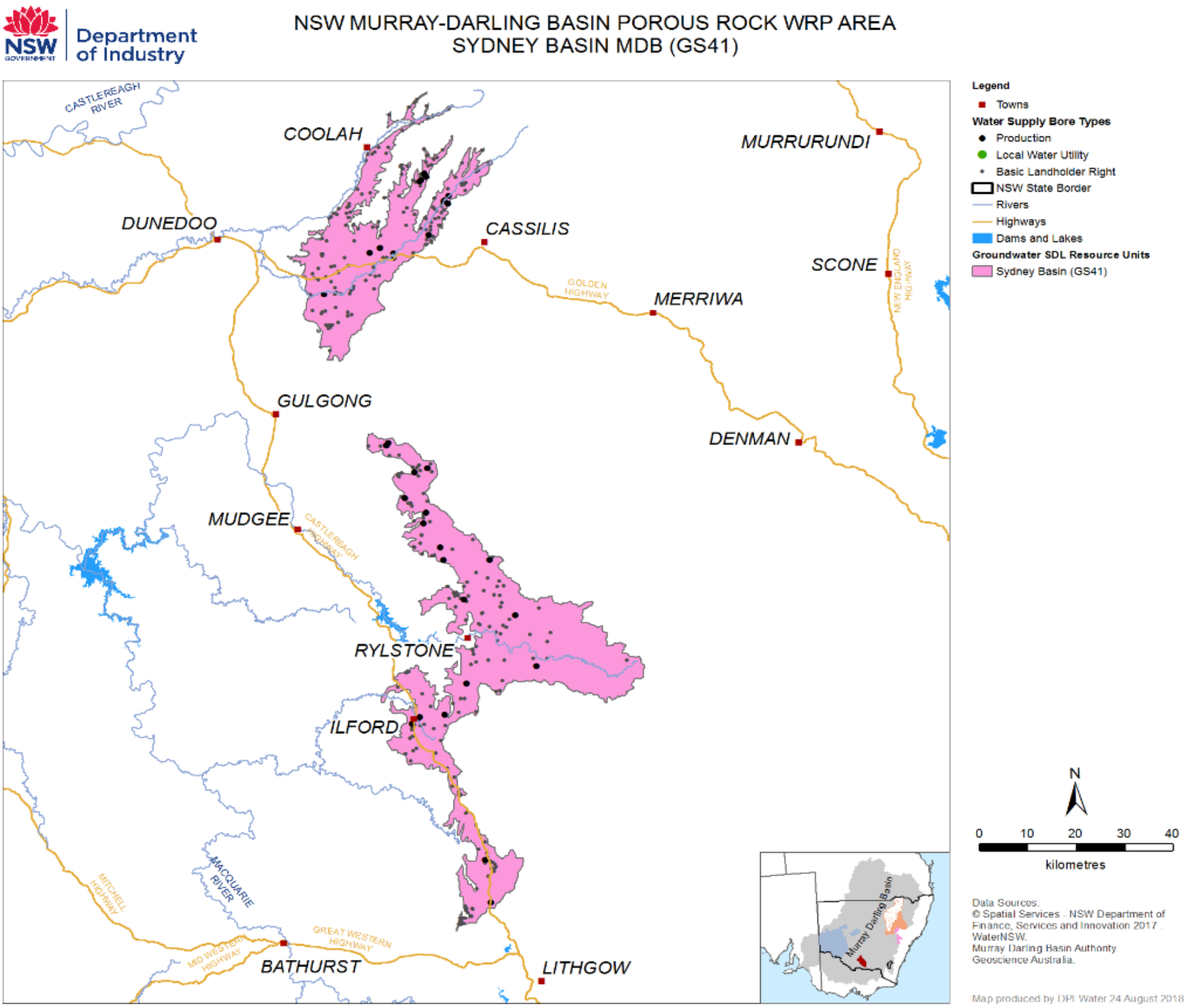


**Figure 21. Registered bores in the Sydney Basin MDB SDL area.**

Groundwater use is influenced by climate and access to surface water. Reliance on groundwater increases in drier years and when there is low rainfall and reduced access to surface water.

There are approximately 5,600 registered bores in these SDL units (Table 5) with the majority being used for stock and domestic purposes. There is also moderate reliance on groundwater for irrigation with approximately four hundred production bores, the majority located within the Gunnedah – Oxley Basin MDB.

Groundwater extraction volumes from individual bores are typically less than 20 ML/yr, however larger volumes have been obtained from some sandstone units within the Gunnedah – Oxley Basin MDB.

Groundwater take in the Western Porous Rock and Gunnedah – Oxley Basin MDB SDL resource units is metered as it is primarily used for stock and domestic supplies, as well as incidental dewatering for mining. There is no metering of groundwater take in the Sydney Basin SDL resource unit.

**Table 5. Water supply bores in the WRP area.**

| SDL Resource Unit | Stock and Domestic (No.) | Production bores (No.) | Local Water Utility | Total |
|---|---|---|---|---|
| Gunnedah-Oxley Basin MDB | 4100 | 283 | 5 | 4,388 |
| Sydney Basin MDB | 359 | 41 | 0 | 400 |
| Western Porous Rock | 759 | 54 | 3 | 816 |
| Oaklands Basin | 0 | 0 | 0 | 0 |
| Total | 5218 | 378 | 8 | 5,604 |

## 8.6 Groundwater dealings

Under the Water Management Act 2000, dealings are permitted in access licences, shares, account water and the nomination of supply works.

Restrictions apply to the trade of allocation or entitlements into the Gunnedah-Oxley Basin MDB (Spring Ridge) Management Zone from other areas of the Gunnedah-Oxley Basin MDB. This reflects the embargo of new applications that was introduced prior to the commencement of the water sharing plan. This restriction limits the growth of groundwater extraction from the high yielding sandstone in this area. Trade of allocation and entitlement is permitted within and out from this management zone but not into it. Specifically the restrictions that apply are given below.

- Dealings under 71Q, 71S and 71W of the Act from an access licence within the Gunnedah-Oxley Basin MDB (Other) Management Zone to an access licence in Gunnedah-Oxley Basin MDB (Spring Ridge) Management Zone is prohibited if the dealing results in the sum of share components exceeding the sum of share components at the commencement of the Plan .
- Dealings within a groundwater source under section 71T of the Act from an access licence in Gunnedah-Oxley Basin MDB (Other) Management Zone to an access licence in Gunnedah-Oxley Basin MDB (Spring Ridge) Management Zone is prohibited if the sum of water allocations credited to the water allocation accounts of all access licences in the Gunnedah–Oxley Basin MDB (Spring Ridge) Management Zone from available water determinations and through temporary trading in that water year exceed the sum of share components of all access licences at the commencement of the Plan.

### 8.6.1 Temporary

The most common type of dealings between groundwater licences are allocation assignments (temporary trades) made under section 71T of the Water Management Act 2000. The volume of temporary trades within the WRP area is shown in Table 6

**Table 6. The number and volume traded under 71T dealings in the WRP area.**

| SDL Resource Unit | 2012-2013 | | 2013-2014 | | 2014-2015 | | 2015-2016 | | 2016-2017 | | 2017-2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | ML | No. | ML | No. | ML | No. | ML | No. | ML | No. | ML |
| Gunnedah-Oxley Basin MDB | 1 | 187.5 | 4 | 721 | 5 | 1,059.5 | 3 | 1,062 | 6 | 1,511.5 | 6 | 1196 |
| Sydney Basin MDB | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | |
| Western Porous Rock | 1 | 200 | 2 | 1,160 | 1 | 900 | 2 | 300 | 2 | 2,500 | 2 | 2500 |
| Oaklands Basin | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | |
| Total | 2 | 387.5 | 6 | 1,881 | 6 | 1,959.5 | 5 | 1,362 | 8 | 4,011.5 | 8 | 3696 |

### 8.6.2 Permanent

Other dealings for groundwater licences are made under sections 71M (licence transfer), 71N (term licence transfer), 71P (subdivision/consolidation) and 71Q (assignment of shares) and 71W (nomination of works) of the Water Management Act 2000.

Dealings that can result in a change in the potential volume that can be extracted from a location and therefore have the potential to cause third party impacts are subject to a hydrogeological assessment and may be approved subject to conditions being placed on the nominated work or combined approvals (such as bore extraction limits) to minimise potential impact on neighbouring bores.

There have only been dealings that result in a change in the potential volume that can be extracted from a location in the Gunnedah – Oxley Basin MDB since commencement of the water sharing plan.

Table 7 shows the statistics for these dealings. 71M dealings are not included as these are a change in ownership only and therefore have no potential for additional third party impacts. The other SDL resource units have had no dealings recorded.

**Table 7. The number of dealings and shares traded as 71Q dealings in the Gunnedah – Oxley Basin.**

| SDL Resource Unit | 2012-2013 Yr | 2013-2014 Yr | 2014-2015 Yr | 2015-2016 Yr | 2016-2017 Yr | 2017-2018 Yr |
|---|---|---|---|---|---|---|
| Gunnedah-Oxley Basin MDB | 0 trades | 1 trade (150 shares) | 1 trade (206 shares) | 1 trade (300 shares) | 2 trades (105 shares) | 0 trades |

# 9 Groundwater Monitoring

Water NSW monitors groundwater level, pressure and quality through its network of groundwater observation bores across the state. The groundwater monitoring network plays an important role in:

- assessing groundwater conditions;
- managing groundwater, including groundwater access and extraction; and
- providing data for the development of groundwater sharing plans.

Figure 22 shows a generalised conceptualisation of a layered groundwater system illustrating how the water level height in bores in an area can vary depending on the depth of the screened interval of the bore.

Groundwater systems typically include a number of aquifers which may be confined or unconfined. An unconfined aquifer is an aquifer whose upper water surface (water table) is at atmospheric pressure.

A confined aquifer is completely saturated with water and is overlain by impermeable material (aquitard) causing the water to be under pressure. If the hydraulic head of groundwater is plotted and contoured on a map this is referred to as the potentiometric surface.

Figure 22 also illustrates the difference between stock and domestic, production and monitoring bores. Stock and domestic bores are often constructed into the shallowest aquifer and have a relatively small diameter and limited extraction capacity. Because they are typically shallow they can be more susceptible to climatic fluctuations in water levels and influence from surrounding pumping.

Production bores are generally much larger diameter and have significantly larger extraction capacity. They are usually constructed into the most productive part of a groundwater system and can be screened in multiple aquifers.

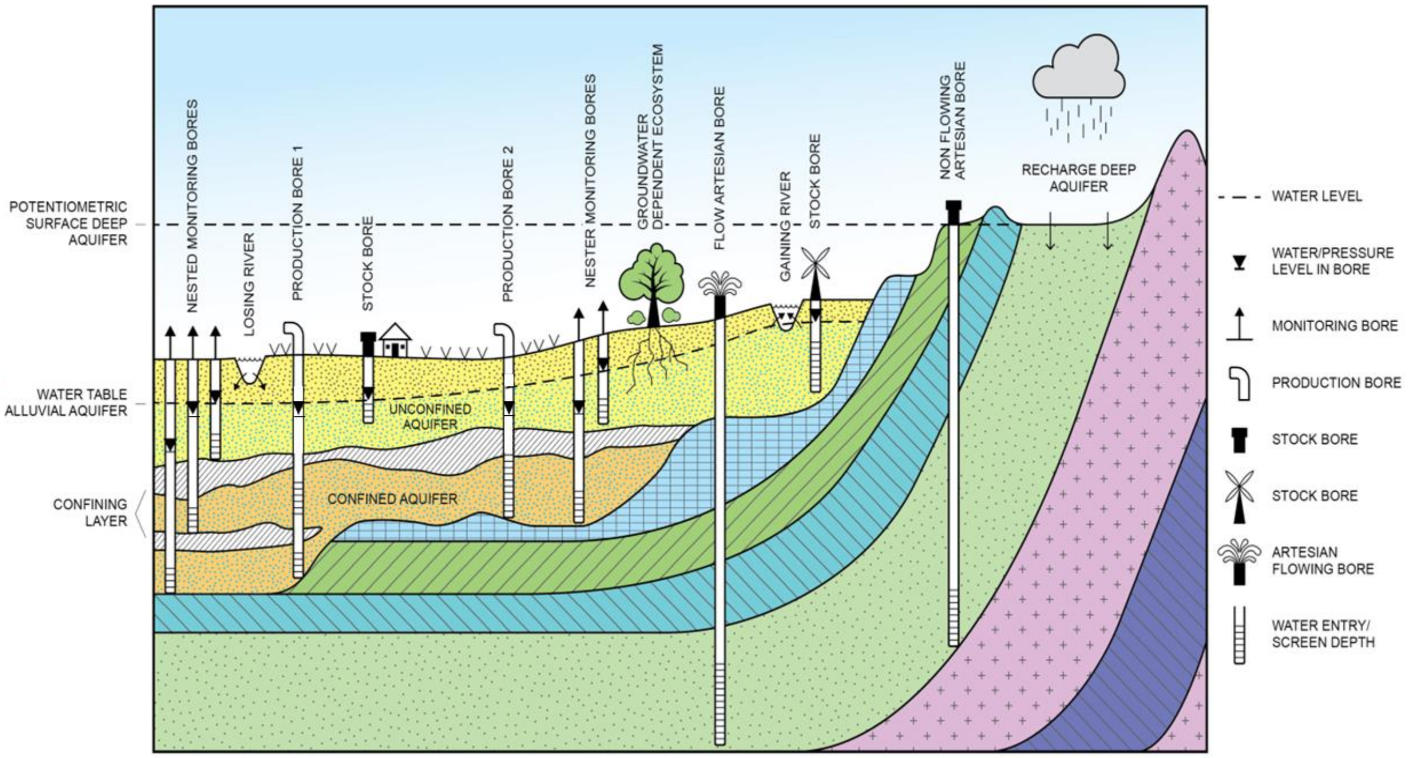


**Figure 22. Schematic diagram of different types of aquifers.**

Monitoring bores are designed to monitor a specific aquifer for water levels and water quality and are generally relatively small diameter. At some monitoring bore locations there are multiple monitoring bores which are screened at different depths to observe the hydraulic relationship between different aquifers.

Figure 22 illustrates how the water level in some of the monitoring bores can be at different levels to nearby production and stock bores because the monitoring bores are screened at a single depth and the water level represents the water table or hydraulic head at that depth. However the water level in a multiple screened production bore is a composite water level influenced by the hydraulic head in all screened aquifers.

Groundwater level and pressure data collected from monitoring bores can be plotted and analysed at a water source scale to assess long- and short-term changes in the system. This data is used to identify areas where there may be a potential management issue.

There are 866 NSW government monitoring bores across the WRP area, with many of these bores being in a nested configuration, i.e. measuring 1, 2, or 3 different depths at each site. Within the WRP area there are no monitoring bores in the Oaklands Basin and the Sydney Basin, 74 in the Gunnedah-Oxley Basin, and the remaining 792 in the Western Porous Rock.  Groundwater monitoring bore locations are shown in Figure 23.

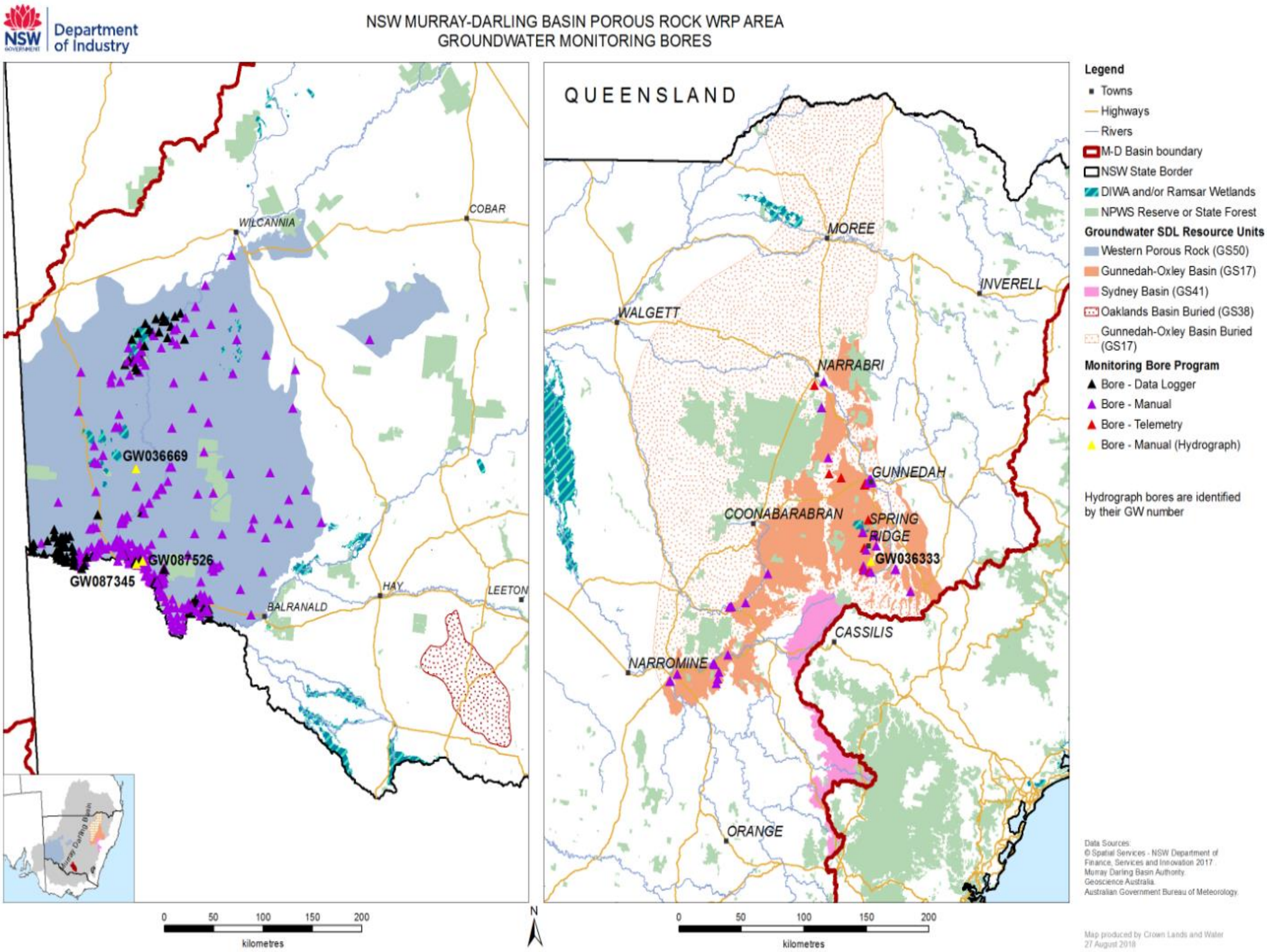


Figure 23. Groundwater monitoring bores within the Water Resource Plan area.

# 10 Groundwater Behaviour

## 10.1 Introduction

A hydrograph is a plot of groundwater level or pressure from a monitoring bore over time (Figure 24). Hydrographs can be used to interpret influences on groundwater such as rainfall, floods, drought and climate change, as well as interpret aquifer response to groundwater extraction.

Figure 24 illustrates the trends that can be observed in groundwater hydrographs. Both short- and longer-term water level trends can be identified. In unconfined and semi-confined aquifers, groundwater can be in hydraulic connection with surface waters. Where this occurs, groundwater levels rise in response to recharge such as rainfall or flooding and decline during periods of reduced rainfall.

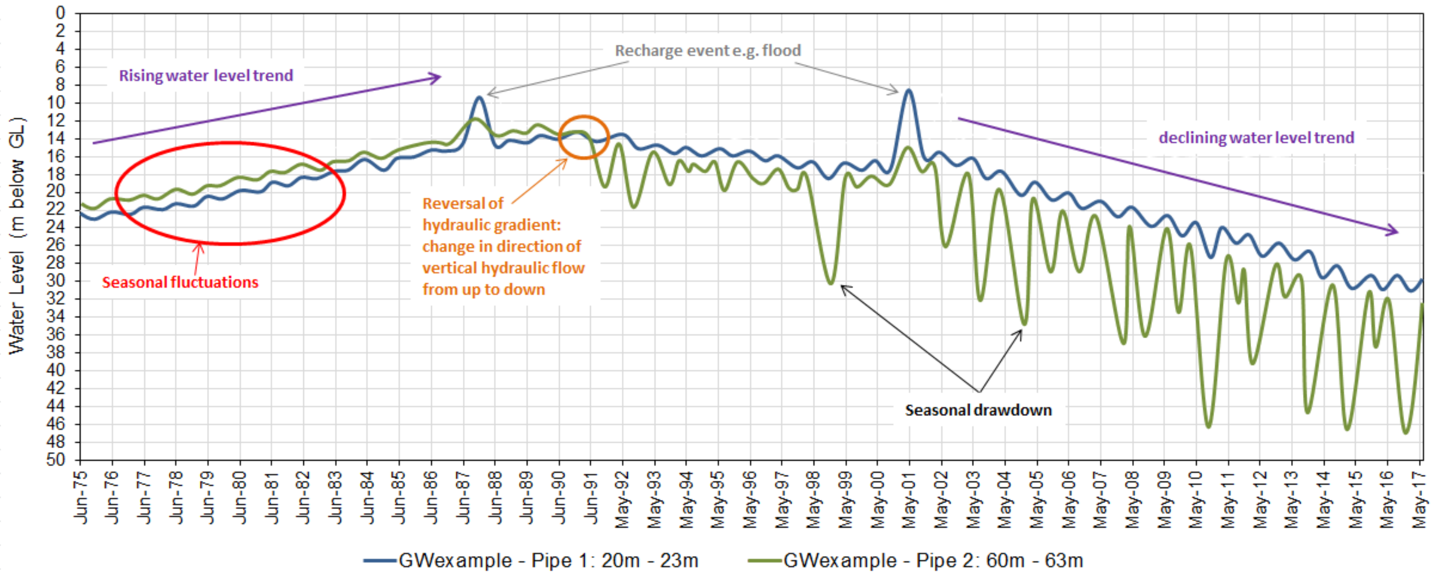


**Figure 24. Example of a groundwater hydrograph identifying trends in groundwater responses to pumping and climate.**

Significant recharge events such as floods can be identified in hydrographs as peaks in the groundwater level record while droughts tend to result in a slow gradual decline in groundwater levels.

In areas where groundwater extraction occurs, hydrographs show a seasonal cyclic pattern of drawdown and recovery. Drawdown is the maximum level to which groundwater is lowered in a bore due to pumping. It is followed by recovery when pumping has ceased or reduced.

Review of the recovered groundwater level over time can be used to assess how a groundwater system is responding to climate and pumping impacts in the long-term. The recovered groundwater level is the highest point to which groundwater has risen in a particular year.

Drawdown can be used to assess more short-term seasonal impacts in a groundwater system. In areas where drawdown occurs, groundwater recovery may not return to the level of the previous year before pumping resumes resulting in a long-term reduction in the recovered groundwater levels.

## 10.2 Review of groundwater levels

Representative hydrographs for the Gunnedah-Oxley Basin MDB and the Western Porous Rock SDL resource units are presented below. The vertical scale of these plots are varied to illustrate the range of water level change at each of these sites.

### 10.2.1 Gunnedah-Oxley Basin MDB

Groundwater level data from the Gunnedah- Oxley Basin MDB typically shows water level responses correlate to climatic variations. That is, rising water levels occur as a result of wetter periods and falling water levels occur as a result of drier periods. Groundwater pumping has negligible impact other than within close proximity of the pumping bores.

The hydrograph depicted in Figure 25 shows groundwater level changes in monitoring bore GW036333 over 28 years. It is located south of Gunnedah in the Spring Ridge area as shown in Figure 23 This monitoring bore has three pipes screened at different depths, in the surficial alluvium (Pipe 1) and underlying Cretaceous/Jurassic sandstones (Pipes 2 and 3) are monitored.

The data shows that the observed groundwater levels become deeper with increasing depth of the monitored interval. This indicates there is a downward potential for water movement, which in turn indicates a possibility for the deeper system to be receiving groundwater recharge in this area.

Also plotted is the cumulative deviation from average rainfall. The plot demonstrates that groundwater level changes are closely related to rainfall variations. A rising trend in the cumulative deviation plot corresponds to a period of above average rainfall and a falling trend corresponds to periods of below average rainfall. This effect carries through to the deeper strata (although slightly subdued) confirming the recharge processes are occurring in this area.

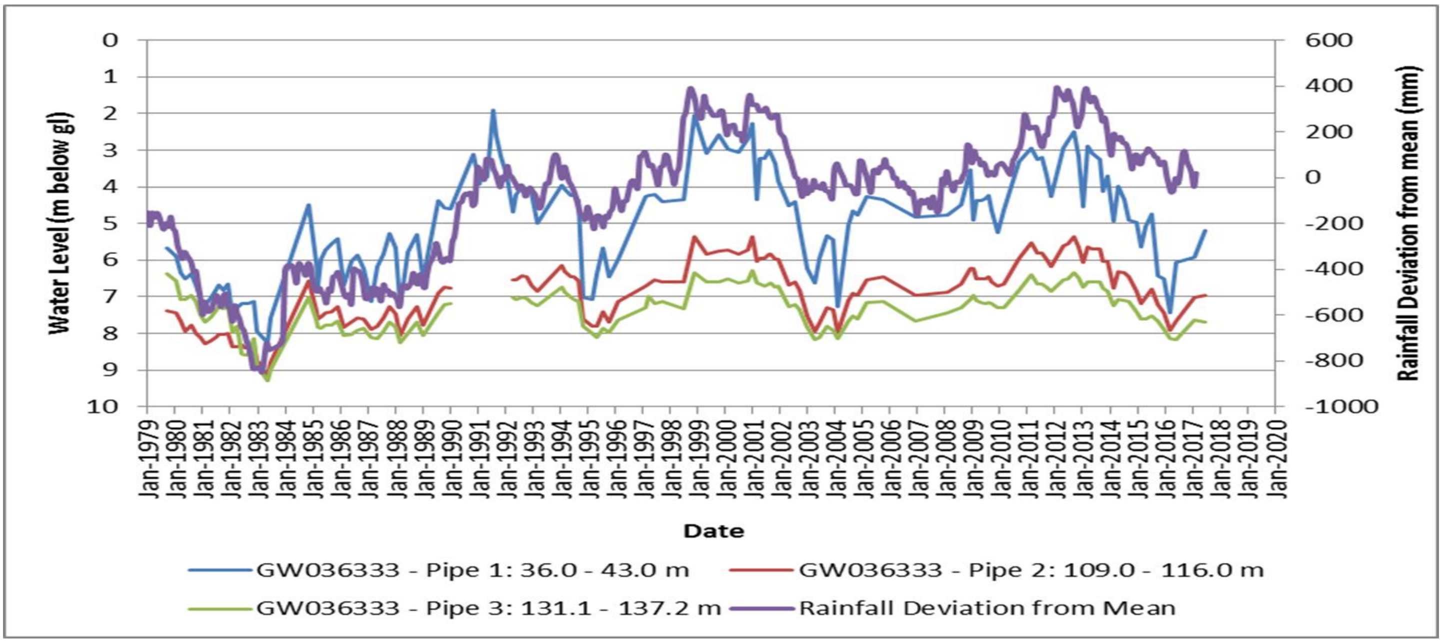


**Figure 25. Groundwater hydrographs for monitoring bore GW036333 within the Gunnedah-Oxley Basin MDB and the cumulative rainfall deviation from average from rainfall station 55024 - Gunnedah.**

### 10.2.2 Western Porous Rock

The groundwater levels within the Western Porous Rock SDL resource unit are generally stable. Within the shallower aquifer (Pliocene sands) there is some minor correlation with climate, that is, with long term rainfall trends rather than seasonal changes. In the deeper confined aquifers groundwater levels do not show any correlation with climate.

Due to the unsuitability of the groundwater quality as a water supply there is limited extraction and consequent extraction impacts. The hydrograph at Figure 25 shows groundwater level data since 1986 from monitoring bore GW036669 located west of Pooncarie. The groundwater levels in all three monitoring pipes have very stable water level behaviour until around 2011 when groundwater extraction as part of mineral sand mining in the area started to influence the groundwater levels in the deeper aquifers.

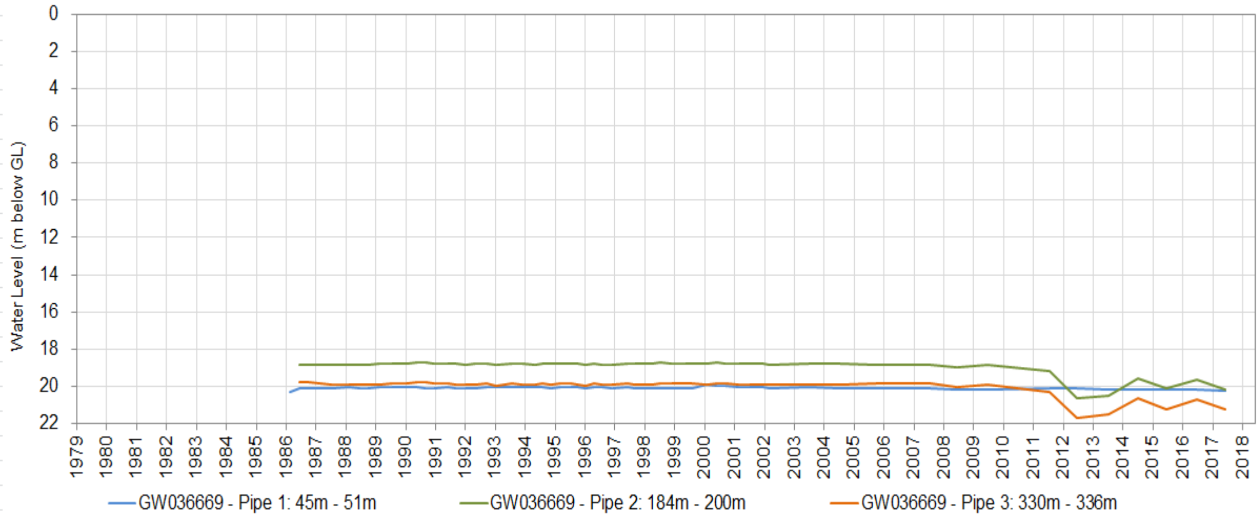


**Figure 26. Water levels within bore GW036669 within the Western Porous Rock SDL**

Within the Murray River floodplain groundwater levels in the shallow aquifers are influenced by river regulation, irrigation and groundwater extraction which is primarily from the operation of the salt interception schemes. Figure 27 shows the water table fluctuations at bore GW087526 reflect seasonal conditions and river flows.

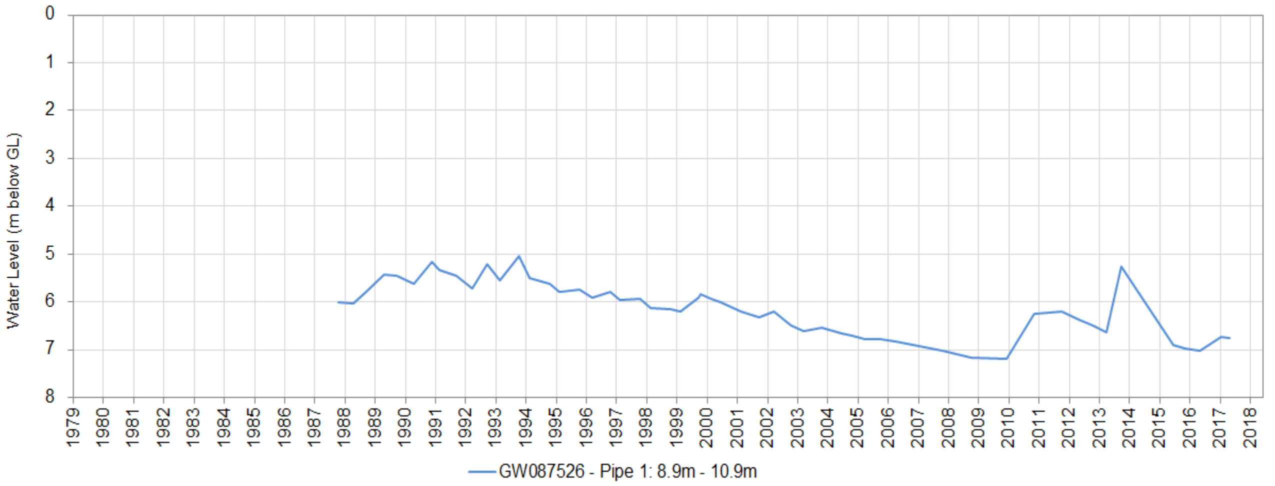


**Figure 27. Water levels within bore GW087526 within the Western Porous Rock SDL**

Figure 28 displays data from monitoring bore GW087345 which shows changes to groundwater levels associated with the salt interception scheme at Buronga. This hydrograph, not density corrected, shows that the operation of the scheme has dropped the groundwater levels of the deeper saline aquifer from around 1993 at this site. This gradient reversal has resulted in a net downward flow of groundwater preventing the more saline deeper groundwater to discharge into the water table aquifer and then in turn into the Murray River.

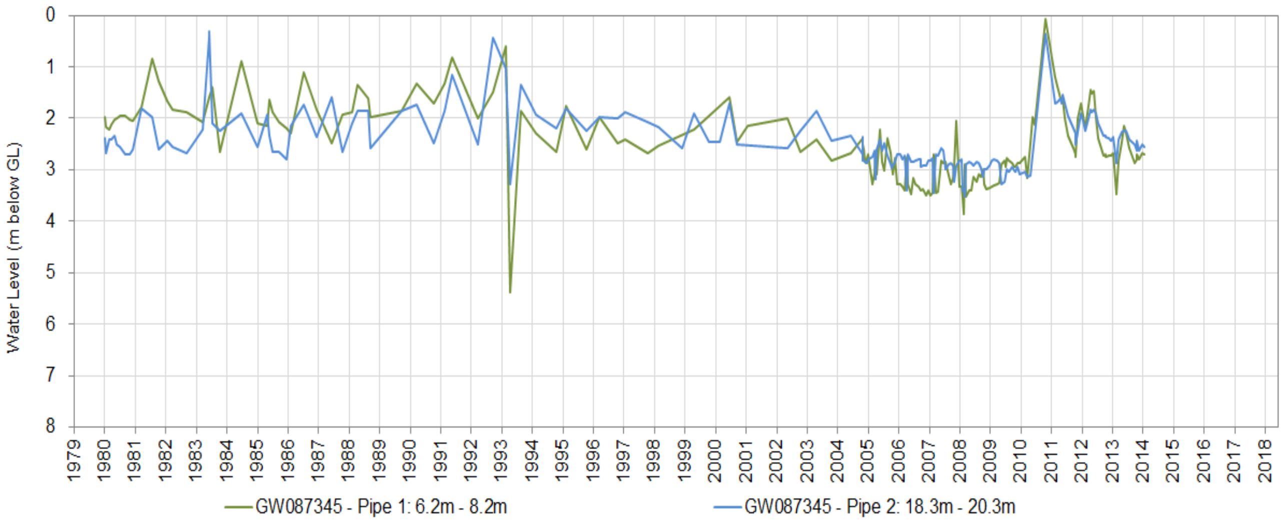


**Figure 28. Water levels within bore GW087345 close to the Buronga salt interception scheme within the floodplain of the Murray River which is part of the Western Porous Rock SDL resource unit.**

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