Guide to Groundwater Resources in NSW

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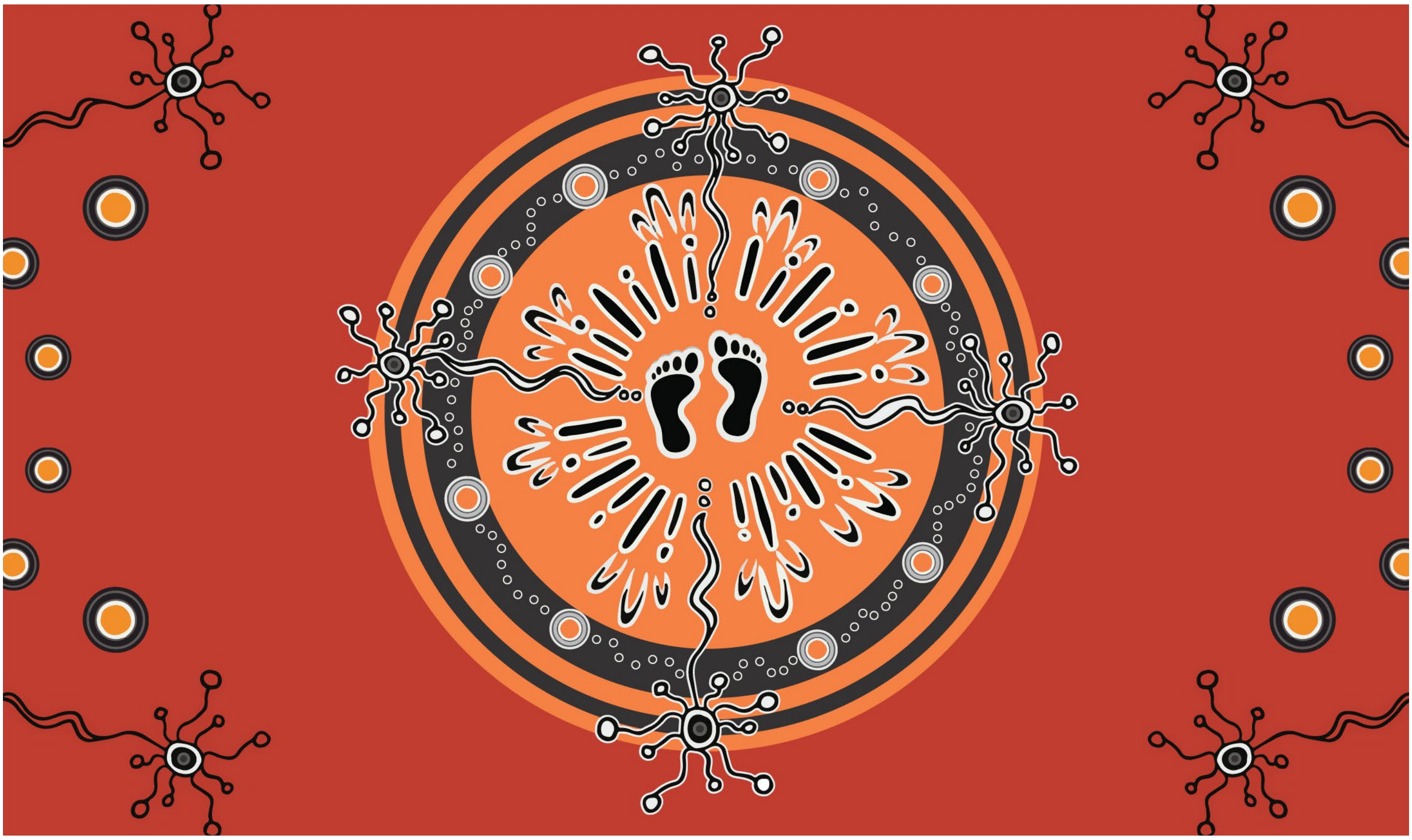
Cover image Image courtesy of Jake Turi. Killen Falls.

More information www.dpie.nsw.gov.au/groundwater-strategy



Acknowledgement of Country

The NSW Government acknowledges First Nations people as its first Australian people and the traditional owners and custodians of the country's lands and water. First Nations people have lived in NSW for over 60,000 years and have formed significant spiritual, cultural, and economic connections with its lands and waters.

Today, they practice the oldest living culture on earth.

The NSW Government acknowledges First Nations people as having an intrinsic connection with the lands and waters of New South Wales. The landscape and its waters provide First Nations people with essential links to their history and help them maintain and practice their traditional culture and lifestyle.

We recognise Traditional Owners as the first managers of Country. Incorporating their culture and knowledge into groundwater management in the region is a significant step towards closing the gap.

Through the NSW Groundwater Strategy, we seek to establish meaningful and collaborative relationships with First Nations people. We seek to shift our focus to a Country-centred approach; respecting, recognising and empowering cultural and traditional Aboriginal knowledge in water management processes at a strategic level.

We show our respect for Elders past and present through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places where First Nations people are included socially, culturally and economically.

As we refine and implement the NSW Groundwater Strategy, we commit to helping support the health and well-being of waterways and Country by valuing, respecting and being guided by First Nations people, who know that if we care for Country, it will care for us.

We acknowledge that further work is required under the NSW Groundwater Strategy to inform how we care for Country and ensure First Nations people hold a strong voice in shaping the future for First Nations communities.

Artwork courtesy of Nikita Ridgeway.

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Image courtesy of Department of Primary Industries. Telemetered bore.

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Facts about groundwater in NSW

Groundwater is water found **below the land surface** in geological formations called aquifers

The groundwater volume in NSW represents **200 times the storage in all major dams, or 10,000 Sydney Harbours**

Groundwater supports a variety of uses, including town water supply, agriculture, and important ecosystems

Groundwater quality varies widely across NSW and determines its suitability for a particular use

A recent CSIRO study suggests average annual **groundwater recharge** from flooding and rainfall **could be reduced by up to 14%** across the state **over the next 30 years**

In NSW, there are **77 groundwater sources west** of the Great Dividing Range and over **450 sources on the coast**

The majority of groundwater use in NSW is from **6 major unconsolidated alluvial systems**

There are over 10,000 groundwater access licences in NSW. Around **60%** of these are held in the major inland unconsolidated alluvial systems

Purpose and context

1

Image courtesy of Department of Planning and Environment. Groundwater site.

Groundwater is a finite resource that supports almost every aspect of our daily lives, from the water we drink and use in our homes to water for crops and activities that support our industries and economy. Many farmers rely on groundwater for domestic, stock and irrigation use, and many water supply authorities have diversified water supply infrastructure that includes groundwater borefields. Without appropriate management of groundwater, mining and many extractive industries would not be possible.

The Guide to Groundwater Resources in NSW (this Guide) provides an overview of the state's groundwater resources – where they are, their quantity, quality and environmental attributes, the values they support, and their current and future uses.

Groundwater is vital to support a healthy environment. It is particularly important as a source of water for both consumptive uses and the environment during drought and when the availability of surface water declines. Groundwater is known to support rivers, cave systems, springs, wetlands, and groundwater dependent vegetation and it holds a critical place for Aboriginal people's cultural values and practices.

The Guide is divided into 4 chapters with 2 appendices:

- Chapter 2 of the Guide explains the fundamentals of groundwater.
- Chapter 3 describes the characteristics of the different groundwater resources across New South Wales (NSW).
- Chapter 4 describes the rights to access groundwater across NSW.
- Appendix A is a glossary of terms and abbreviations.
- Appendix B provides further information on the characteristics of groundwater resources in NSW.

Information in this Guide is derived from the following sources:

- Chapter 2: NSW and Commonwealth water agency reports and CSIRO technical studies; conceptual text and diagrams from Department of Planning and Environment–Water and private consultancy hydrogeologists
- Chapter 3: current and historical groundwater resource and technical reports written by Department of Planning and Environment–Water and its predecessors; latest annual monitoring reports; water sharing plans and relevant background documents; hydrogeological maps; data from the NSW groundwater database of registered water bores
- Chapter 4: current water sharing plans, Department of Planning and Environment water licence database and relevant background documents.

The companion document to this Guide is the Guide to Groundwater Management in NSW, which details the state's current management framework – the applicable laws and regulations, management plans, roles and responsibilities, policies, and implementation tools such as licensing and approvals.

The Guide to Groundwater Resources in NSW, and its companion Guide to Groundwater Management in NSW support the state's first NSW Groundwater Strategy which prioritises future groundwater management actions and reforms over a 20-year horizon.

Fundamentals of groundwater resources

2

Image courtesy of Jess Thompson. Bingawilpa Spring.

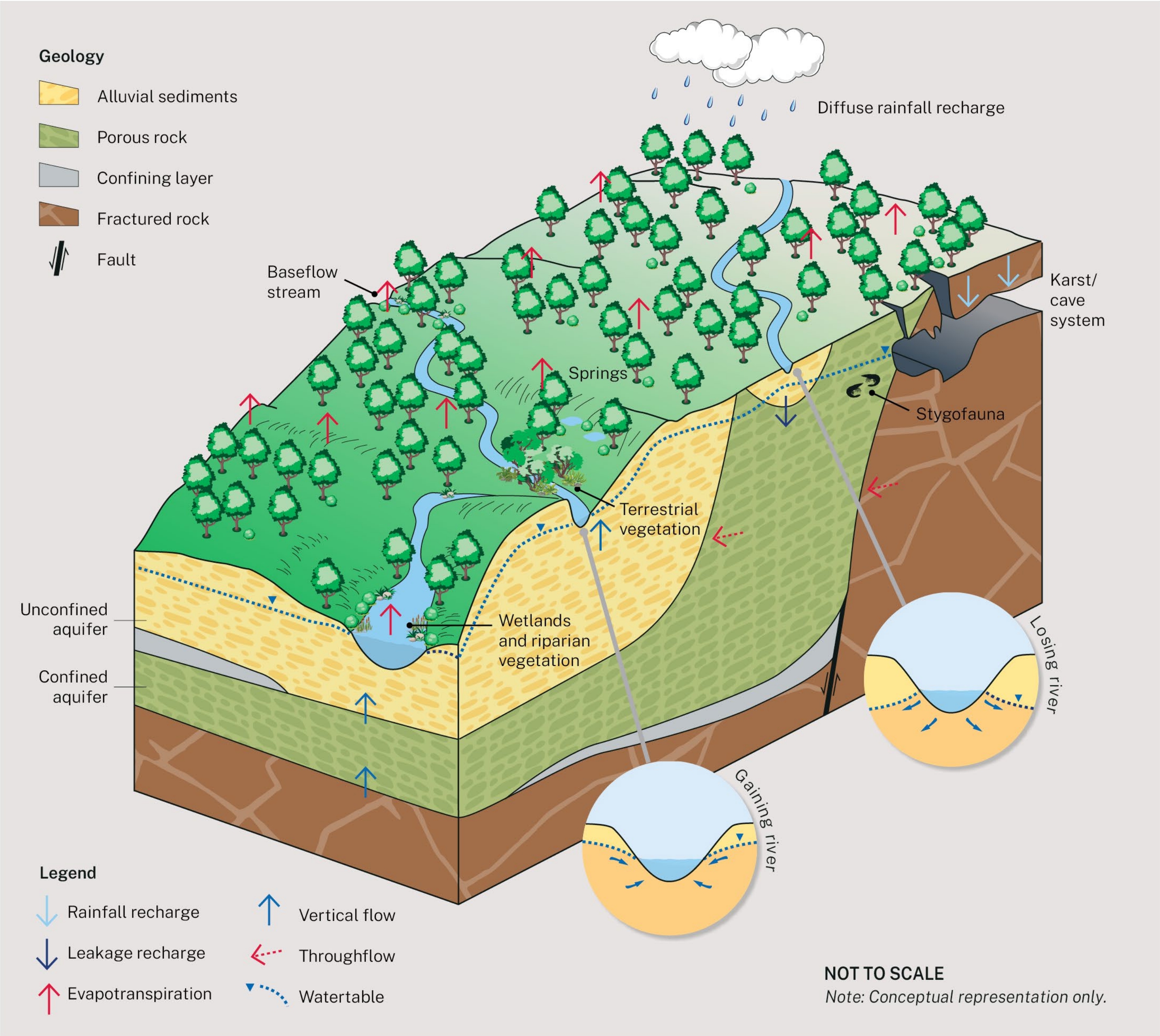
Groundwater and the water cycle

Groundwater is sometimes a forgotten resource as it is rarely seen and difficult to access and measure. Groundwater is contained in aquifers – underground geological formations with the capacity to store and yield groundwater. Aquifers are replenished by recharge from rainfall and surface water sources (such as rivers, creeks and floods) seeping into the ground and recharging the water table. Water then migrates laterally and vertically to discharge naturally at sites such as springs, streams, and wetlands. Recharge volumes are small in comparison to rainfall, surface water and evapo-transpiration but groundwater storages can be very large.

Figure 1 shows the natural groundwater components of the water cycle, including the ecosystems that depend on groundwater to survive and flourish.

Some aquifers are confined between impermeable rock layers and are under pressure, causing water levels to rise above the saturated zone. In cases where the recharge area is higher than a bore site or the discharge zone, the natural pressure produces a flowing (artesian) supply at the surface. For example, in north western NSW where deep aquifers in the Great Artesian Basin flow. Unconfined aquifers tend to be shallower and open to the atmosphere, with the top of the saturated zone representing the water table.

Figure 1. Natural groundwater components of the water cycle



Types of groundwater resources

Groundwater occurrence is closely linked to soils and geology because groundwater accumulates in the open spaces or defects (such as fractures) in the sediment or rock. There are fundamentally 3 types of groundwater systems in NSW:

- Fractured rock groundwater systems (basement fold belts and basalts). Groundwater is stored and moves through the cracks and fissures in these rocks.
- Porous rock groundwater systems (sedimentary basins). Where groundwater can be stored in and move through the fissures and cracks and pores of these cemented rocks.
- Unconsolidated sediment groundwater systems (alluvial and sand dune/beach deposits on or near the surface). Where groundwater is stored and moves between the uncemented sands, gravels and clay particles.

Figure 2 illustrates conceptually the different types of groundwater systems and how they relate to each other across the landscape, while Figure 3 maps the location of the primary groundwater system types in NSW.

Basement fold belt rocks occur across the whole of NSW. In elevated areas they are exposed at the surface, but in lower catchment areas they are buried beneath sedimentary basins and alluvial deposits. All the sedimentary basins overlie the basement rocks, and the younger alluvial and dune deposits at or near the surface overlie either sedimentary basins or basement rocks. Basalts that occur high in the landscape are different as these young, fractured rocks can overlie basement rocks, sedimentary basins and even old alluvial deposits.

Figure 2. Conceptual overview of how the NSW groundwater system types are layered

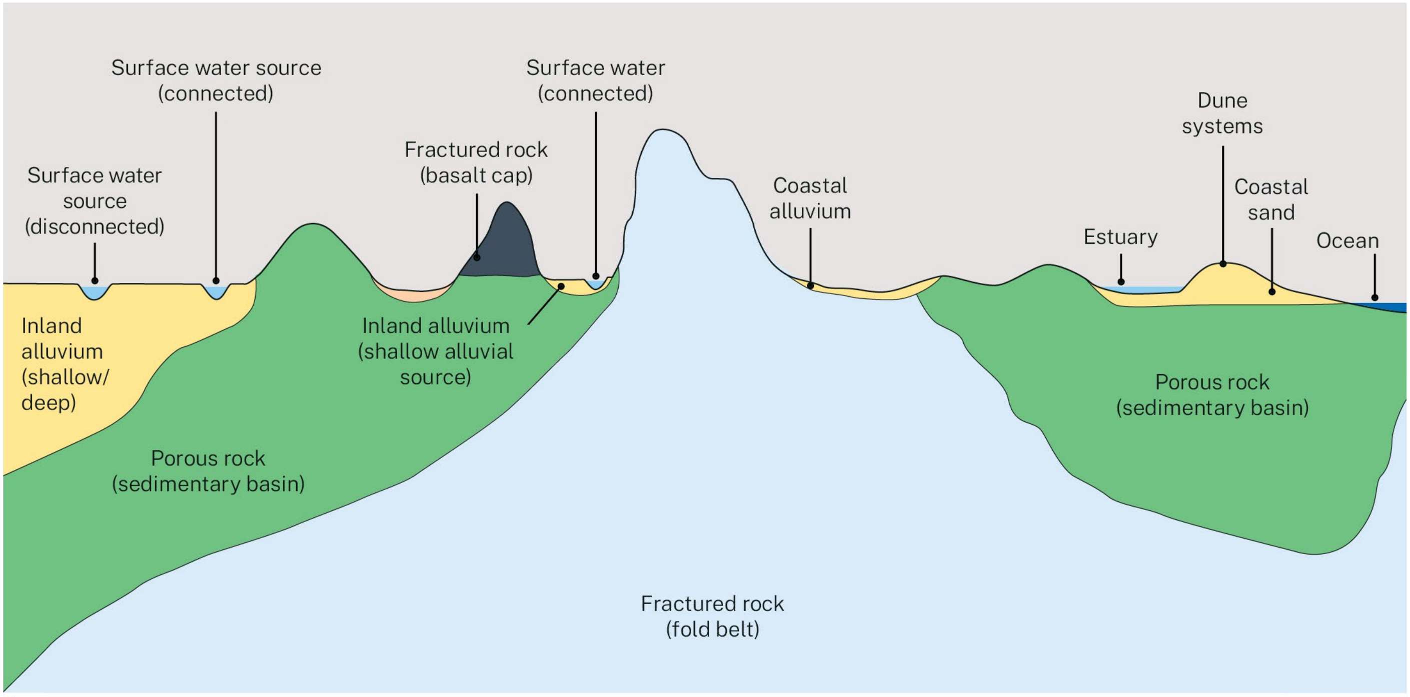
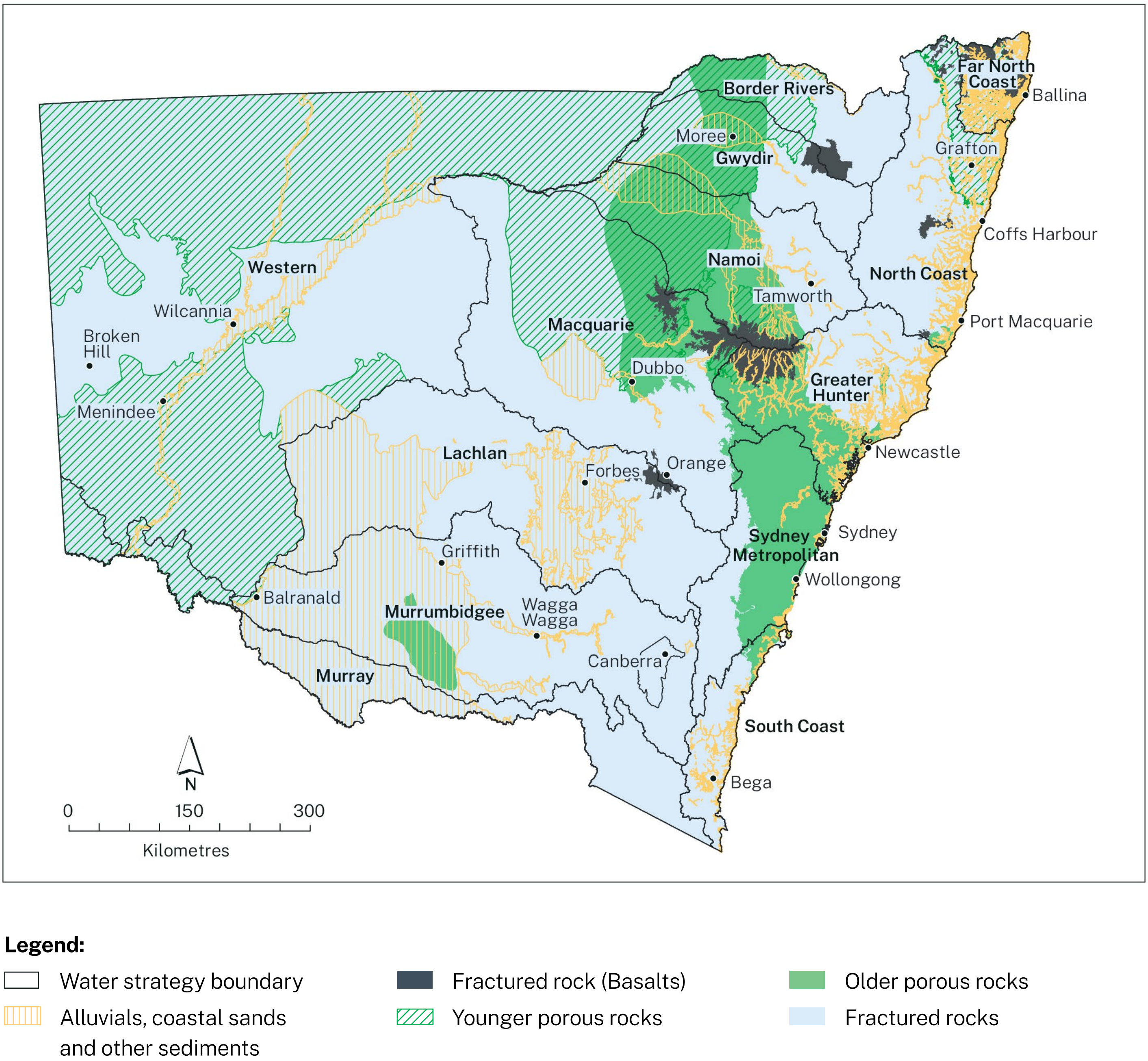


Figure 3. Groundwater resources across NSW



Groundwater is usually accessed by constructing a bore, well or spearpoint using appropriate materials to exclude contamination from surface water, saline groundwater and the cross connection of aquifers at depth. The diameter of a water supply bore can range from 150 mm to more than 500 mm. In contrast, wells are frequently shallow and have bigger structures that are typically greater than one m in diameter. Spearpoints are generally used in coastal sand systems, and are typically less than 6 m deep and between 25 and 300 mm in diameter. Bores must be constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia.[1]

1. National Uniform Drillers Licensing Committee in 2020, *Fourth Edition*. This is available for download at: adia.com.au/wp-content/uploads/2020/09/Minimum-Construction-Requirements-Edition-4.pdf

Characteristics of groundwater resources

Although groundwater occurs everywhere below the ground surface, its quantity and quality can vary. The ability to get water out of the ground (yield) and the quality (such as salinity) depends on the geology, the nature of the overlying soils and recharge/flow characteristics. Some groundwater is fresh and suitable for drinking. Other groundwater is salty or contaminated, making it unsuitable for most purposes.

Quantity

Yields of water bores are highly variable and are mostly determined by the geology and the permeability of the groundwater system. Unconsolidated alluvial aquifers have the highest yields of any groundwater system (typically in the range of 5 to 300 L/s while fractured rock aquifers have the lowest yields (typically less than 5 L/s). The largest bore yields occur in the alluvial fans of the major Murray–Darling Basin catchments such as the Lower Murrumbidgee Valley.

Groundwater levels can change naturally over time due to changes in weather patterns and climate. During wet periods, the water table rises in response to more water reaching the unconfined aquifer. During droughts the water table falls as recharge declines. The storage volume in most groundwater systems is an important attribute that helps maintain consumptive and environmental use during severe droughts.

Water levels are affected by groundwater pumping, and by incidental water take by mines and subsurface infrastructure such as tunnels. Buried infrastructure and associated drainage have the potential to alter the natural flow of groundwater.

Rainfall (and associated stream flow and flooding) is the primary recharge mechanism source for most groundwater systems. The amount of direct rainfall recharge to the water table can range from less than 1% of total rainfall in low permeability soils to more than 30% of rainfall in high permeability sands.

In some systems, recharge can occur within hours and days and groundwater can migrate hundreds of metres per year. In other systems, flow can be very slow, taking more than tens of thousands of years to move from recharge to discharge areas. Groundwater flow depends on the geology and geometry of the aquifer and the slope of the water table (hydraulic gradient).

Quality

The quality of groundwater determines the suitability of the water for a particular purpose. A number of important attributes determine suitability, with the salinity of the groundwater being the most critical. Salinity is the level of concentration of total dissolved salts in the groundwater, where higher levels of salinity (salts) are indicative of poorer water quality.

Groundwater salinity is related to the time water spends in the groundwater system, the geology (that is, the type of sediment, porous or fractured rock that hosts the groundwater system) and the length of the flow path. Groundwater sources with long flow paths, older geology and sediments/rocks with a marine origin have higher salinity concentrations and therefore poorer quality groundwater. The most saline groundwater sources typically occur in western NSW associated with marine sediments in the south-western portion of the Murray–Darling Basin, some inland alluvial discharge areas such as those within the deep aquifers below the Macquarie Marshes, and deeply weathered fold belt rocks in the arid areas of western NSW.

More details on the suitability of groundwater for different purposes and acceptable concentration levels for different chemical compounds in the water are provided in national water quality guidelines.[2]

Other water quality characteristics are also important in determining whether a particular water source is fit for purpose. For example, groundwater could be low salinity but polluted by hydrocarbons, making it unsuitable for human and animal consumption.

Image courtesy of Department of Planning and Environment. Flowing bore.

2. ANZECC, *Water Quality Guidelines 2020* and the *Australian Drinking Water Quality Guidelines 2021*

Groundwater quality can be degraded by pollutants and human-related activities including:

- diffuse pollutants such as:
  - fertilisers that elevate nitrate and phosphate concentrations
  - pesticides
  - stormwater runoff
  - pumping that causes saltwater intrusion from overlying or adjacent aquifers, or from tidal river reaches, estuaries or beaches.
- point source pollutants such as:
  - contaminants such as petroleum products from underground storage tanks
  - Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) from fire-fighting practices
  - chemicals from leaking pipelines and storage tanks
  - nutrients and pathogens from sewerage systems, septic tanks, and effluent irrigation
  - leachate from landfills
  - waste streams associated with industrial and mining sites.

Groundwater quality is particularly at risk where these potentially polluting activities are located within the recharge areas of the groundwater source.

Groundwater dependent ecosystems

Groundwater sustains surface and sub-surface ecosystems and habitats that depend on this water to survive and thrive.

Groundwater dependent ecosystems (GDEs) are defined as ‘ecosystems that need access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services’.

GDEs include a broad range of surface and sub-surface environments. The surface environments include terrestrial vegetation types such as riparian vegetation, wetland and rainforest areas, and aquatic environments such as streambeds, saltmarshes, and even marine environments supporting sea grasses. These GDEs can be highly specialised, featuring unique flora and fauna with characteristics that separate them from other ecosystems. The dependence of GDEs on groundwater varies from seasonal or episodic, to continual. They can range in size from a few square metres (such as a spring discharge zone) to many square kilometres (such as an interconnected cave system).

Typical GDEs include:

- groundwater dependent terrestrial vegetation (such as river red gums along the riparian areas of all inland rivers)
- groundwater dependent wetlands (such as the Crowdy Bay National Park)
- stream baseflows and springs
- cave and karst systems (such as the Jenolan Caves)
- porous aquifers with open void spaces that support stygofauna (fauna that live in groundwater systems).

The occurrence of GDEs in the landscape is shown conceptually in Figure 1.

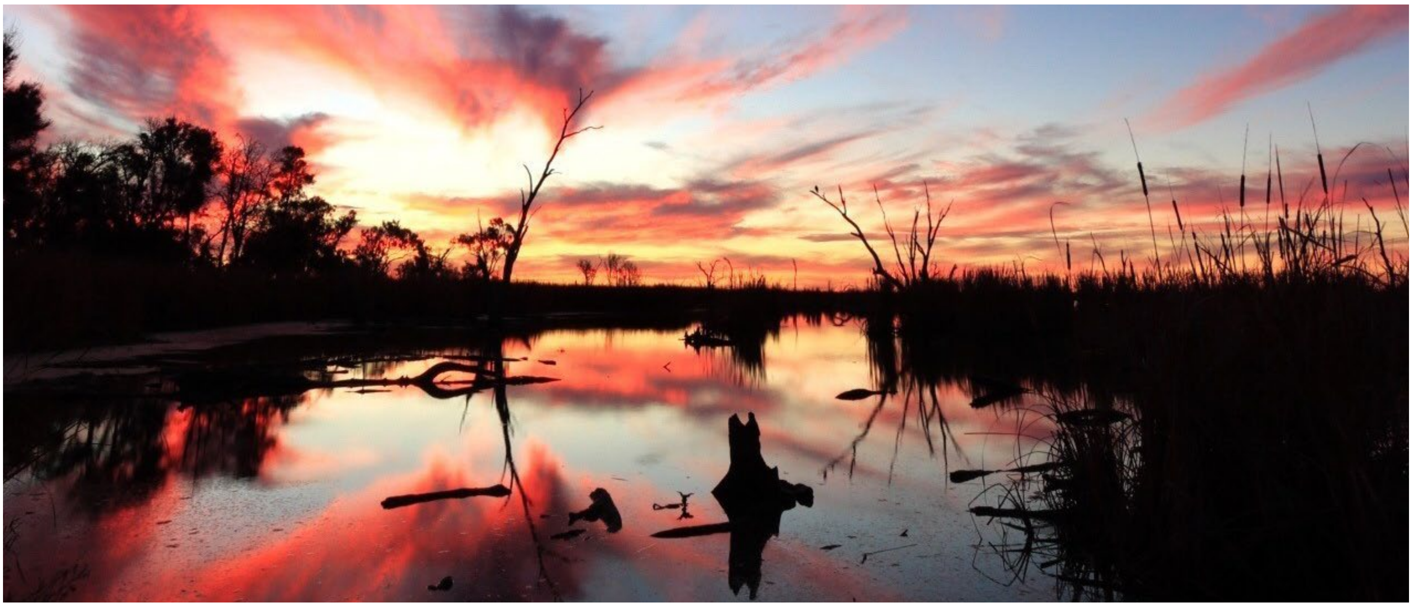


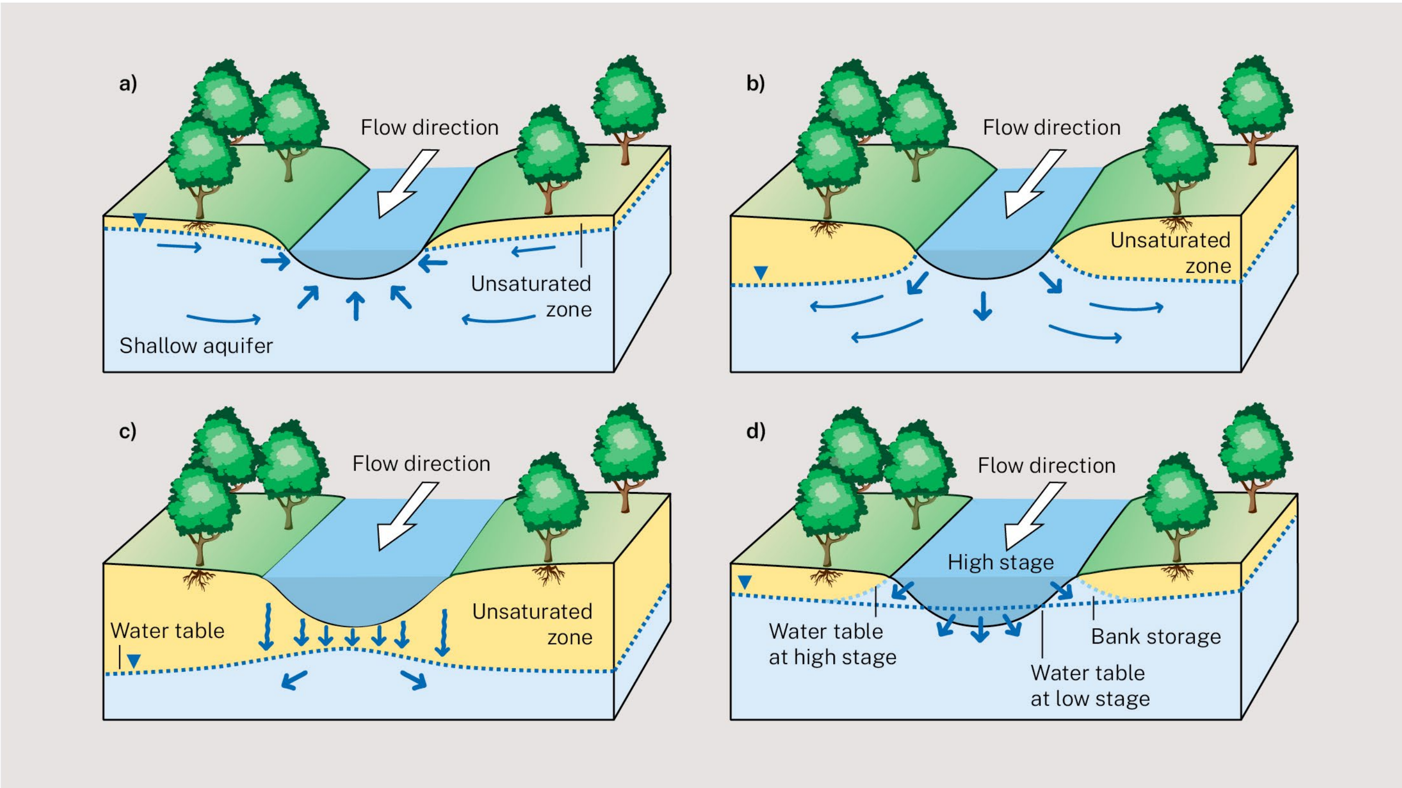
Image courtesy of James Faris, Department of Planning and Environment. Bunnor Waterhole, Gwydir Wetlands.

Surface water and groundwater interactions

As water flows along a stream, water may be gained from or lost to the underlying groundwater system. When the water level in a stream is higher than the water table, water from the stream flows to the underlying aquifer as recharge. The reverse also occurs – when the water table in the underlying aquifer is higher than the stream water level, groundwater can flow to the stream to discharge as baseflow.

These stream scenarios are known as 'connected losing' (where the water table is slightly lower but in connection with the streambed), 'disconnected losing' (where the water table is much deeper than the streambed) and 'connected gaining' (where the water table is slightly higher than the streambed). The different types of stream interaction are shown in Figure 4.

Figure 4. Surface and groundwater connectivity – (a) connected gaining (b) connected losing (c) disconnected losing and (d) temporary reversal from connected gaining to connected losing during a flood event



Source: Adapted from Safeeq, M and Fares, A 2016, *Groundwater and Surface Water Interactions in Relation to Natural and Anthropogenic Environmental Changes in Fares*, A (ed) Emerging Issues in Groundwater Resources, Advances in Water Security, Springer, Cham., doi.org/10.1007/978-3-319-32008-3_11

Image courtesy of Department of Planning and Environment. Cottrell MacIntyre River, NSW.

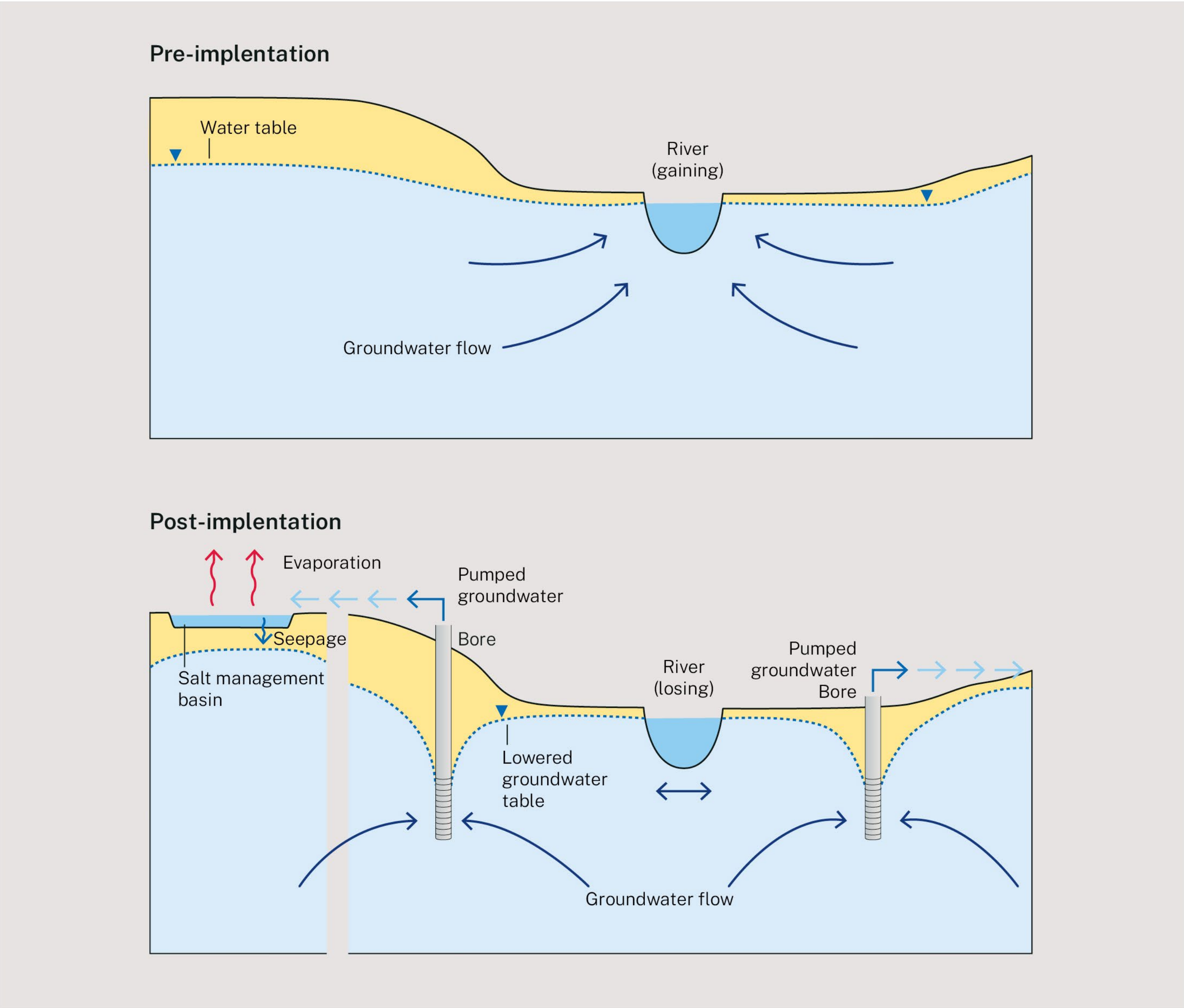
Permanent streams are mostly connected gaining in the upper parts of both inland and coastal catchments in NSW. Groundwater contributions to baseflow are predominantly from fractured rock and porous rock aquifers. In the mid catchment areas where there is more alluvium, streams can be either connected gaining or connected losing depending on the local geography. For instance, if there is a constriction in a valley with narrowing alluvium, then the river system is typically connected gaining as groundwater discharges as stream baseflow. In the lower alluvial fan areas in most inland catchments (where there are extensive floodplain areas), the permanent streams are connected losing at the apex of the fan and then change to disconnected losing further downstream.

Along the Lower Murray River and parts of the Darling River, there is a complex interaction between surface water and groundwater. Thin freshwater lenses (convex-shaped layers of water) are sustained by the rivers and rainfall typically overlie deeper salty groundwater.

However, at some locations saline groundwater discharges as baseflow, causing the river salinity to increase. In these areas, salt interception schemes (SIS) have been constructed to intercept the saline groundwater and dispose of it remotely. Importantly, these schemes maintain surface water quality for a variety of downstream users.

In a SIS scheme, groundwater is intercepted by bores that target the saline aquifer and lower the water table close to the river. This groundwater is then pumped and piped to inland evaporation basins where the groundwater concentrates and precipitates as salt. Some groundwater is allowed to seep back into the regional saline aquifer where the disposal site is remote and the travel time for groundwater to return to the river is very long. Figure 5 shows how a SIS works.

Figure 5. The workings of a salt interception scheme



Source: Adapted from Murray–Darling Basin Authority 2010, *Keeping Salt out of the Murray Fact Sheet*, September 2010.

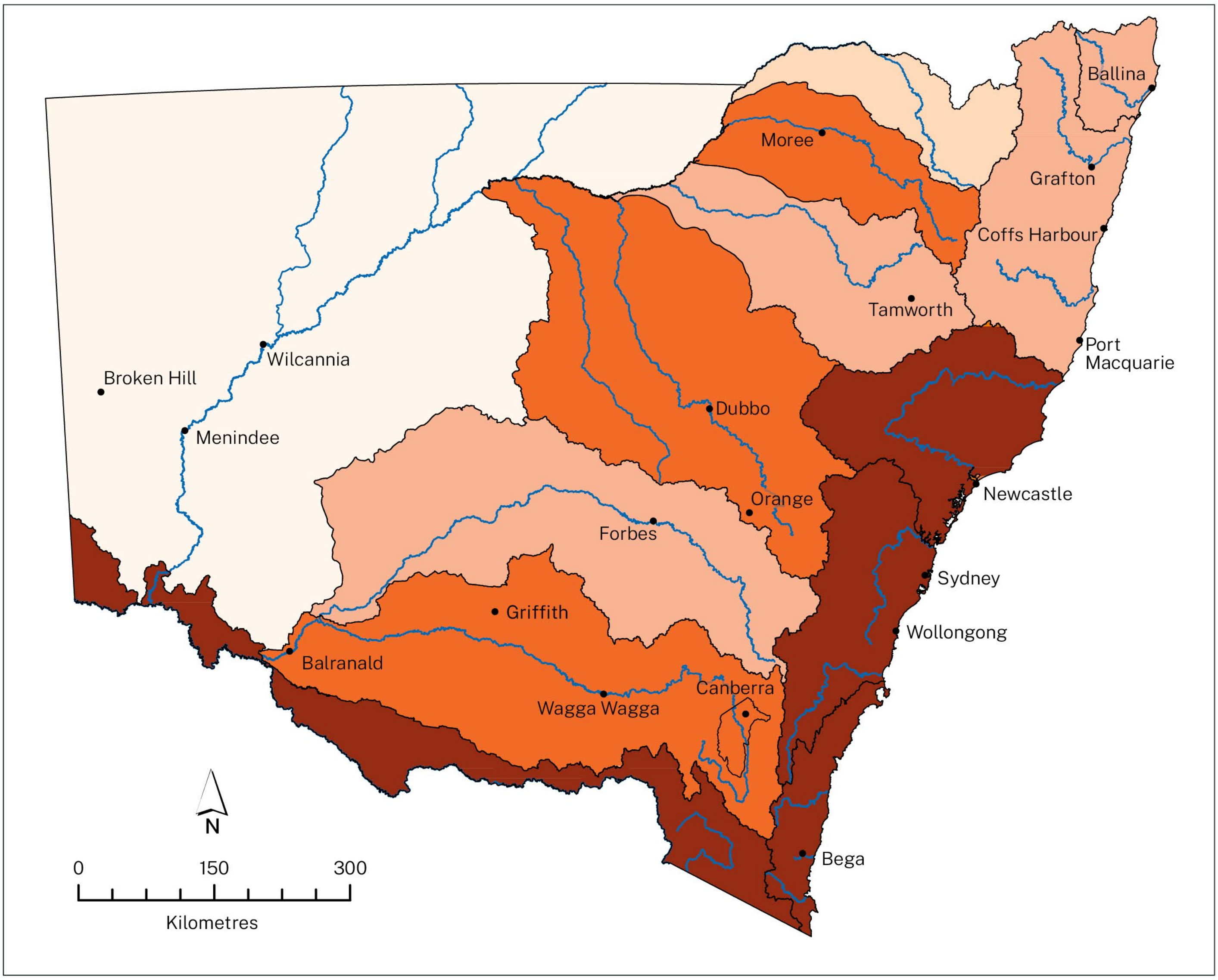
Impacts of land use and climate variability and change

The largest threats to the long-term sustainability of groundwater resources are from population growth, changed land uses (particularly inappropriate or more intensive land uses) and climate change.

Population growth

Over the next 30 years, substantial population growth is predicted for coastal NSW, particularly across the Sydney basin, along the transport corridor to Canberra and throughout the Central Coast and Hunter regions. The Far North Coast and some inland regional areas are also expecting more than 10% growth. Expected changes in population to 2040 are shown in Figure 6.

Figure 6. Population growth projections for NSW in 2040



Legend:

Water strategy boundary

Rivers

Population change (2020 to 2040)

10 to 20% decline

Up to 10% decline

Up to 10% growth

10 to 20% growth

20 to 40% growth

Source: NSW Population projections 2022

Most of this growth will be in the major cities and towns as people move for lifestyle reasons and job opportunities. Agriculture and mining will sustain most of the inland regional economies, while people wanting to live outside of the major cities and a growing tourism sector will drive growth along coastal NSW. With growth comes the associated demand for more water and for improved water supply resilience, particularly during climate emergencies such as drought, floods and bushfires.

Groundwater can provide new and diversified water supplies in some growth areas such as the central west and coastal NSW and is being considered increasingly by water authorities to overcome short term availability concerns when surface water supplies diminish or become degraded. In areas where groundwater is already fully committed, groundwater use will move from low value to high value uses. In addition, the scarcity of water will encourage more recycling and the uptake of innovative technologies such as managed aquifer recharge (MAR) and groundwater desalination.

Land use

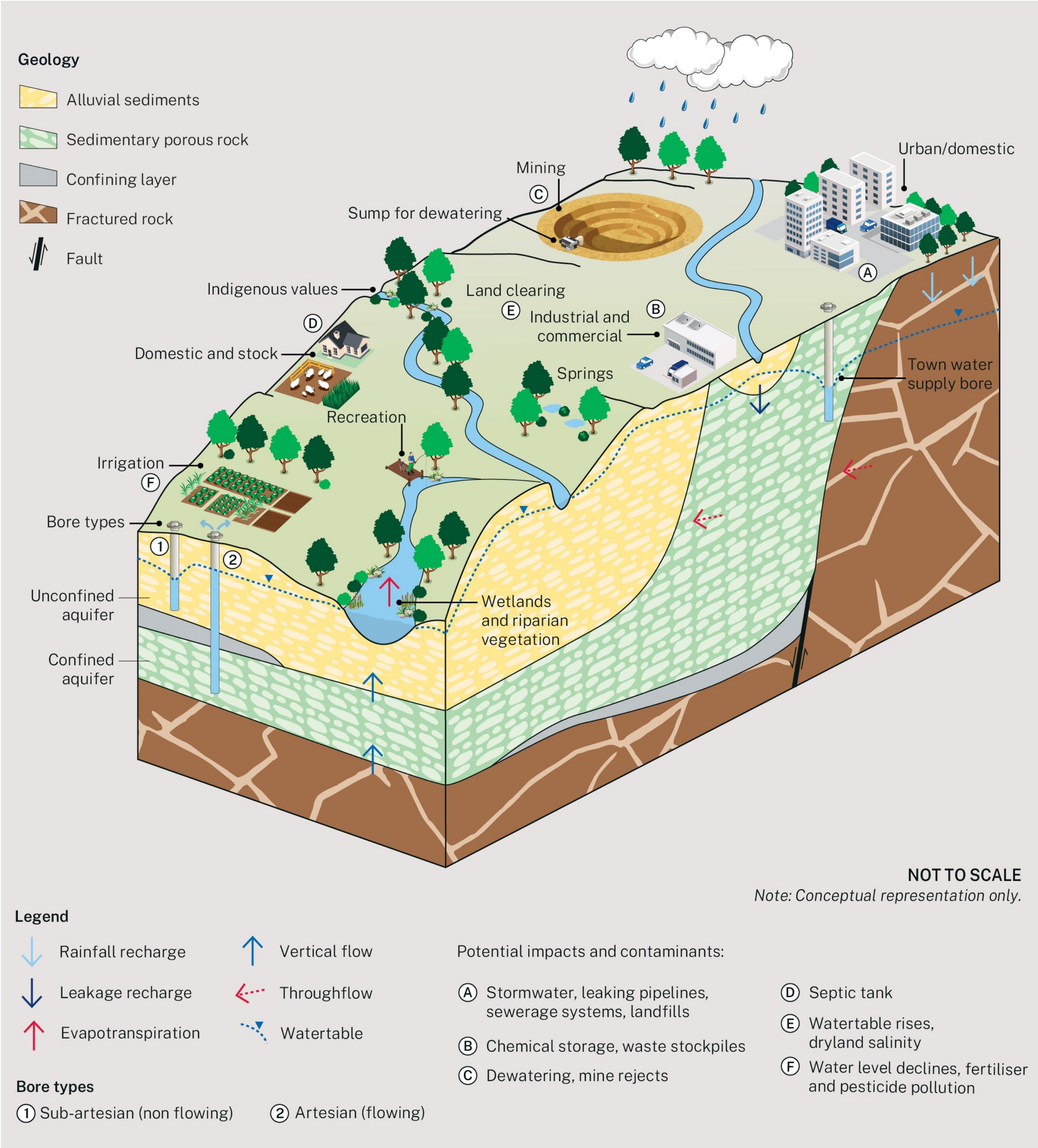
Groundwater can be intercepted and impacted by human activities and artificially discharged through water bores, mines and underground infrastructure such as tunnels and basements. Our actions such as land clearing, irrigation, mining, urbanisation and industrial activities can affect the quantity and quality of our groundwater resources.

Land clearing reduces vegetation cover that causes increased recharge and potentially rising water tables. Irrigation practices can increase water tables if crops are over watered or decrease water levels if groundwater is the irrigation water supply source. Mining and other extractive industries can also cause groundwater levels to decline because of dewatering. Urbanisation and industrial activities can affect both groundwater quantity and quality resulting in decreased recharge and pollution from chemical storage and waste disposal practices.

Figure 7 shows the impacts that certain human-related activities can have on groundwater systems.

Image courtesy of Department of Primary Industries. Sheep grazing at Cowra.

Figure 7. Impacts of land use activities on groundwater systems



Land use changes will inevitably change the quantity and quality attributes of underlying and adjacent groundwater resources and any dependent ecosystems. All elements of a groundwater system (that is, recharge, discharge, throughflow and the storage itself) can be impacted by inappropriate development.

For instance, an industrial area sited on a permeable sand dune groundwater source could restrict rainfall infiltration rates and lower water tables, and if chemicals or waste streams are inappropriately stored on site there is a risk of leaks and spills that could impact water quality. The southern industrialised portion of the Botany Basin in Sydney is an example of a groundwater source that has been severely impacted by pollution for more than a century. Impacts may not be evident for many years, and it is sometimes difficult to reverse or minimise long-term degradation of aquifers.

A summary of recharge area impacts for a range of land use activities is provided in Table 1.

Table 1. Impact of different land uses on groundwater recharge

Impact of land use on groundwater recharge	Influence on		Note
	Recharge rate	Recharge quality	
Deforestation (clearing of native vegetation)	Small to substantial increases in recharge rates expected.	No change except in semi-arid and arid climates where mobilisation of salts in the near surface can occur.	Potential for dryland salinity to emerge in some landscapes.
Floodplain infrastructure	Floodplain levees and harvesting activities interfere with flood flows, reduce inundation areas and reduce groundwater recharge volumes.	Generally, no change.	
Grazing	No change.	Generally, no change.	Increasing grazing intensity will trigger increased nutrient losses and potentially soil compaction that locally may decrease recharge.
Dryland farming	Ploughed and fallowed land likely to result in small increase in recharge rates.	Generally, no change but ploughing can produce a flush of nutrient losses.	
Irrigation	Small to substantial increases in recharge rates expected via leaky distribution systems and higher than required application rates, especially where flood irrigation practised.	Moderate risk of diffuse pollution from nutrients and pesticides.	Additional hazard arises if wastewater is used for irrigation.
Industrialisation	Reduced recharge due to impermeable surfaces (roads, roofs etc).	High risk of point source pollution from product leaks and waste storage/ disposal practices.	Heavy industry is higher risk than light industry.

Table 1. Impact of different land uses on groundwater recharge (continued)

Impact of land use on groundwater recharge	Influence on		Note
	Recharge rate	**Recharge quality**	
Urbanisation	Increased recharge from leaking water/ sewer mains but reduced recharge due to impermeable surfaces (roads, roofs etc).	High pollution risk from nitrogen compounds, hydrocarbons, other chemicals and sometimes pathogens and salinity.	Pollution hazard varies quite widely depending on land use zonings and hydrogeological setting.
Urban infrastructure	Tunnels, building basements and subsurface storages can alter groundwater flow and intercept groundwater.	High pollution risk from undetected losses from both above ground and subsurface storages.	Interrupted flow paths can have long-term impacts on groundwater dependent ecosystems, groundwater quality, aquifer integrity and groundwater levels.
Mining	Small to substantial increases in recharge rates expected. Large recharge rate increases can be expected where subsidence and cracking occur at surface.	High risk of pollution from waste rock stockpiles. Cross contamination of aquifers, particularly loss of good quality groundwater into poorer quality aquifers.	Underground operations (especially 'longwall mining')[3] can induce higher rates of recharge and reduce baseflows to streams.

Climate variability and change

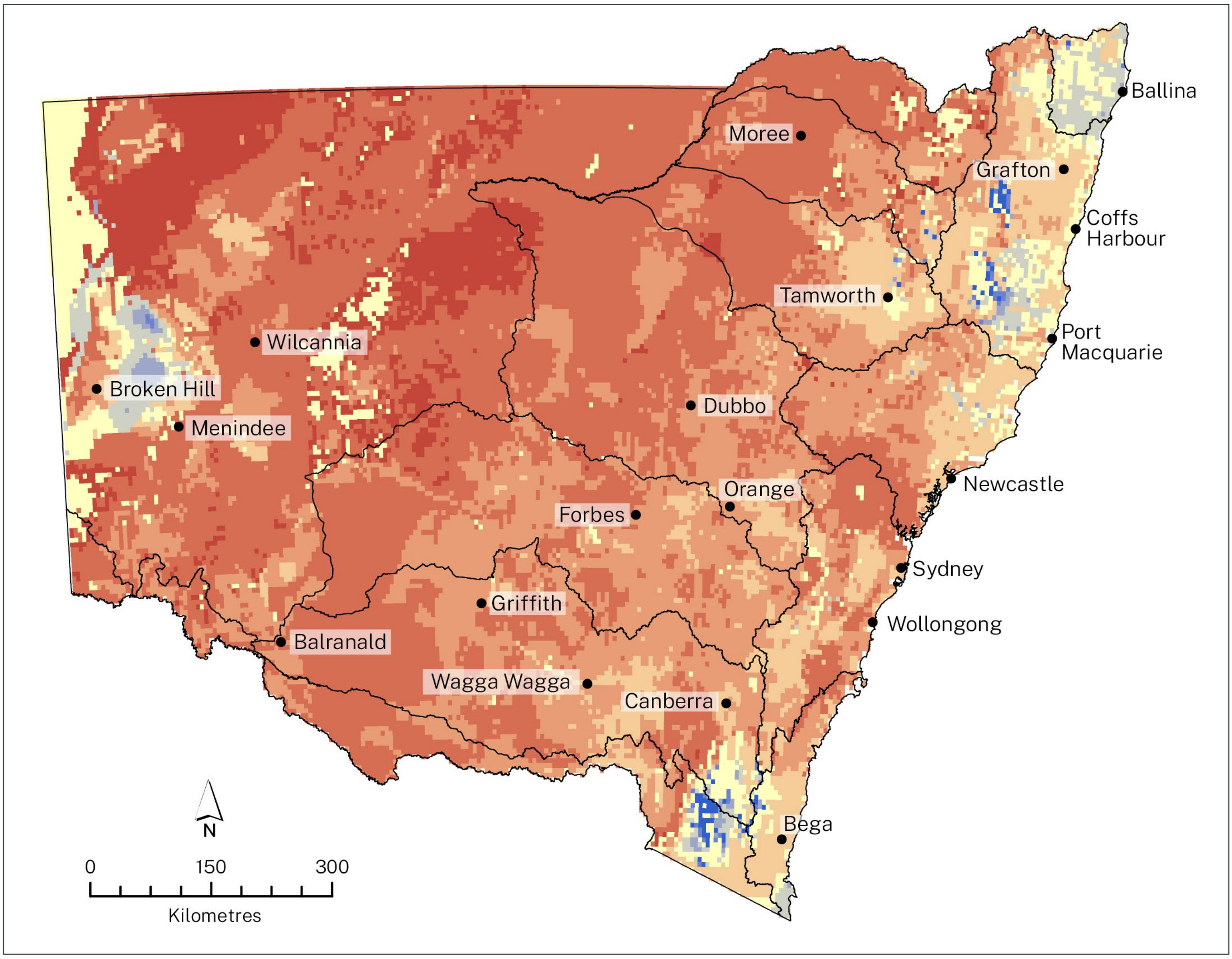
Climate variability is common in the Australian landscape as we are a land 'of drought and flooding rains'.[4] This variability is already factored into how groundwater is used and managed across NSW. Trends since the 1960s have seen surges in groundwater use every time drought conditions prevail.

In inland alluvial groundwater systems, there is a risk of reduction in recharge of groundwater from surface water (water that recharges shallow and connected aquifers as streams flow downstream) and from overbank flooding (where the recharge occurs across the floodplain). Floodplain recharge processes are especially important for the large inland alluvial groundwater systems associated with major rivers in the Murray–Darling Basin.

Climate change is potentially a greater risk to our groundwater resources as changed rainfall and flooding patterns occur, especially in the Murray–Darling Basin. Initial climate modelling by CSIRO suggests that under a future drier climate, rainfall and flood recharge is expected to significantly decrease across most of NSW over the next 30 years.[5] Recent work suggests the average annual decrease across NSW is 14%, with some sources areas potentially experiencing decreases of more than half. The predicted future annual change in groundwater recharge volumes is shown in Figure 8.

3. Where a large block or seam of coal is mined in a single horizontal slice
4. Dorothea Mckellar 1971, *My Country,* The Poems of Dorothea Mackellar, Australia, Rigby Ltd
5. Department of Planning and Environment 2022 – Report prepared by CSIRO – Crosbie, RS, Charles, SP, Rojas, R, Dawes, W, Fu, G, Rassam, D, Barry, K and Pickett, T 2022, *Impact of climate change on groundwater in NSW – Assessment of the sensitivity of recharge and groundwater resources to a projected drying climate*

Figure 8. Future annual groundwater recharge change (%)



Legend:

Water strategy boundary

Change in recharge (%)

- <-50
- -50 to -20
- -20 to -10
- -10 to -2
- -2 to 2
- 2 to 10
- 10 to 20
- 20 to 50
- >50

Note: This figure shows modelled results for changes in diffused groundwater recharge.

Source: Adapted from Department of Planning and Environment 2022 – Report prepared by CSIRO – Crosbie, RS, Charles, SP, Rojas, R, Dawes, W, Fu, G, Rassam, D, Barry, K and Pickett, T 2022, *Impact of climate change on groundwater in NSW – Assessment of the sensitivity of recharge and groundwater resources to a projected drying climate*

Episodic high intensity rainfall events will become even more important to maximise recharge and to replenish groundwater storages. However, these events can be quite localised and natural infiltration processes may not be sufficient to replenish resources over large areas.

CSIRO researchers have identified groundwater sources that are a high priority for future investigation and increased management based on their sensitivity to climate change and their level of stress:

- A groundwater source is <u>sensitive</u> to climate change if it is small and thin (that is, a 'small storage') relative to how quickly it recharges. This is particularly important if a small water source experiences reduced recharge.
- A groundwater source is <u>stressed</u> if its extraction limit is a high proportion of its recharge, and the water licence commitments are a high proportion of its extraction limit. This stress can be exacerbated by climate change and reduced recharge.

The most vulnerable sources to climate change are the shallow alluvial groundwater systems such as those in the Peel, Bell, Cudgegong and Belubula catchments and coastal sand groundwater systems such as the Botany Sands.

The least vulnerable sources are the large inland porous rock groundwater resources and fractured basement resources in the central and southern parts of the state that have very large groundwater storages.[6]

Along coastal NSW, rising sea levels are likely to impact coastal groundwater resources, particularly the sand dune water sources. The consequences of higher sea levels, higher tides and changed tidal limits will increase the risk of saltwater intrusion, thereby reducing the size of these groundwater sources and the availability of freshwater. Importantly, there will also be changes in any connected GDEs such as freshwater swamps and saltwater marshes, and potentially some dune vegetation that previously relied on these freshwater sources.

Image courtesy of John Spencer, Department of Planning and Environment. Wetland flooded paperbark trees, Crowdy Bay National Park.

6. Adapted from Department of Planning and Environment 2022, Report prepared by CSIRO – Crosbie, RS, Charles, SP, Rojas, R, Dawes, W, Fu, G, Rassam, D, Barry, K and Pickett, T 2022, *Impact of climate change on groundwater in NSW – Assessment of the sensitivity of recharge and groundwater resources to a projected drying climate*

Image courtesy of Jamie Plaza Van Roon, Department of Planning and Environment. Cattai Wetlands, Coopernook, NSW.

Groundwater resources in NSW

3

Image courtesy of Jess Thompson. Bingawilpa Spring.

The volume of all groundwater stored in aquifers in NSW is estimated to be 5,110 million ML or 5,110,000 GL. However, not all groundwater can be accessed and used.

For most groundwater systems across NSW, groundwater in storage protects the needs of the environment and cannot be taken or used for any other purpose. Only a proportion of the estimated annual recharge to groundwater storages is allocated for consumptive use. The remainder is allocated to protect the groundwater source and dependent ecosystems. Chapter 4 below discusses groundwater access in NSW in further detail.

The average annual recharge volume for all groundwater systems across NSW is estimated to be more than 15,500 GL/yr and the extraction limits under all groundwater sharing plans are around 3,300 GL/yr.[7] Over 250 towns are dependent on groundwater fully or partially for their water supply.

Groundwater system types across NSW were introduced in chapter 2 and their location shown in Figure 3. Resource descriptions in the following chapters are based on these 3 types of groundwater systems and are then further characterised by geology and individual groundwater sources. Groundwater system types, the groundwater resources and the groundwater sources covered by current water resource plans and water sharing plans across NSW are listed in Appendix B: see Table 28 (fractured rock), Table 29 (porous rock), Table 30 (unconsolidated sediments – alluvium) and Table 31 (unconsolidated sediments – sands).

Did you know?

The total volume of groundwater in storage is:

- 200 times the capacity of all major dams in NSW
- 10,000 Sydney Harbours
- sufficient to cover the whole of NSW to a depth of 4 m.

Groundwater recharge each year is less than 0.05% of the total volume in storage.

Image courtesy of Department of Planning and Environment. Sydney Harbour, NSW.

7. Department of Planning, Industry and Environment 2021, *Groundwater Supply & Demand for NSW: Task 1 – Available Groundwater in NSW*, Final Report prepared by GHD for Department of Planning, Industry and Environment–Water Group.

Fractured rock groundwater systems

Fractured rocks are found in the regional fold belt areas, predominantly the Lachlan Fold Belt (LFB) and the New England Fold Belt (NEFB). As the basement rocks across the whole of NSW, these rocks are the oldest rock types and are 300 to 540 million years old. The exceptions are the basalt plateaus and ranges across the elevated portions of eastern NSW that are associated with relatively recent volcanic activity that occurred between 10 and 50 million years ago.

There are 2 major fold belt areas and 3 minor fold belt areas, as shown in Figure 9. The main basalt provinces are shown in Figure 3.

Fractured rocks include igneous rocks (such as granite, andesite and basalt), hardened sedimentary rocks (such as silicified sandstone and shale) and metamorphosed rocks (such as quartzite and slate).

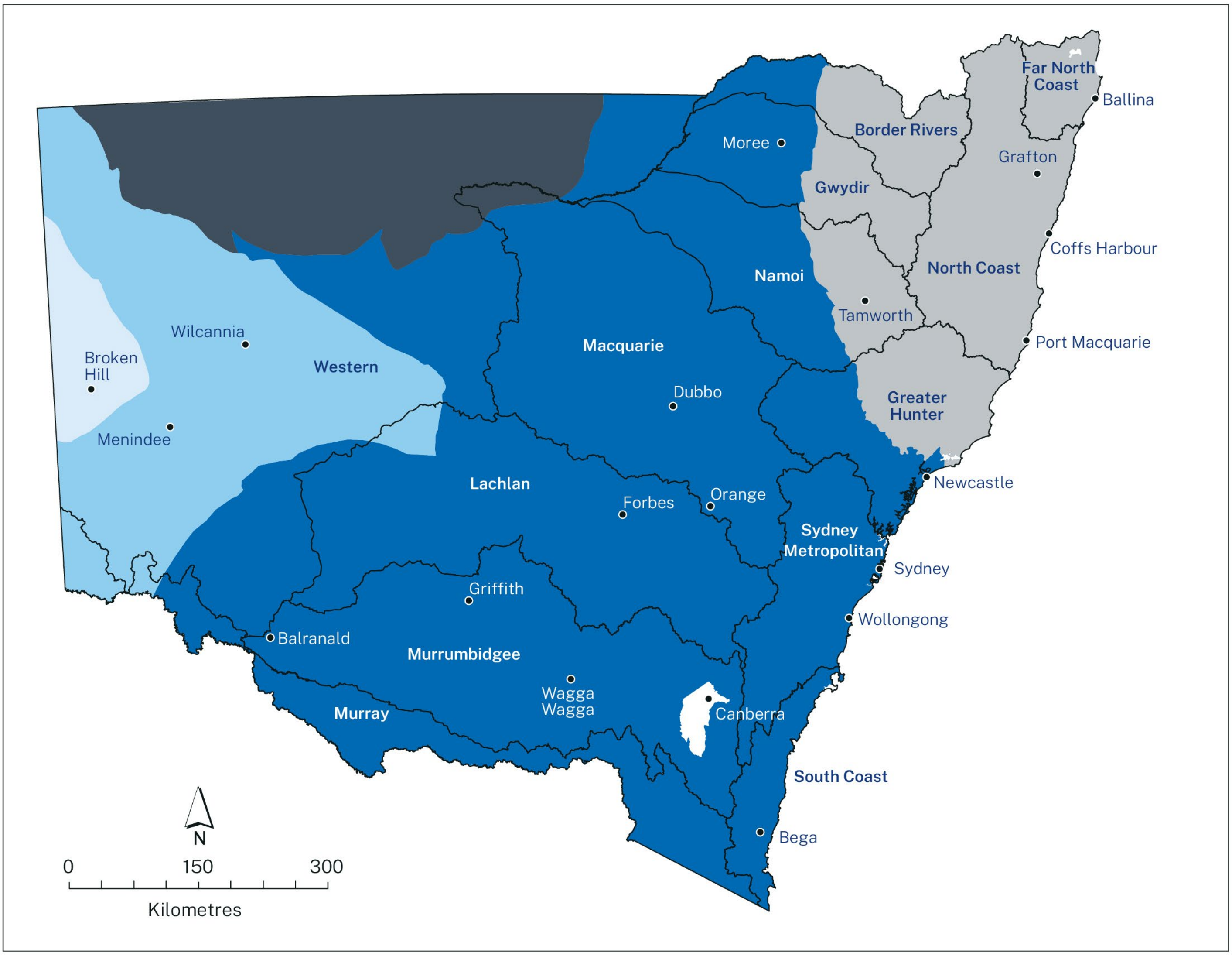
Groundwater does not flow through the solid rock itself; instead, it moves slowly though fractures and faults after falling as rainfall and seeping to the water table. Fractured rock groundwater systems have a large volume of groundwater in storage because they are so widespread and deep. However, bore yields are generally low (on average less than 2–3 L/s) and water quality is brackish to saline except in high rainfall areas.

To access these resources, bores are drilled to intercept fracture systems below the water table. The bore depths can range from as shallow as 15 m from the surface to more than 300 m. If water tables are deeper than 100 m from the surface, then pumping groundwater is generally uneconomic – except if it is the only potential water supply source and a secure water supply is required.

Inland cities that overlie different fractured rock groundwater systems include Albury, Wagga Wagga, Parkes, Bathurst, Orange and Tamworth.

The groundwater sources located within the fractured rock groundwater systems are listed in Appendix B (Table 28).

Figure 9. Location of fold belts across NSW



Legend:

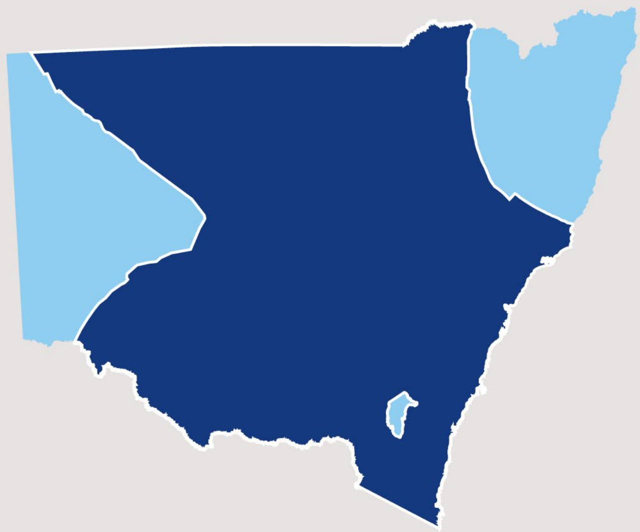
- Water strategy boundary
- Lachlan Fold Belt
- Adelaide Fold Belt
- New England Fold Belt
- Kanmantoo Fold Belt
- Thomson Fold Belt

Lachlan Fold Belt

The Lachlan Fold Belt (LFB) extends south and west from Sydney into central and western NSW and south into Victoria. The Great Artesian Basin (GAB) sits on top of the LFB in north-western NSW and the Murray–Darling Basin (MDB) covers the south-west portion of the LFB in NSW. The Sydney Basin overlies the LFB around Sydney and Wollongong on the east coast. The LFB forms the elevated areas of the Macquarie, Lachlan, Murrumbidgee and Murray River catchments, as well as all coastal catchments south of Sydney. The LFB is approximately 610,000 km^2 and is the largest groundwater resource in NSW underlying most of the state. The ancient rock types include deformed sandstone, siltstone, limestone and hornfels, interbedded with acid volcanics and intruded by granite. The granite intrusions are typically hundreds of square kilometres in size throughout the LFB.

Groundwater in these fractured rock types is found in shallow weathered zones, as well as in the deeper fractured rock. Where there are deeply weathered profiles, the groundwater is typically saline and very low yield. The 7 groundwater sources within this resource area are described briefly in Table 2.

Bore yields are typically less than 5 L/s and water quality is low salinity in coastal catchments but more saline in inland areas. These resources can be impacted by both urbanisation (such as nutrient, bacterial and chemical pollutants) and agricultural activities (such as fertilisers and pesticides).



Highlights

- Fractured rock aquifers across the LFB have low to moderate bore yields.
- Groundwater quality is highly variable and ranges from fresh to saline.
- Aquifers are used mainly for stock and domestic, and small-scale irrigation purposes.
- In some western areas with highly weathered rock, there are negligible prospects of obtaining a suitable supply.
- Groundwater is solely recharged from rainfall.
- Groundwater discharges as springs and provides baseflow to streams in upper catchment areas.

Image courtesy of Department of Primary Industries. Groundwater monitoring bore headworks.

Table 2. Groundwater attributes of aquifers within the Lachlan Fold Belt groundwater sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Goulburn/ Coxs River	20 to 75	0.5 to 10	200 to 1,000	Stock and domestic Extractive industry	60,079	Terrestrial vegetation, springs and baseflow ecosystems
LFB Coast	20 to 75	0.5 to 10	200 to 500	Stock and domestic	20,000	Terrestrial vegetation, springs and baseflow ecosystems
LFB Murray–Darling Basin	20 to 250	0.1 to 10	500 to 15,000	Stock and domestic Mining Small scale irrigation	253,788	Terrestrial vegetation, karst/ caves, springs and baseflow ecosystems
LFB North-Western	NA	Unknown	Unknown	None	NA	None
Yass catchment	20 to 150	0.5 to 10	200 to 1,000	Stock and domestic Small scale irrigation	5,212	Springs and baseflow ecosystems
Young granite	20 to 300	0.25 to 8	150 to 500	Stock and domestic Small scale irrigation	7,110	Springs and baseflow ecosystems

Groundwater is mainly used for on-farm stock, limited domestic, small-scale irrigation and mining purposes. It is intensively used in some areas such as around Murrumbateman in the Yass catchment and around Young where it is used extensively for irrigation. Permanent plantings, such as stone fruit (cherries, plums, peaches, etc.), almonds and wine grapes, are commonly grown across the LFB using groundwater. Numerous copper-gold mines operate across the LFB (such as those near Orange, Parkes and Cobar) and use groundwater intercepted by their operations. In most cases, mine inflows are low and need to be supplemented with water from external sources. Only a few towns and villages use groundwater from the LFB for town supply.

Groundwater is underutilised in the LFB (except for around Yass and Young) because of the low bore yields, variable groundwater quality and the availability of surface water in upper catchment areas.

Fractured rock aquifers support localised GDEs such as some types of terrestrial vegetation, springs and baseflow to streams. The high priority GDEs (mostly spring and karst areas) are listed in the respective water sharing plans (WSPs).[8] Examples of important GDEs include the cave complexes at Abercrombie, Jenolan, Wellington, Wombeyan and Yarrangobilly Caves.

Growth in population and increasing water demand for towns, mining and industry, along with land use changes and economic development, pose challenges to future groundwater availability and use in localised areas of the LFB. Addressing this is a priority under the NSW Groundwater Strategy Priority 2 (Actions 2.2 and 2.3).

Limited groundwater monitoring networks (except for around Young) mean that long-term water level and water quality data are sparse and trends over time cannot be observed across this groundwater resource. The connection between these fractured rock aquifers and ecosystems is also poorly understood on a regional scale.

Further reading:

Department of Planning, Industry and Environment–Water 2020, *Groundwater Annual Report – Young Granite Groundwater Source 2020*.

Department of Primary Industries–Water 2011, *Water Sharing Plan for the Murray–Darling Basin Fractured Groundwater Sources – Background document*.

Department of Primary Industries–Water 2016, *Water Sharing Plan for the South Coast Groundwater Sources – Background document*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

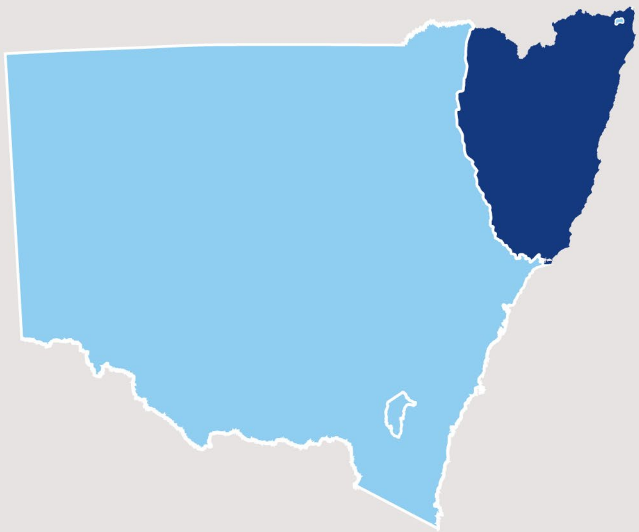
8. *Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources Order 2020, Water Sharing Plan for the South Coast Groundwater Sources 2016* and *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.*

New England Fold Belt

The New England Fold Belt (NEFB) extends north from the Hunter Valley and into Queensland. These basement rocks comprise metasediments and granite intrusions. The New England Fold Belt forms the higher catchment areas of the Hunter, Namoi, Gwydir and Border Rivers catchments, as well as all coastal catchments north of the Hunter. The ancient rocks are more than 300 million years old and include mostly deformed sandstone, siltstone, hornfels and greywacke with interbedded with intrusions of basic rocks. Nearly half of the New England Fold Belt is underlain by a large granite intrusion, the New England Batholith located to the north and west of Armidale. The New England Fold Belt covers approximately 57,000 km^2 of the north-east section of the state.

Groundwater in these fractured rock types is found in shallow weathered zones, as well as in the deeper fractured rock. The 3 groundwater sources within this resource area are described briefly in Table 3.

Bore yields are typically less than 3 L/s and water quality is mostly low salinity. These resources can be impacted by urbanisation (such as nutrient, bacterial and chemical pollutants) and agricultural activities (such as fertilisers and pesticides).



Highlights

- Fractured rock aquifers across the NEFB have low to moderate bore yields.
- Groundwater quality is usually fresh.
- Aquifers are used mainly for stock and domestic purposes.
- Groundwater is solely recharged from rainfall.
- Groundwater discharges as springs and provides baseflow to streams in upper catchment areas.

Table 3. Groundwater attributes of aquifers within the New England Fold Belt groundwater sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
NEFB Coastal	20 to 100	0.5 to 10	100 to 800	Stock and domestic	60,000	Terrestrial vegetation, springs and baseflow ecosystems
NEFB Murray–Darling Basin	20 to 100	0.5 to 5	200 to 800	Stock and domestic	39,253	Terrestrial vegetation, springs and baseflow ecosystems
Peel*	20 to 150	0.5 to 10	200 to 800	Stock and domestic Small scale irrigation Commercial/ Industrial	15,874	Terrestrial vegetation, springs and baseflow ecosystems

*This is the water source name for the fractured rock water source around Tamworth.

Groundwater in the NEFB is mostly used for on-farm stock and limited domestic use. Around Tamworth, groundwater is also used for small sub-division water supplies, small scale irrigation and some commercial/industrial uses. A few towns and villages use groundwater as supplementary supply during periods of extreme drought.

Across the NEFB groundwater is underutilised across this groundwater resource (except for around Tamworth) because of the low bore yields, variable groundwater quality and the availability of surface water.

Fractured rock aquifers support localised GDEs such as some types of terrestrial vegetation, springs and baseflow to streams. The high priority GDEs (mostly spring areas) are listed in the respective water sharing plans.[9]

Growth in population and increasing water demand for towns and industry, along with land use changes and economic development, pose challenges to future groundwater availability and use. Fewer mining projects are likely compared to the LFB area in western NSW; hence, most demand will continue to be from agriculture and industry.

Negligible groundwater monitoring means that long-term water level and water quality data are sparse and trends over time cannot be observed across this groundwater resource. The connection between these fractured rock aquifers and ecosystems is also poorly understood on a regional scale.

Further reading:

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background documents.*

Department of Primary Industries–Water 2011, *Water Sharing Plan for the Murray–Darling Basin Fractured Groundwater Sources – Background document.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

9. *Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources Order 2020* and *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016.*

Other minor fold belts

There are 3 other minor fold belt areas in western NSW:

- The Adelaide Fold Belt in far western NSW west of Broken Hill to the South Australian border.
- The Kanmantoo Fold belt east of Broken Hill and north to Tibooburra and south to the Victorian-South Australian border.
- The Thomson Fold Belt located north of Bourke and extending into Queensland.

These are the oldest basement rocks in NSW and the 2 western fold belts are more than 450 million years old. The Thomson Fold Belt is slightly younger at around 400 million years. For water management purposes, the Thomson Fold Belt fractured rock aquifers are included with the Lachlan Fold Belt groundwater sources.

These fold belts are mainly buried beneath the GAB or Murray Basin porous rocks. Groundwater is rarely sourced from these basement rocks due to the depth of drilling, the low yields and poor water quality. The 4 groundwater sources within this resource area are described briefly in Table 4.

Groundwater is used mainly for stock purposes. There is no predicted growth in population or other activities in these areas, so it is highly unlikely that any increased groundwater use will occur in future years. There are no groundwater monitoring networks across these water sources.

Table 4. Groundwater attributes of fractured rock aquifers within the other fold belt water sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Adelaide Fold Belt Murray–Darling Basin	60 to ?*	0.1 to 1.5	1,000 to 3,000	Stock and domestic	6,900	None known
Adelaide Fold Belt North-Western	60 to ?*	0.1 to 1	2,000 to 6,000	Stock	30,381	None known
Kanmantoo Fold Belt Murray–Darling Basin	60 to ?*	0.1 to 1.5	5,000 to 10,000	Stock	18,700	None known
Kanmantoo Fold Belt North-Western	60 to ?*	0.1 to 1	Unknown	Stock	27,930	None known

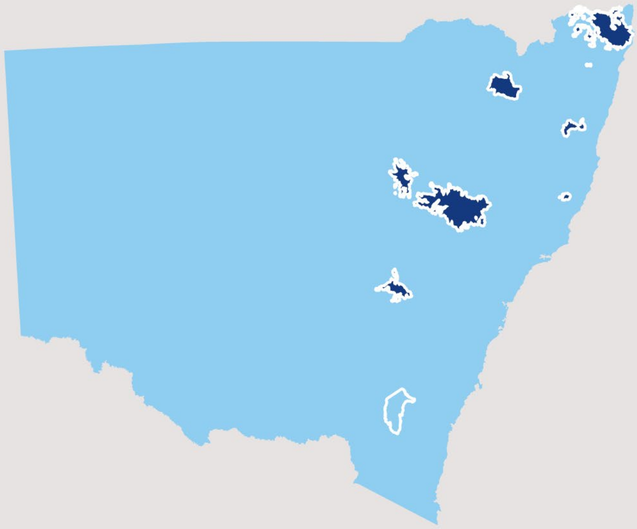
*There has been insufficient drilling and exploration in these water sources to confirm aquifer depths.

Basalts

Basalts underlie fertile plateau areas across multiple areas of eastern NSW. The most extensive areas are located on the Far North Coast of NSW and at higher elevations along the Great Dividing Range. These volcanic extrusions occurred between 15 and 50 million years ago and contain multiple lava flows that form useful fractured rock aquifers. The main basalt areas are in the Far North Coast (including the Alstonville plateau), Comboyne, Dorrigo, Liverpool Ranges, Inverell, Warrumbungle, Orange, Robertson and Nimmitabel areas.

There are high rainfall recharge rates across all these basalt areas and moderate groundwater supplies can be found in multiple aquifers, associated either with major fracture zones or higher permeability lava flows. The most important basalt groundwater sources are managed separately to the other fractured rock aquifers and are described briefly in Table 5. The other smaller basalt areas are incorporated into the underlying fold belt groundwater sources.

Bore yields are typically less than 5 L/s, although higher yields are possible where there is a high density of open fractures. Water quality is almost always low salinity and is used for a wide variety of purposes. Basaltic soils are highly permeable and therefore these water sources are vulnerable to pollution. Again, the pollutants in urban areas are typically nutrients and bacteria from stormwater and sewerage systems, and chemical pollutants from industrial/commercial facilities and landfills. Agricultural activities can introduce fertilisers and pesticides.



Highlights

- Basalts provide moderate to high yields in bores that penetrate multiple fracture zones.
- Rainfall recharge rates are high and consequently groundwater is mostly low in salinity.
- Due to favourable quality water, basalt sources can be used for town water supply, irrigation, commercial and stock and domestic use.
- Basalt aquifers support a diverse range of native vegetation ecosystems, springs and baseflows to permanent streams.

Image courtesy of Destination NSW. The Breadknife volcanic rock formation in the Warrumbungle National Park.

Table 5. Groundwater attributes of basalt aquifers within the different water sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
North Coast Volcanics	10 to 150	1 to 10	100 to 300	Stock and domestic Small scale irrigation	13,000	Terrestrial vegetation, springs and baseflow ecosystems
Alstonville Basalt Plateau	10 to 200	1 to 15	100 to 300	Stock and domestic Small scale irrigation Town water Bottled water	8,895	Terrestrial vegetation, springs and baseflow ecosystems
Dorrigo Basalt	10 to 100	1 to 7.5	75 to 200	Stock and domestic Town water	5,000	Terrestrial vegetation, springs and baseflow ecosystems
Comboyne Basalt	10 to 150	1 to 10	100 to 300	Stock and domestic Small scale irrigation	2,600	Terrestrial vegetation, springs and baseflow ecosystems
Inverell Basalt	20 to 150	1 to 10	150 to 300	Stock and domestic Small scale irrigation Town water	4,150	Terrestrial vegetation, springs and baseflow ecosystems
Warrumbungle Basalt	20 to 150	1 to 5	200 to 500	Stock and domestic	550	Terrestrial vegetation, springs and baseflow ecosystems
Orange Basalt	10 to 150	1 to 20	100 to 300	Stock and domestic Small scale irrigation	9,561	Terrestrial vegetation, springs and baseflow ecosystems
Liverpool Range MDB	20 to 150	1 to 15	100 to 300	Stock and domestic Small scale irrigation	2,160	Terrestrial vegetation, springs and baseflow ecosystems
Liverpool Range Coastal	20 to 150	1 to 10	75 to 300	Stock and domestic	12,000	Terrestrial vegetation, springs and baseflow ecosystems

Increasingly, groundwater in these basalt water sources is used for small scale irrigation (annual crops and permanent plantings), commercial/industrial and town water supply use. Tropical nuts, berries and fruit such as macadamias, avocados, mangoes and lychees are irrigated in coastal areas, with apples and stone fruit more suited to inland areas. Alstonville-Wollongbar, Glen Innes and some smaller towns and villages use groundwater from basalt aquifers, mostly as supplementary supplies during extreme drought. There is moderate to high use of groundwater in most of these water sources.

Basalt aquifers also support important GDEs such as terrestrial vegetation (riparian and some rainforest areas), springs, associated wetlands, baseflow to streams and associated aquatic ecosystems. The high priority GDEs (mostly spring and wetland areas) are listed in the respective WSPs.[10] There is a high degree of surface water-groundwater connectivity, with groundwater providing significant spring baseflows to permanent streams in basaltic landscapes.

Expected high growth in population in some inland areas (for example, the central west around Orange) and Far North Coast areas (for example, around Ballina and Byron Bay) will generate increased water demand for towns, agriculture and industry. These land use changes and associated economic development pose challenges to future groundwater resource protection, availability and use for consumptive users, cultural water and the environment.

Limited groundwater monitoring networks (with the exception of around Alstonville and Orange) mean that long-term water level and water quality data are sparse and trends over time cannot be observed across many sources.

Further reading:

Department of Planning, Industry and Environment–Water 2021, *Groundwater Annual Report – Orange Basalt Groundwater Source 2020*.

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background documents*.

Department of Primary Industries–Water 2016, *Water Sharing Plan for the South Coast Groundwater Sources – Background document*.

Department of Primary Industries–Water 2011, *Water Sharing Plan for the Murray–Darling Basin Fractured Groundwater Sources – Background document*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

10. *Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources Order 2020,* and *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016.*

Porous rock groundwater systems

Porous rocks, comprising consolidated deposits of sandstone, siltstone, claystone, conglomerates, shale and coal, form the sedimentary basins across NSW and are much younger than the fractured rocks that comprise the basement fold belts.

These large sedimentary, porous rock basins form regional groundwater systems with multiple aquifers. These systems store large amounts of groundwater due to their wide extent and depth. Sandstone and coal seams are the most common aquifers and typically form semi-confined and confined aquifers. Often there are layers of low permeability rocks (for example claystone, siltstone and shale) between individual sandstone and coal seam aquifers.

Geologically, there are 2 types of sedimentary basins in NSW: older Devonian and Permian-Triassic basins, and younger Jurassic-Cretaceous-Paleogene basins (Appendix A). Examples of these basin types in NSW include:

- Devonian basins (360 to 420 million years old) – the Darling Basin in far western NSW
- Permian-Triassic basins (200 to 300 million years old) – the Sydney Basin in central coastal NSW and the Hunter Valley, and the Gunnedah–Bowen Basin that extends from Quirindi through Gunnedah and Narrabri before being buried beneath the GAB
- Jurassic-Cretaceous-Paleogene basins (15 to 200 million years old) – the GAB extending from Dubbo, Narrabri and Warialda in the east to the Queensland and South Australian borders, the Oxley Basin beneath the Liverpool Ranges, the Clarence-Morton Basin in far north coastal NSW and the western Murray Basin in far south-western NSW.

These sedimentary basins can be up to 5,000 m deep. Productive aquifers are normally within the uppermost 500 m, although the GAB has artesian aquifers to depths in excess of 1,000 m from the surface. The sandstone and coal seam aquifers are unconfined near their recharge areas and are confined at depth due to the substantial overburden of other sedimentary rocks and alluvial cover.

Groundwater is recharged via direct rainfall recharge in areas of outcrop, a portion of which then seeps to the water table. In the deeper parts of these basins, groundwater is recharged by water migrating laterally from the recharge areas and by slow vertical leakage.

The major sedimentary basins that contain NSW's porous rock groundwater systems are shown in Figure 10. In the east, the Sydney–Gunnedah–Bowen Basin system is partially overlain by the GAB, which includes the Surat Basin and Eromanga Basin. Geologically, the Oxley Basin is part of the Surat Basin but is a separate water source. The Clarence–Moreton Basin extends from north-eastern coastal NSW into southern Queensland. To the west, the Darling Basin is overlain by the GAB and the Murray Basin.

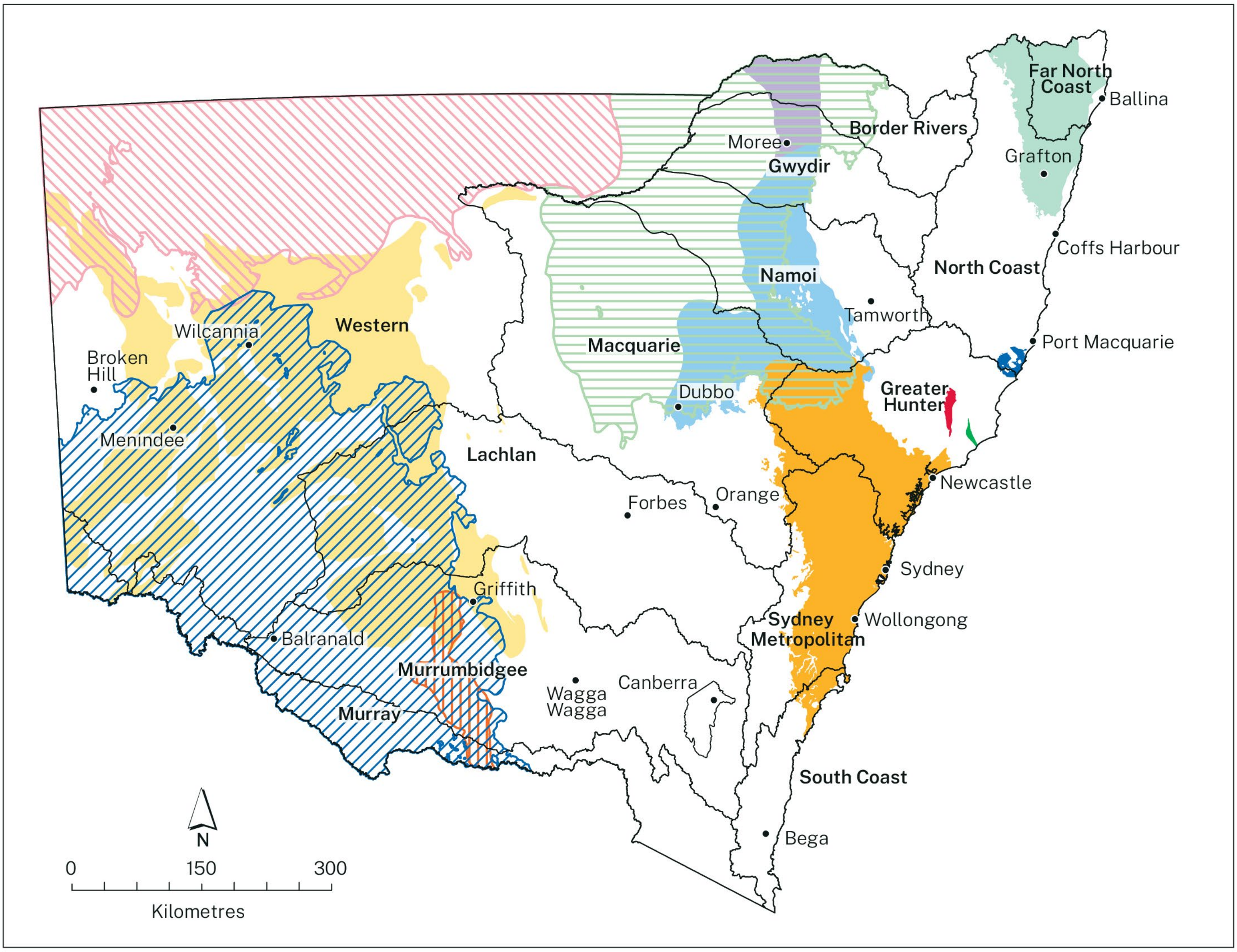
Most of north-west NSW is covered by the GAB, which contains one of the largest groundwater resources in the world. Artesian supplies of 50–60 L/s are possible from deep sandstone aquifers. The older Sydney and Gunnedah–Bowen Basins contain most of the coal and gas resources of NSW but the aquifers have highly variable yields and water quality. The other sedimentary basins have mostly low yields (typically less than 5 L/s) and variable quality groundwater from as fresh as rainwater to saltier than seawater.

The groundwater sources located within the porous rock groundwater systems are listed in Appendix B (Table 29).

Did you know?

Over 60% of NSW is covered by sedimentary basins, which contain the state's porous rock groundwater systems.

Figure 10. Location of major sedimentary basins in NSW



Legend:

- Water strategy boundary
- Surat Basin
- Bowen Basin
- Bulladelah Basin
- Clarence Morton Basin
- Murray Basin
- Oaklands Basin
- Gunnedah Basin
- Gloucester Basin
- Eromanga Basin
- Darling Basin
- Sydney Basin
- Lorne Basin

Great Artesian Basin

The Great Artesian Basin (GAB) is a large, young sedimentary basin of permeable rock and the largest groundwater resource in Australia. Covering 22% of Australia's landmass, the GAB spans parts of Queensland, South Australia and the Northern Territory and 25% of NSW.

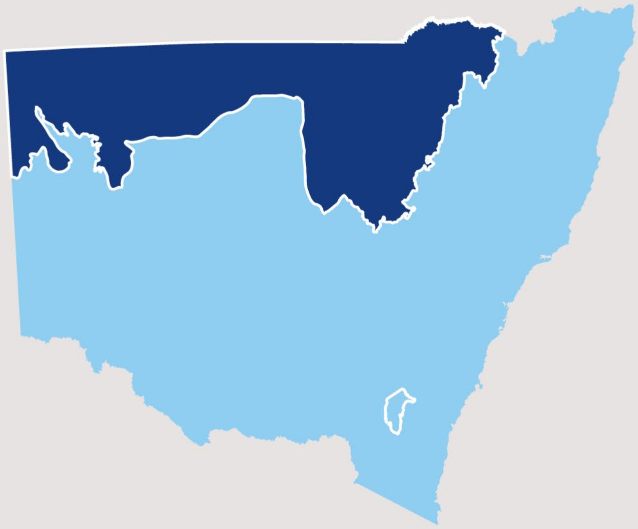
The discovery of artesian water in the GAB occurred in the late 1870s and over the next 50 years many thousands of bores were drilled to tap this valuable resource.

There are 2 geological basins within the NSW portion of the GAB: the Eromanga Basin and the Surat Basin (see Figure 10). Both basins contain deep Jurassic sandstone (artesian and sub-artesian) aquifers and shallower (mostly sub-artesian) Cretaceous sandstone aquifers. Aquifer depths are typically greater than 400 m below surface for the deep aquifers and between 150 m and 350 m below surface for the shallow aquifers.

The Central and Warrego water sources are located within the Eromanga Basin; the Surat, Southern Recharge and Eastern Recharge water sources are located within the Surat Basin. The GAB is approximately 1.7 million km^2 in size of which around 207,000 km^2 occur in north-western NSW. It is thought to have a maximum thickness of around 1,800 m in the northern NSW part of the Surat Basin, but has an average thickness of around 600 m across the whole basin in NSW. Some of the important attributes for the deepest GAB aquifers in NSW are summarised in Table 6.

Did you know?

Not only is the GAB the largest aquifer in NSW, but it is also considered one of the largest aquifers in the world. At 1.7 million km^2, its equivalent to about 7 times the area of the UK.



Highlights

- The GAB is the largest groundwater resource in NSW (both in terms of extent and storage volumes).
- A large part of the central and western portions of the GAB contains confined aquifers. Artesian flows occur from bores drilled into the deep sandstone aquifers.
- The Cap and Pipe the Bores Program has led to a significant recovery of artesian pressures across the basin in recent decades.
- The GAB has variable water quality, with the deeper confined aquifers containing better water quality than shallow aquifers.
- Groundwater is unsuitable for irrigation purposes except in the eastern and southern recharge areas.
- The GAB has a range of agricultural, town water and mining uses, and sustains important ecosystems.

Image courtesy of Jess Thompson. Mascot Spring.

Table 6. Groundwater attributes of deep sandstone aquifers within the GAB water sources

Water source	Range of depths to deep aquifers (m)	Typical flows* and bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Central	400 to 900	1 to 35* 1 to 50	900 to 2,000	Stock and domestic	5,193	Geothermal springs
Warrego	400 to 750	1 to 55* 1 to 50	500 to 2,000	Stock and domestic	8,816	Geothermal springs
Surat	400 to 1,500	5 to 45* 1 to 50	500 to 1,300	Stock and domestic Town water Mining	43,446	Geothermal springs
Southern Recharge	50 to 300	0.1 to 3* 1 to 50	200 to 900	Stock and domestic	38,700	Terrestrial vegetation, springs and baseflow ecosystems
Eastern Recharge	60 to 380	0.1 to 4* 1 to 100	200 to 1,000	Stock and domestic Irrigation	16,200	Terrestrial vegetation, springs and baseflow ecosystems

*The range of known uncontrolled artesian flows from the deep sandstone aquifers.

The GAB has large recharge areas that outcrop along the western slopes of the Great Dividing Range in NSW and Queensland where rainfall is relatively high. Recharge occurs by direct rainfall across sandy soils and exposed sandstone. The groundwater flow direction is towards the west meaning water slowly moves to areas of low and unreliable rainfall further inland. Groundwater discharge is to various mound springs mostly in the western areas of NSW and along the southern edge of the GAB. Groundwater can take up to 2 million years to migrate from recharge areas to discharge areas.

In the Surat, Central and Warrego Groundwater Sources, high sodium concentrations make the water unsuitable for irrigation; however, in the recharge areas the sodicity of the water is lower so it can be used for irrigation on suitable soils. Across the GAB, the temperature of the deep groundwater is around 30°C and can be as high as 60°C. Bore baths and health spa facilities using artesian water have been established in inland towns such as Lightning Ridge, Moree and Walgett to provide therapeutic and recreational opportunities for tourists.

There is a heavy reliance on groundwater for stock and domestic purposes, with more than 8,000 production bores drilled and operational. The availability of permanent water in this part of NSW since the 1880s has allowed grazing (particularly for the sheep and wool industry) and regional towns to establish and grow.

The long history of groundwater use by the agricultural industry, which often saw free flowing bores and open bore drains, resulted in pressure losses within the GAB and seepage and evaporation losses at surface in the early and mid 20th century. Pressures have recovered over the last 30 years with the piping of bore drains and the capping, refurbishment and replacement of uncontrolled artesian bores. The Cap and Pipe the Bores Program[11] offers financial incentives to landholders to replace aging artesian bores and bore drains with new bores and reliable and efficient reticulated water-supply systems. Since its inception, the program has saved about 80,000 ML of water per year, controlled 400 free-flowing bores and installed 18,000 km of pipes. As a result, groundwater pressures within most of the deep artesian aquifers of the GAB are increasing.

The GAB sustains important GDEs. Most are geothermal mound springs in the discharge areas in western NSW. The greatest concentration of springs is located north of Bourke. Collectively, this area is known as the Bourke spring complex, with the Peery springs within the Paroo-Darling National Park being one of the most important.

Growth in population in some regional centres and associated water demand for towns, mining and industry, along with land use changes and economic development, may pose challenges to maintaining artesian pressures and water levels in some areas. However, with further refurbishment of aging artesian bores and ongoing programs to ensure that all water from the basin is piped, there should be a general improvement in the security of water supplies.

More than 60 artesian bores across the flowing portion of the GAB and more than 50 sites across the eastern and southern recharge areas are monitored for groundwater pressure, level and water quality trends.

Further reading:

Department of Planning, Industry and Environment 2020, *Groundwater Resource Description NSW Great Artesian Basin.*

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Great Artesian Basin groundwater source*s.

Department of Planning, Industry and Environment 2021, *Hydrogeology and ecology survey of the Great Artesian Basin springs in NSW.*

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library

Mapping:

Hydrogeology of the Great Artesian Basin 1:2,500,000 scale available for download at www.ga.gov.au/scientific-topics/water/groundwater/gab/hydrogeological-atlas-of-the-great-artesian-basin

11. Further details available at www.industry.nsw.gov.au/water/plans-programs/water-recovery-programs/cap-and-pipe-the-bores

Oxley Basin

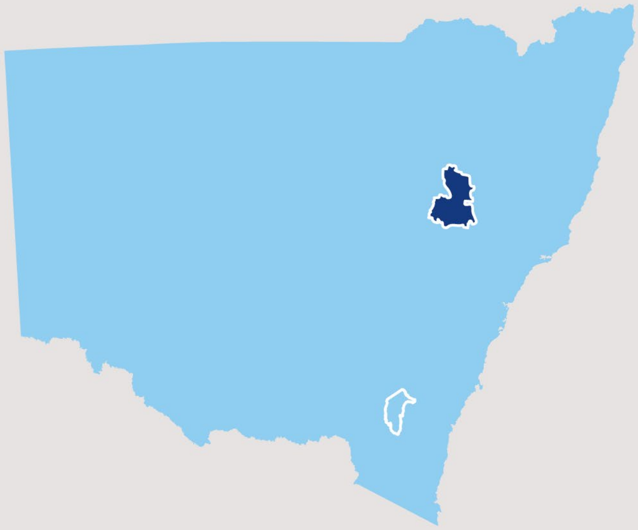
The Oxley Basin is a large (young) sedimentary basin of permeable rock and contains similar sandstone aquifers to the GAB but at much higher elevation. It occurs beneath the Liverpool Ranges and straddles the divide between the coastal Hunter catchment and the inland Namoi and Macquarie–Castlereagh catchments. The Oxley basin covers an approximate area of 83,000 km^2. A large part of the basin is overlain by the Liverpool Ranges basalt. Geologically, it is included in the Surat Basin of the GAB but from a groundwater perspective it is hydraulically disconnected and does not form part of the GAB recharge area.

For groundwater management purposes, the Oxley Basin is part of the (inland) Gunnedah–Oxley Basin MDB Groundwater Source, as well as the Oxley Basin Coast Groundwater Source in the Hunter coastal catchment. Because of high bore density and extraction in the Spring Ridge and Coolah areas, these areas are covered by the Gunnedah–Oxley Basin MDB (Spring Ridge) Management Zone and the Sydney Basin MDB (Macquarie Oxley) Management Zone.

The basin extends from Murrurundi in the east to Merriwa/Cassilis in the south, Coolah in the west and Tambar Springs/Spring Ridge in the north.

The sedimentary rock sequence is thickest beneath the Liverpool Ranges basalt and is estimated to reach depths of more than 300 m. The deepest bores are mostly in the Spring Ridge area in the Namoi catchment where production bores are around 100 m deep, although the sandstone aquifer is known to locally extend to depths of 200 m. The connection between aquifers in the younger Oxley Basin and the underlying older Gunnedah Basin to the north and Sydney Basin to the south is poorly known.

Some of the important attributes for the Oxley Basin aquifers are summarised in Table 7.



Highlights

- The sandstone aquifers in the Oxley Basin have similar groundwater characteristics to the recharge areas of the GAB.
- High yields are possible from deep large diameter bores.
- Water quality is excellent and is suitable for most consumptive uses including drinking water.
- Groundwater within the basin is mostly used for agricultural purposes, including intensive irrigation in some areas.
- There is little known about the GDEs associated with this groundwater resource.

Table 7. Groundwater attributes of water sources within the Oxley Basin

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Oxley Basin Coast	30 to ?***	1 to 20	Fresh	Stock and domestic Small scale irrigation	9,600	Terrestrial vegetation, springs and baseflow ecosystems
Gunnedah–Oxley Basin MDB	30 to 200	1 to 65*	200 to 1,000*	Stock and domestic Irrigation Town water	127,500**	Terrestrial vegetation, springs and baseflow ecosystems

*The range of expected bore yields and water quality from just the Oxley Basin sandstone aquifers.

** This extraction limit is for the whole water source; there is no separate limit for the Oxley Basin portion of this water source.

***There has been insufficient drilling and exploration in these water sources to confirm aquifer depths.

The intensive irrigation areas around Spring Ridge are all watered from these sandstone aquifers. Groundwater use is high and seasonal groundwater levels vary by up to 10 m depending on rainfall recharge and pumping trends. Elsewhere, extraction is low to moderate and groundwater levels are maintained by rainfall recharge across the outcrop areas and leakage from the Liverpool Range basalt. The salinity of the groundwater is low due to the high permeability and clean nature of the sandstone.

The sandstone aquifers are exploited for a variety of uses, including stock watering and broadacre and centre pivot irrigation of annual crops such as cereals and sunflowers. There are also several towns and villages – including Spring Ridge, Merriwa and Cassilis – that rely on this water source for drinking water. Agriculture is expected to be a primary driver of future demand. Growth in population centres is unlikely, and increased demand from other users apart from agriculture is also unlikely.

Little is known about the GDEs across the basin; however, there are many springs located in the discharge areas around the edge of the basin and these are listed as high priority GDEs in water sharing plans.[12] These springs are likely to support adjacent terrestrial vegetation and localised baseflow ecosystems. Further research is required to understand the groundwater dependence of these ecosystems.

There is limited groundwater monitoring across the basin, except for the extensive and long-term network established in the Spring Ridge area.

Further reading:

Department of Planning, Industry and Environment 2019, *Groundwater Resource Description NSW Murray–Darling Basin Porous Rock Water Resource*.

Department of Primary Industries–Water 2012, *Water Sharing Plan for the Murray–Darling Basin Porous Rock Groundwater Sources – Background document*.

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background document*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

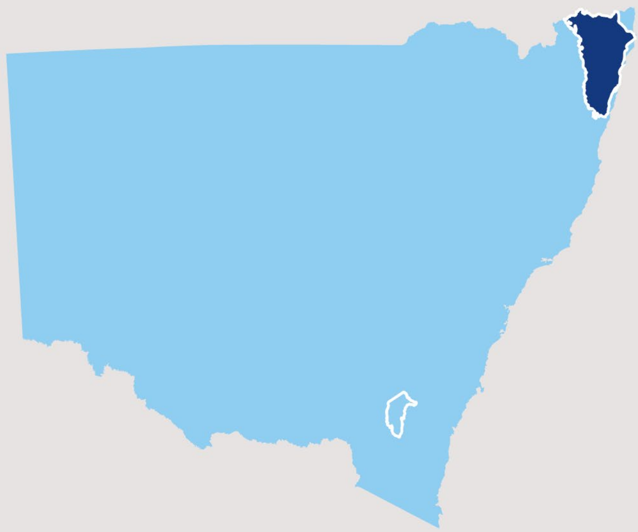
12. *Water Sharing Plan for the NSW Murray–Darling Basin Porous Rock Groundwater Sources Order 2020* and *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016.*

Clarence–Moreton Basin

The Clarence–Moreton Basin is also a young sedimentary basin, similar in age and the way it was formed to the GAB. The basin is found in the Northern Rivers region of NSW and extends into Queensland where it merges with the GAB. In the north it is overlain by basalt (part of the Wollumbin/ Mount Warning Complex) which includes the North Coast Volcanics and Alstonville Basalt Groundwater Sources. The eastern part of the basin is overlain by alluvial and coastal sand deposits. The total on-shore area of the basin is 26,000 km^2 of which about 16,000 km^2 (60%) occurs in NSW. The basin in NSW has coal and gas reserves but is largely unexplored for groundwater resources.

The sedimentary rock sequence is between 3,000 and 4,000 m thick in the central part of the basin; however, most water bores are less than 100 m deep.

Some of the important attributes for the Clarence–Moreton Basin aquifers are summarised in Table 8.



Highlights

- Yields to bores are generally low to moderate, although there are some areas with potential for high yields.
- Groundwater is used mainly for stock and domestic, and limited irrigation purposes.
- The extent of GDEs is poorly known.

Table 8. Groundwater attributes of aquifers within the Clarence–Moreton Basin

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Clarence–Moreton Basin	30 to ?*	1 to 15	150 to 1,000	Stock and domestic Small scale irrigation	300,000	Terrestrial vegetation, springs and baseflow ecosystems

*There has been insufficient drilling and exploration in this water source to confirm aquifer depths.

The variability in bore yields and groundwater quality across the basin is not well known because of limited drilling and minimal use of groundwater. The highest bore yields are obtained from the sandstone aquifers for stock and domestic and small-scale irrigation purposes. Water quality is generally fresh because of the high rainfall and porous soils across the basin; however, poorer water quality is found in aquifers within the mudstone and coal rocks.

The porous rock aquifers supply water to GDEs, including water to many wetland and spring ecosystems across the basin, however the size and extent of these requires more investigation. There are no priority GDEs identified at this time.

Population growth and associated increased water demand for towns and industry, along with land use changes and economic development, pose challenges if groundwater is adopted as a new or supplementary water resource across the basin. This is a priority under the NSW Groundwater Strategy Priority 2 (Actions 2.2 and 2.3).

There is insufficient groundwater level and water quality data to support long-term trend analysis and inform management decisions on consumptive uses or environmental requirements. This is another priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Further reading:

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background document.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

NSW Groundwater Strategy available for download at www.dpie.nsw.gov.au/water/plans-and-programs/nsw-groundwater-strategy

Image courtesy of Peter Robey, Department of Planning and Environment. Field irrigation, Dubbo.

Sydney Basin

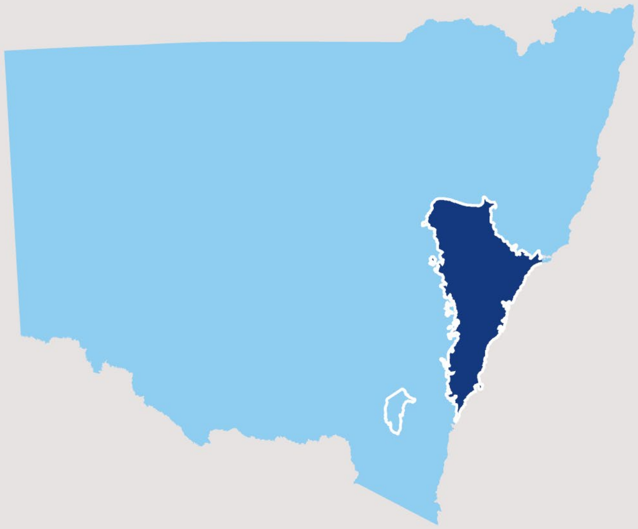
The Sydney Basin is an old sedimentary basin that is part of the Sydney–Gunnedah–Bowen Basin system, a major sedimentary basin extending from southern coastal NSW to central Queensland. The total on-shore area of the Sydney Basin is approximately 44,000 km^2. It is underlain by LFB basement rocks.

The basin contains the state's major resources of coal used for domestic consumption and export. Small scale coal mining commenced in the 1790s at Newcastle, with larger underground mines operating from the 1850s. Mines are located around the edges of the basin in the Southern Coalfields (south of Appin and along the Wollongong coast), Western Coalfields (around Lithgow and Ulan) and throughout the Hunter Valley. Coal seam gas is extracted from several underground mines and a small coal seam gas wellfield in Camden supplies gas for domestic use.

For groundwater management purposes, the Sydney Basin is covered by several WSPs[13] and is split into multiple groundwater sources in both inland and coastal catchments.

The sedimentary rock sequence is around 5,000 m thick in the central part of the basin however the deeper and older rocks associated with the coal seams (a banded deposit of coal that is visible within layers of rock) do not yield groundwater of sufficient quantity or quality for use. It is the younger Triassic sandstones within and around the edges of the basin that have the greatest potential for water supply. Unfortunately, beneath Sydney these sandstones are overlain by a thick marine shale sequence that impedes rainfall recharge and degrades the sandstone groundwater quality. Groundwater is recharged through direct rainfall infiltration in outcrop areas. Groundwater then flows laterally from recharge areas to discharge areas. In some areas, groundwater is tens of thousands to hundreds of thousands of years old.

A brief description of the 11 groundwater sources within this groundwater resource is provided in Table 9.



Highlights

- Sandstone aquifers that occur around the fringes of the Sydney Basin are the primary aquifers.
- Deeper coal seams have low yields and poor water quality.
- High yields are possible from deep large diameter bores in sandstone aquifers in structurally deformed areas.
- Water quality is excellent close to the recharge areas and is suitable for most consumptive uses including drinking water.
- Coal mining intercepts groundwater which is mostly reused.
- There are numerous terrestrial vegetation, swamps and baseflow ecosystem GDEs associated with this groundwater resource.

13. *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (to be replaced by Draft replacement of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources), Water Sharing Plan for the NSW Murray–Darling Basin Porous Rock Groundwater Sources Order 2020* and *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016.*

Table 9. Groundwater attributes of groundwater sources within the Sydney Basin

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)*	Salinity (mg/L TDS)*	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Kulnura-Mangrove Mountain	20 to 100	1 to 8	100 to 300	Stock and domestic Small scale irrigation Bottled water	5,700	Terrestrial vegetation, springs and baseflow ecosystems
Sydney Basin – North Coast	20 to 100	1 to 10	200 to 1,000	Stock and domestic Mining	90,000	Terrestrial vegetation, springs, and baseflow ecosystems
Sydney Basin – South Coast	20 to 100	1 to 10	200 to 1,000	Stock and domestic Small scale irrigation	3,100	Terrestrial vegetation, springs and baseflow ecosystems
Sydney Basin West	20 to 300	<1 to 50	100 to 500	Stock and domestic Mining Small scale irrigation	45,250	Swamps, springs and baseflow ecosystems
Sydney Basin Central	20 to 300	<1 to 10	500 to 2,000	Industrial Recreation Mining	45,915	Terrestrial vegetation, springs, baseflow ecosystems
Sydney Basin Murray–Darling Basin	20 to 60	1 to 10	200 to 750	Stock and domestic Mining	19,100	Springs, baseflow ecosystems
Sydney Basin Nepean	20 to 200	5 to 50	50 to 300	Stock and domestic Irrigation Bottled water Mining	99,568	Terrestrial vegetation, swamps, springs and baseflow ecosystems
Sydney Basin North	20 to 150	1 to 30	200 to 1,000	Stock and domestic	19,682	Springs, baseflow ecosystems
Sydney Basin South	20 to 150	1 to 30	200 to 1,000	Stock and domestic	69,892	Springs, baseflow ecosystems

*These depths, yields and salinities relate to the primary aquifers in the Triassic sandstones.

The highest bore yields and best water quality are found in the Hawkesbury Sandstone, the main regional aquifer. In areas where the sandstone has been deformed by fracturing and faulting, large supplies of up to 50 L/s are possible at selected sites (such as at Kangaloon, Wallacia and Leonay). Typically, water levels are deep at elevated sites, but artesian conditions are known at selected sites along the base of the Lapstone Structural Complex that extends from Bargo in the south to Kurrajong in the north.

Groundwater in the Sydney Basin generally has low salinity and is suitable for most uses except in areas affected by overlying or adjacent marine shales.

In the Sydney Basin groundwater is used for a wide variety of purposes including bottled water, small scale irrigation, stock and domestic, recreation and some industrial/commercial purposes. Incidental groundwater is captured by coal mines across the basin (mostly from underground operations) and then used on-site. If there is water left over, it is treated and disposed of or supplied to others for uses such as irrigation and power generation. Currently, there is limited use of groundwater for town supply. Deep sandstone aquifers in the Kangaloon-Bowral area and in western Sydney at Wallacia and Leonay/Emu Plains have been identified as potential emergency drought water supply sources for local communities across the Greater Sydney area.

Natural discharges from sandstone aquifers via springs and seeps also sustain GDEs across the basin. Most GDEs are localised features and include terrestrial vegetation, swamps, springs and baseflow ecosystems. The Temperate Highland Peat Swamps on Sandstone ecological community (distributed temporary and permanent swamps) is an important example of a GDE that occurs on the sandstone outcrops of the southern and western Sydney Basin.

Expansion of the Greater Sydney urban and peri-urban areas will increase the demand for water to supply a growing population and associated commercial/industrial activities. Groundwater is likely to be part of the solution. With the closure of coal mines in future decades additional groundwater will be available for use, however the location and quality of this water may not align with the city's growth centres. Controlling mine water and repurposing closed mine sites will be challenging. Nevertheless, land use changes and economic development will present opportunities to better protect, manage and use groundwater resources for future sustainable uses. This is a priority under the NSW Groundwater Strategy Priority 2 (Action 2.3).

There are monitoring networks established by Department of Planning and Environment–Water and WaterNSW across some water sources where there is moderate to high use of groundwater; however, other underdeveloped water sources have negligible or no monitoring networks in place.

Further reading:

Department of Planning, Industry and Environment 2019, *Groundwater Resource Description NSW Murray–Darling Basin Porous Rock Water Resource*.

Department of Primary Industries–OoW, 2011 *Water Sharing Plan Greater Metropolitan Region Groundwater Sources – Background document*.

Department of Primary Industries–Water 2012, *Water Sharing Plan for the Murray–Darling Basin Porous Rock Groundwater Sources – Background document*.

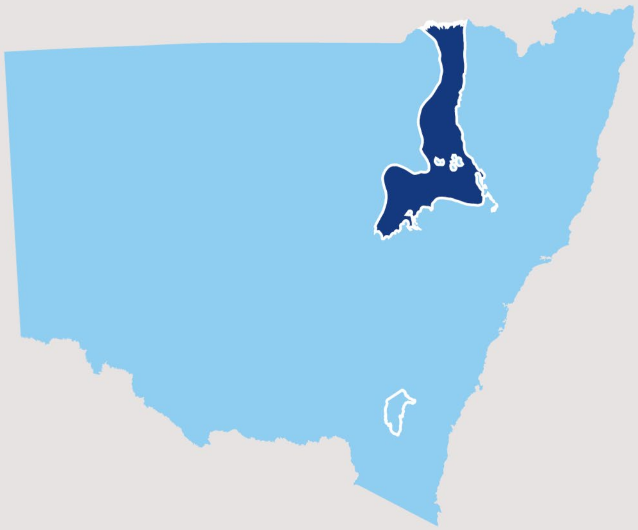
Department of Primary Industries–2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background document*.

Department of Primary Industries–2016, *Water Sharing Plan for the South Coast Fractured and Porous Rock Groundwater Sources – Background document*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Image courtesy of Department of Planning and Environment.
Prospect Reservoir, Greater Sydney.

Gunnedah–Bowen Basin



The Gunnedah–Bowen Basin is an old sedimentary basin that is part of the Sydney–Gunnedah–Bowen Basin system. It is a major sedimentary basin extending from southern coastal NSW to central Queensland. The Gunnedah–Bowen Basin covers an area of approximately 40,000 km². It is underlain by LFB basement rocks and is overlain to the north and to the west by the Surat Basin (part of the GAB).

The Bowen Basin is totally buried in NSW, and a large portion of the Gunnedah Basin is also buried beneath the GAB and alluvial sediments. Most of the Gunnedah Basin underlies the fertile Liverpool Plains of the Mooki Valley and the floodplain areas of the Namoi Valley from Carroll to Narrabri. The Gunnedah Basin contains additional resources of coal used for domestic use and export. Small scale coal underground mining commenced in the Gunnedah region in the 1880s. Today, open cut mines are mostly located between Gunnedah and Narrabri. The Narrabri Gas Project has been approved but not currently constructed to extract coal seam gas for domestic use from the Pilliga State Forest area located south of Narrabri.

There is limited use of groundwater from the basin, and consequently there is only one water source defined in WSPs. For management purposes, this water source is combined with the Oxley Basin. Some of the important attributes for the Gunnedah Basin aquifers are summarised in Table 10.

Highlights

- Coal and sandstone aquifers across the basin yield small supplies.
- Coal measure rocks have poor water quality.
- Coal mining intercepts incidental groundwater which is mostly reused.
- There are no known GDEs associated with this groundwater resource.

Table 10. Groundwater attributes of the Gunnedah–Oxley Basin MDB water source

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Gunnedah–Oxley Basin MDB	30 to 90	<1 to 5*	500 to 5,000*	Stock and domestic Mining	127,500**	None known

*The range of expected bore yields and water quality from just the Gunnedah Basin aquifers.

**This extraction limit is for the whole water source; there is no separate limit for the Gunnedah Basin portion of this water source.

The coal and sandstone aquifers yield small supplies of brackish to slightly saline groundwater, which limits its use to mostly stock and limited domestic purposes. Incidental groundwater inflows into coal mines are reused on site.

Little is known about any GDEs across the basin. Few systems are suspected because of the limited outcrop and no obvious groundwater discharge areas.

Limited (if any) growth in demand for groundwater is expected from this basin. With the closure of coal mines in coming decades, groundwater demand may even decline.

Recently the Department of Planning and Environment–Water installed a broad regional monitoring network to assess water levels and quality in the Gunnedah Basin in the vicinity of coal mines and coal seam gas projects. These sites should be sufficient to observe long-term trends and inform management decisions about groundwater use and environmental impacts.

Further reading:

Department of Planning, Industry and Environment 2019, *Groundwater Resource Description NSW Murray–Darling Basin Porous Rock Water Resource.*

Department of Primary Industries–Water 2012, *Water Sharing Plan for the Murray–Darling Basin Porous Rock Groundwater Sources – Background document.*

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwatermanagement-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Darling River Basin 1:1,000,000 scale available for download at: ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/18733

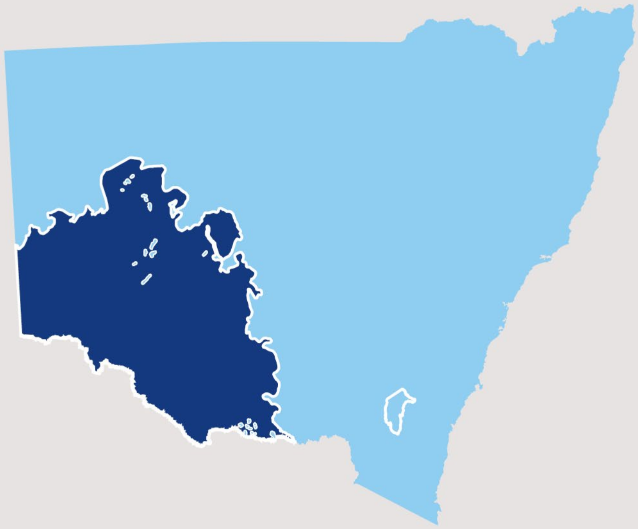
Murray Basin

The Murray Basin is the youngest porous rock basin in NSW and covers a large area of south-western NSW extending into Victoria and South Australia. The Murray Basin includes sequences of poorly consolidated and unconsolidated sediments. Only the sediments found near the surface and the poorly consolidated sediments of the western Murray Basin are covered in this chapter of the Guide. This western portion of the basin is approximately 73,000 km^2 in size. Sediments include basal alluvial and estuarine sediments, then poorly consolidated marine limestones, and marine sands near the surface. The marine limestones are 12 to 32 million years old, while deeper sediments are up to 50 million years old.

The unconsolidated sediments for the remainder of the basin are considered as unconsolidated sediment groundwater systems, and discussed later in this Guide.

The basin overlies several basement depressions, containing older rocks (mostly Darling Basin sedimentary rocks and younger unnamed basin sedimentary rocks).

Most of the groundwater is saline and managed as a single water source known at the Western Murray Porous Rock water source. A brief description of this water source is provided in Table 11.



Highlights

- Porous rock aquifers of the western Murray Basin are highly permeable but contain saline water.
- Large yields are possible from bores in the fluvial and marine sand units.
- Water quality is only suitable for limited stock and mining purposes.
- Where shallow freshwater lenses exist then water is suitable for domestic use.
- This shallow freshwater also sustains important GDEs such as riparian vegetation and wetlands.

Table 11. Groundwater attributes of the Western Murray Porous Rock water source

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs*
Western Murray Porous Rock	20 to 500	1 to 100	3,000 to 30,000*	Stock Mining Salt interception schemes	226,000	Riparian vegetation, wetlands

*Thin lenses of fresh water can occur near the surface at the water table to sustain GDEs and support limited stock and domestic uses.

The shallow groundwater in the marine sand units is connected to the Murray and Darling rivers. The interaction between the rivers and shallow groundwater is complex and dynamic. For instance, in the Lower Murray River prior to reaching the South Australian border, the river alternates from losing to gaining conditions.

SISs operate where large volumes of salty groundwater discharge to the river. In NSW, these schemes include the Mallee Cliffs SIS and the Buronga SIS. SIS locations across the Murray–Darling Basin are shown in Figure 11.

Figure 11. SIS schemes across the Murray–Darling Basin

Legend:

1 Waikerie	8 Rufus River
2 Qualco–Sunlands (*State managed scheme*)	9 Mildura–Merbein
3 Woolpunda	10 Buronga
4 Loxton	11 Mallee Cliffs
5 Bookpurnong	12 Upper Darling (*downstream of Bourke*)
6 Pike	13 Barr Creek (*drainage diversion scheme*)
7 Murtho	14 Pyramid Creek

Source: Murray–Darling Basin Authority, www.mdba.gov.au/issues-murray-darling-basin/salinity

In recent years there has been an expansion in heavy mineral sand mining of beach deposits in this western portion of the Murray Basin. In some instances where dewatering below the water table is required, large volumes of saline groundwater need to be pumped and disposed of in leaky basins or reinjected back into the shallow aquifer at distance from the mine sites.

There are substantial terrestrial vegetation and wetland GDEs located along riverbanks and anabranches where there are shallow lenses of freshwater. Examples include river red gums within the Kemendok National Park located between Euston and Mildura, and the Millewa Forest located further east. These communities have high ecological value as they contain threatened flora and fauna species.

Localised groundwater demand for mining is expected to increase in future years north of Euston and west of Balranald, but regionally across the whole resource little change in use is expected as most of the groundwater is saline and not suitable for agriculture.

There are more than 700 monitoring bores installed across this water source. These include regional nested bores monitoring different aquifers at different depths, and local shallow monitoring bores monitoring groundwater in the vicinity of the Murray and Darling rivers in association with each SIS.

Further reading:

Department of Planning, Industry and Environment 2019, *Groundwater Resource Description NSW Murray–Darling Basin Porous Rock Water Resource*.

Department of Primary Industries–Water 2012, *Water Sharing Plan for the Murray–Darling Basin Porous Rock Groundwater Sources – Background document.*

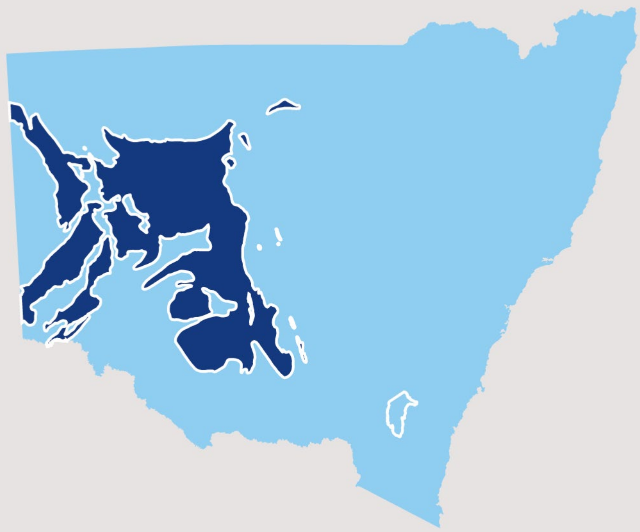
Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Murray Basin 1:250,000 scale series (Ana Branch, Menindee, Manara, Pooncarie, Balranald sheets) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Image courtesy of Wentworth Shire Council. Darling and Murray River junction.

Darling Basin



The Darling Basin, located in western-central NSW, is a series of smaller deformed basins and is the oldest sedimentary basin in NSW with sedimentary rocks reaching up to 8,000 m in thickness. It mostly occurs west of Cobar, east of Broken Hill and west of Narrandera. A large portion of the Darling Basin is buried beneath the Eromanga Basin (part of the GAB) to the north and the Murray Basin to the south. Covering an area of over 100,000 km^2 it is one of Australia's largest underexplored basins for minerals, oil and gas, and groundwater.

Currently there is negligible use of groundwater from the basin; consequently, this basin is not separated out into its own water source. For management purposes, this water source is part of the Lachlan Fold Belt MDB and Kanmantoo Fold Belt MDB water sources (see chapter 2 – Fractured rock groundwater resources).

It is suspected that low salinity groundwater and yields up to 10 L/s may be possible from the sandstone aquifers at shallow depths (less than 250 m from surface) close to recharge areas. Substantial groundwater investigation programs are required to determine the basin's potential as a useful groundwater resource. There are no known GDEs associated with this groundwater resource because most of the basin is buried beneath the GAB and Murray Basin.

It is unlikely there will be any appreciable groundwater development across this basin in the short-to-medium term. Growth in population is not expected; however, increased water demand from mining and industry may trigger increased use.

There is no established groundwater monitoring network across this basin.

Highlights

- Very little is known about the groundwater resources of this basin.

Other minor basins

There are several smaller sedimentary basins across NSW that have limited porous rock groundwater resources. These basins are all Permian sedimentary basins around 300 million years old that contain deformed sandstone, coal and mudstone rocks. Some of these resources have defined water sources under different WSPs.

Gloucester Basin

The Gloucester Basin is a relatively small sedimentary basin located in the Upper Manning and Karuah River catchments, approximately 40 km long, 10 km wide and 3,000 m thick with a total area of 380 km^2. It contains coal and coal seam gas resources; only the coal resources of the basin are developed.

Groundwater is low yield and mostly brackish to slightly saline. There is very low groundwater use for stock and limited domestic purposes, and minor incidental water take during open cut coal mining operations. There are no known GDEs.

Bulahdelah Sandstone

The Bulahdelah Sandstone is another small sedimentary basin located 60 to 70 km north of Newcastle and is approximately 25 km long and 5 km wide but of unknown depth.

Groundwater is low yield and mostly brackish to slightly saline. There is very low groundwater use for stock and limited domestic purposes only. There are no known GDEs.

Lorne Basin

The Lorne Basin is a small sedimentary basin located south of Port Macquarie. It is a shallow basin that is mostly circular, about 950 km^2 in size and approximately 200 m thick.

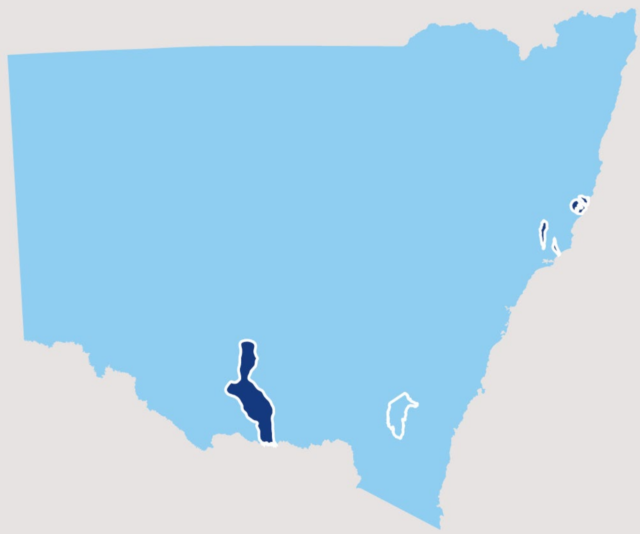
Groundwater is low yield and mostly brackish. There is very low groundwater use for stock and limited domestic purposes only. There are no known GDEs.

Oaklands Basin

The Oaklands Basin is a buried sedimentary basin centred on Jerilderie in the Riverina district of southern NSW. It covers an area of about 3,800 km^2 and has a maximum depth of approximately 2,000 m. The basin extends north-northwest over approximately 120 km and is approximately 50 km wide. It lies in a basement structure beneath the eastern portion of the Murray Basin and is completely buried.

Groundwater is expected to be low yield and mostly saline. There is no groundwater use and there are no GDEs.

A brief description of these water sources is provided in Table 12.



Highlights

- Very little is known about the groundwater resources of these basins.

Table 12. Groundwater attributes of the minor porous rock water sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Gloucester Basin	30 to 75	<0.5 to 1	500 to 3,000	Stock and domestic Mining	2,030	None known
Bulahdelah Sandstone	30 to 75	<0.5	Unknown	Stock and domestic	130	None known
Lorne Basin	30 to 75	<0.5	500 to 1,500	Stock and domestic	9,500	None known
Oaklands Basin	Unknown	Unknown	Unknown	None	2,500	None

There is unlikely to be any increased demand for groundwater from these water sources given their small size, low yields and marginal water quality.

Negligible growth in population and demand for groundwater is expected across most of these water sources in future years.

Department of Planning and Environment–Water has installed a small groundwater monitoring network to assess water levels and quality trends in the Gloucester Basin. There is no monitoring in the other basins.

Further reading:

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources – Background document.*

Department of Planning, Industry and Environment 2019, *Groundwater Resource Description NSW Murray–Darling Basin Porous Rock Water Resource*.

Department of Primary Industries–Water 2012, *Water Sharing Plan for the Murray–Darling Basin Porous Rock Groundwater Sources – Background document.*

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Murray Basin 1:250,000 scale series (Jerilderie) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Unconsolidated sediment groundwater systems

Unconsolidated sediments include river deposited alluvium, as well as windblown and beach sands.

Alluvium is usually found along the floors of valleys and forms large floodplains. These sediments are typically associated with current or ancient watercourses. The catchment geology, watercourse type and water flow rate influence how thick the alluvium is, as well as the sediment type, size and distribution.

Sand deposits are found along the whole of the NSW coast and in inland parts of the Murray–Darling Basin. The coastal sand deposits are derived from sandstones eroded from sedimentary basins (such as the coastal Sydney Basin); inland, the sand deposits are mostly derived from Lachlan Fold Belt granites.

Alluvium

Groundwater is held in the spaces between sand, gravel, pebbles, silt and clay deposits in the alluvium. Sand and gravel aquifers have the highest permeability, while clayey sediments form confining layers and have the lowest permeability. Deposits that are well sorted and are free from silt and clay form productive aquifers and transmit high volumes of groundwater.

Sediment thicknesses can vary from less than 5 m in narrow upstream catchment areas to more than 400 m in downstream alluvial fan areas. The near-surface alluvium is usually Quaternary in age (that is less than 2.6 million years old) while deeper alluvium (if present) is Paleogene in age and can be up to 35 million years old. The Paleogene alluvium is found in buried channels in the bedrock that were carved out when sea levels were lower.

Shallow alluvial aquifers are unconfined and are recharged by direct rainfall infiltration, stream leakage, overbank flooding and side slope runoff. Deep buried alluvial aquifers are confined and receive recharge from vertical leakage from shallow aquifers and throughflow from upstream areas.

The most productive and economically important groundwater systems in NSW are the large inland alluvial systems of the Murray–Darling Basin where much of state's irrigation activities are located. Coastal alluvium is less extensive but local groundwater systems provide valuable supplies for consumptive users and the environment.

Inland irrigated crops include annual crops such as wheat, barley and sorghum, permanent plantings such as citrus and nut plantations, and fibre crops such as cotton. Bores yielding the highest supplies (some more than 300 L/s) are usually located at depth in highly permeable sand and gravel aquifers. Along coastal NSW, most of the alluvial water sources yield less than 20 L/s and are used for stock, domestic and small-scale irrigation of permanent and improved pasture. Apart from widespread use for irrigation, these alluvial aquifers are also accessed by many towns and inland cities for drinking water.

The major productive alluvial areas of the Murray–Darling Basin are shown in Figure 12. In NSW, these areas are located in the Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee and Murray catchments.

Coastal alluvium occurs in all coastal catchments, mostly upstream of the tidal limit. The largest areas of coastal alluvium occur in the mid to lower sections of the Richmond, Manning, Hunter, Hawkesbury and Bega catchments.

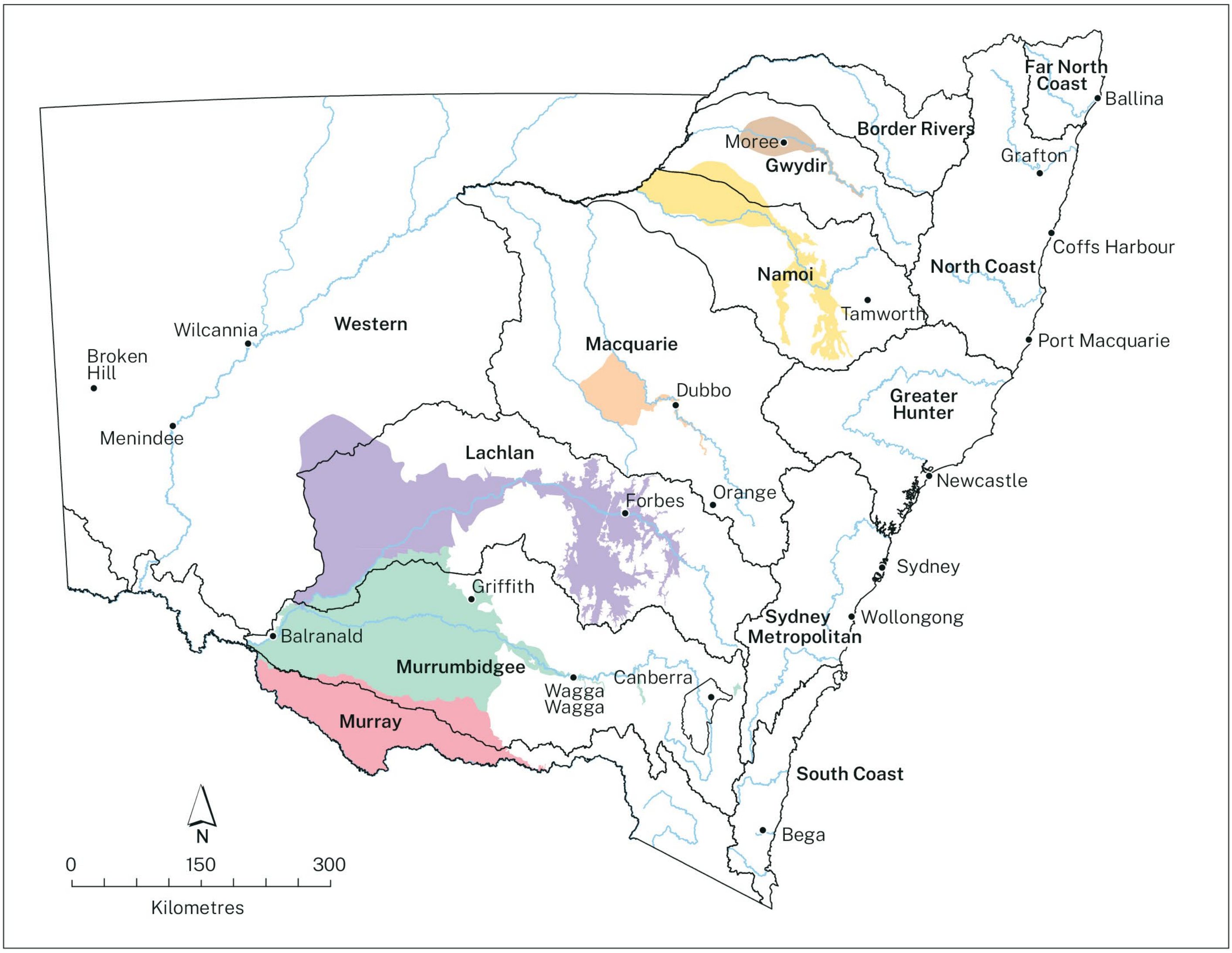
Coastal sands

Sand dune and beach sediments deposited by beach and wind action typically occur in lower coastal catchments next to estuaries, bays and the open ocean. The larger coastal sand dune systems (such as the Tomago–Tomaree system north of Newcastle) comprise an inland barrier dune system and a coastal barrier dune system deposited at different times during the last 50,000 years.

Sand dune aquifers are usually less than 20 m thick but can extend up to 50 m in depth. They are unconfined and are recharged solely by direct rainfall infiltration.

The groundwater sources located within the unconsolidated sediment groundwater systems are listed in Appendix B (Table 30 and Table 31).

Figure 12. Productive alluvial groundwater resources of the Murray–Darling Basin



Legend:

- Water strategy boundary
- Gwydir Alluvium
- Namoi Alluvium
- Macquarie Alluvium
- Lachlan Alluvium
- Murrumbidgee Alluvium
- Murray Alluvium

Northern inland

Gwydir

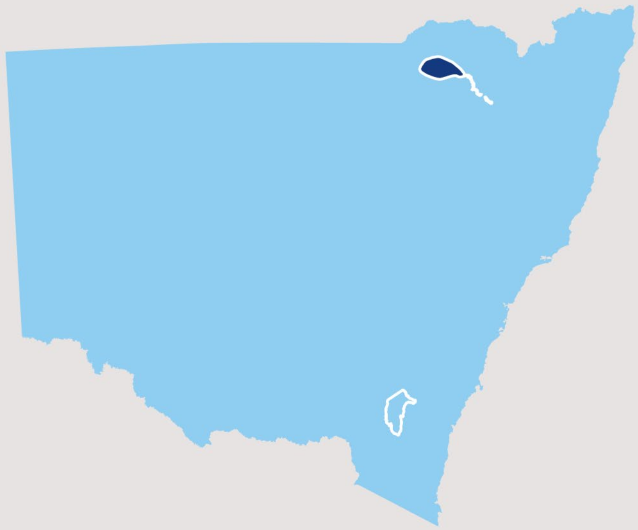
The Gwydir River catchment is a significant inland catchment in northern NSW with moderately large groundwater resources. A large alluvial fan occurs beneath the floodplain area centred on Moree, however, unlike the catchments to the south, there are no substantial upstream alluvial deposits. The Gwydir Alluvial systems have an approximate area of 3,600 km^2 with the lower alluvium accounting for most of the area. Alluvial thickness varies across the floodplain area from about 30 m on the edges of the alluvial fan to a maximum of 90 m in the deepest sections.

Groundwater recharge is through rainfall, stream losses and overbank flooding. The Gwydir River and its branches across the downstream floodplain area are losing streams.

Bore yields are typically less than 5 L/s in the upper alluvial source but can reach 90 L/s in the Lower Gwydir Alluvium. Water quality is almost always low salinity and hence it is used for a wide variety of purposes.

Groundwater development is less than in the southern catchments because of shallow alluvium, thinner aquifers and the greater availability of surface water. It is mainly used for irrigation and town water supply, as well as on-farm stock and domestic use.

A brief description of the 2 alluvial groundwater sources is provided in Table 13.



Highlights

- Moderate bore yields are available across the alluvial fan area.
- Groundwater is low salinity except on the edges of the floodplains and in western areas of the Lower Gwydir water source.
- Groundwater is used extensively for a large variety of uses; irrigation and town water supply are the most important consumptive uses.
- There is strong surface water – shallow groundwater connectivity particularly upstream of Moree.
- There are riparian vegetation and wetland ecosystem GDEs.

Table 13. Groundwater attributes of water sources within the Gwydir River catchment

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Lower Gwydir	20 to 90	5 to 75	200 to 1,000	Stock and domestic Irrigation Town supply	33,000	Riparian vegetation, and wetlands
Upper Gwydir Alluvial	10 to 20	0.5 to 5	Fresh	Stock and domestic	721	Riparian vegetation, and baseflow ecosystems

There are several towns and villages across the catchment, including Moree, that use groundwater as their drinking water source and for commercial activities.

Riparian vegetation (particularly river red gum woodland communities) is likely to be groundwater dependent in the upper and mid catchment areas. High and very high ecological value GDEs have been identified in the western part of the Lower Gwydir Alluvium and are collectively known as the Gwydir wetlands.

With the development of the Moree Special Activation Precinct[14] (leveraging the Inland Rail project), some growth in agribusiness, logistics and industrial/commercial activities and associated water use is expected. Population growth across the local government area, together with economic development, may pose challenges to future groundwater availability and use, although irrigation is expected to remain the primary driver of access and use.

There is a large monitoring network of 123 monitoring bores at 58 sites across the Lower Gwydir water source that has been established since the 1970s to monitor groundwater level and water quality trends.

Further reading:

Department of Planning, Industry and Environment 2018, *Gwydir Alluvium Water Resource Plan – Groundwater Resource Description*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Gwydir Groundwater Source*.

Department of Planning and Environment 2022, *Lower Gwydir Groundwater Source – 2021 Groundwater level review*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0020/192323/Gwydir-alluvium-resource-description-report.pdf

Mapping:

Moree 1:250,000 scale series available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Image courtesy of Department of Planning and Environment. River red gum.

14. www.planning.nsw.gov.au/Plans-for-your-area/Special-Activation-Precincts/Moree-SAP

Namoi

The Namoi River catchment is one of the Murray–Darling Basin's largest catchments. Extensive alluvial deposits are found in the floodplain areas of the Namoi, Mooki and Coxs Creek catchments. Shallower deposits are found along valley floors in upstream catchments, with the major tributary being the Peel River centred on Tamworth. Alluvial thicknesses increase downstream, with 10 to 30 m of sediments in upstream catchments and more than 120 m of sediments in areas downstream of Narrabri. The total size of the low salinity resource area is approximately 12,000 km^2.

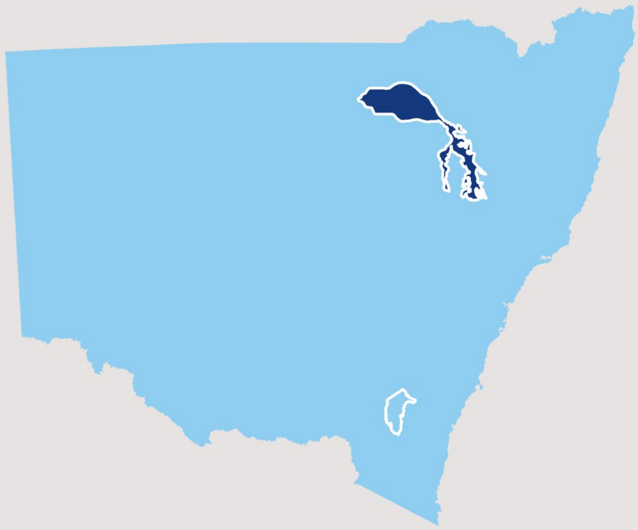
The alluvium hosts a major alluvial groundwater resource recharged by rainfall, stream losses and overbank flooding. There is strong hydraulic connection between groundwater in shallow aquifers and surface water, particularly along the regulated rivers in the areas upstream of Narrabri.

Bore yields are typically less than 20 L/s from shallow aquifers but can reach 130 L/s from deep aquifers in the palaeochannel areas. Water quality is almost always low salinity and hence it is used for a wide variety of purposes.

There is a very high demand for groundwater for consumptive uses including irrigation, mining and industrial/commercial purposes, as well as supply for town water and stock and domestic use. The growth of the cotton industry since the 1960s has been the main driver for increased groundwater use in the 1970s, 1980s and 1990s.

Groundwater use for irrigation is very high in most water sources and in most seasons. Volumes pumped are close to extraction limits. Consequently, there are permanent water level declines in some deep aquifers remote from recharge sources.

Brief descriptions of the 18 groundwater sources within the Namoi are provided in Table 14.



Highlights

- High bore yields are available across most alluvial areas.
- Groundwater is low salinity except on the edges of the floodplains and in western areas of the Lower Namoi water source.
- Groundwater is widely used for a large variety of uses; irrigation and town water supply are the most important consumptive uses.
- There is strong surface water – shallow groundwater connectivity along the regulated rivers upstream of Narrabri.
- There are riparian vegetation and wetland ecosystem GDEs in the mid-upstream catchment areas.

Image courtesy of Destination NSW. Cotton Farm, Moree.

Table 14. Groundwater attributes of groundwater sources within the Namoi River catchment

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Currabubula Alluvial	10 to 20	1 to 2.5	Fresh	Stock and domestic Small scale irrigation	60	NA
Lower Namoi	30 to 130	5 to 150	200 to 1,500	Stock and domestic Irrigation Town water	88,255	Riparian vegetation
Manilla Alluvial	10 to 20	1 to 15	Fresh	Stock and domestic Small scale irrigation	1,229	NA
Peel Alluvium	10 to 40	5 to 50	200 to 500	Stock and domestic Small scale irrigation Commercial	9,344	Riparian vegetation, and baseflow ecosystems
Quipolly Alluvial	10 to 20	<1 to 2	Fresh	Stock and domestic Small scale irrigation	476	NA
Quirindi Alluvial	10 to 20	1 to 15	Fresh	Stock and domestic Small scale irrigation	1,231	NA
Upper Namoi Zone 1, Borambil Creek	10 to 40	1 to 20	Fresh	Stock and domestic Small scale irrigation Town supply	2,127	Riparian vegetation
Upper Namoi Zone 2, Cox's Creek	30 to 120	5 to 100	Variable	Stock and domestic Irrigation Town supply	7,327	Riparian vegetation
Upper Namoi Zone 3, Mooki Valley (Breeza to Gunnedah)	30 to 120	5 to 120	300 to 1,300	Stock and domestic Irrigation Town supply	17,499	Riparian vegetation
Upper Namoi Zone 4, Namoi Valley (Keepit Dam to Gin's Leap)	30 to 120	5 to 120	300 to 1,000	Stock and domestic Irrigation Town supply	26,121	Riparian vegetation, and baseflow ecosystems

Table 14. Groundwater attributes of groundwater sources within the Namoi River catchment (continued)

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Upper Namoi Zone 5, Namoi Valley (Gin's Leap to Narrabri)	30 to 120	5 to 80	300 to 1,000	Stock and domestic Irrigation Mining Town supply	16,128	Riparian vegetation, and baseflow ecosystems
Upper Namoi Zone 6, Tributaries of the Liverpool Range (South to Pine Ridge Road)	10 to 40	1 to 50	Fresh	Stock and domestic Small scale irrigation	14,096	Riparian vegetation
Upper Namoi Zone 7, Yarraman Creek (East of Lake Goran to Mooki River)	10 to 40	1 to 50	Fresh	Stock and domestic Small scale irrigation	3,721	NA
Upper Namoi Zone 8, Mooki Valley (Quirindi - Pine Ridge Road to Breeza)	30 to 100	5 to 80	200 to 600	Stock and domestic Irrigation Town supply	16,114	Riparian vegetation
Upper Namoi Zone 9, (Cox's Creek (Up-stream Mullaley)	10 to 90	5 to 80	200 to 600	Stock and domestic Small scale irrigation Town supply	11,441	Riparian vegetation
Upper Namoi Zone 10, Warrah Creek	10 to 20	1 to 20	Fresh	Stock and domestic Small scale irrigation	4,518	NA
Upper Namoi Zone 11, Maules Creek	10 to 30	5 to 40	100 to 600	Stock and domestic Small scale irrigation	2,269	NA
Upper Namoi Zone 12, Kelvin Valley	10 to 20	1 to 10	Fresh	Stock and domestic Small scale irrigation	2,042	NA

Groundwater use surges in drought years when surface water is unavailable for irrigation, as cotton, cereal and stock feed crops such as sorghum require intensive watering. In upper catchment areas, irrigation of permanent pasture dominates. Most irrigation is flood irrigation in the large floodplain areas; in the smaller more confined areas of the upper catchments, pivot and spray irrigation is common.

There are many towns and villages including Quirindi, Gunnedah and Narrabri, that use groundwater as their drinking water source across the catchment.

GDEs are common across each of the groundwater sources. These include terrestrial vegetation along riparian corridors and baseflow discharges in gaining sections of the major rivers and creeks. The dominant GDE vegetation communities include river red gum riparian woodlands, other riparian forests and woodlands, and shallow freshwater wetlands. There is one wetland of national significance: the ephemeral Lake Goran, located in the Mooki River catchment north west of Spring Ridge towards Mullaley.

The Narrabri Special Activation Precinct will see growth in agribusiness, logistics and associated industrial/commercial water use. Population growth centred on the Tamworth region, together with land use changes and economic development, may impact on groundwater availability and use as the alluvial (and fractured rock) groundwater sources are fully committed.

Groundwater level and water quality trends are monitored by a very large network of 580 monitoring bores at 243 sites across the Lower Namoi water source, 640 monitoring bores at 330 sites across the Upper Namoi water sources and 63 monitoring bores at 62 sites in upper catchment areas (Peel and Cockburn River areas). Some of these sites were established and have been operational since the 1960s. Maintenance of this network is the primary challenge given its age and susceptibility to flood damage. This is a priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Image courtesy of Destination NSW. Yarran Wines, Yenda.

Further reading:

CSIRO 2020, *Ground displacements in the Lower Namoi region*.

Department of Planning, Industry and Environment 2019, *Namoi Alluvium Water Resource Plan – Groundwater Resource Description*.

Department of Planning, Industry and Environment 2021, *Lower Namoi Groundwater Source – Preliminary analysis of influence of groundwater extraction on water quality: 2003-2019*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Namoi Groundwater Source*.

Department of Planning, Industry and Environment 2020, *Groundwater Annual Report – Upper Namoi Zone 1 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 2 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 3 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 4 and 12 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 5 and 11 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 6 and 10 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 7 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 8 Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Namoi Zone 9 Groundwater Source*.

Department of Planning and Environment 2022, *Upper and Lower Namoi groundwater sources – 2021 Groundwater level review*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0017/230804/Namoi-Alluvium-WRP-resource-description.pdf

Mapping:

Narrabri 1:250,000 scale series available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Macquarie–Castlereagh

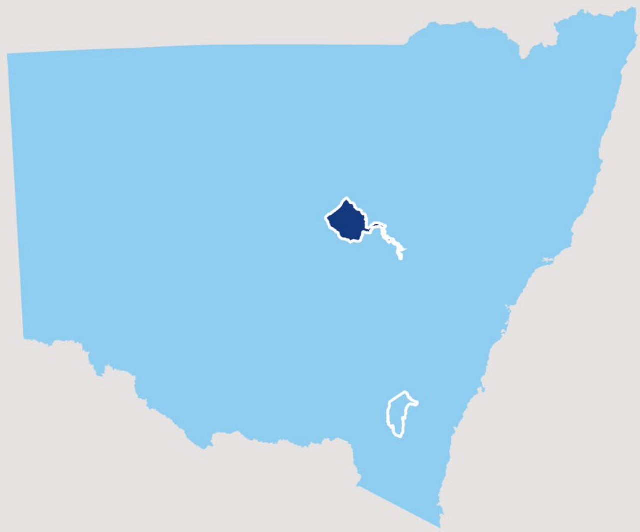
The combined Macquarie and Castlereagh River catchment is another of the Murray–Darling Basin's major catchments. Many alluvial deposits occur along the floodplain areas of the Macquarie and Castlereagh catchments, together with shallower deposits along valley floors in the upstream Cudgegong and Bell River catchments. Alluvial thicknesses increase downstream, with 10 to 30 m of sediments in upstream catchments and more than 120 m of sediments in areas downstream of Narromine. The total size of the low salinity resource area across all water sources is approximately 5,000 km^2.

Downstream of the Talbragar and Macquarie River confluence, the Upper Macquarie Alluvium intersects underlying GAB sandstone sequences. Some degree of groundwater connection between the alluvium and the GAB is expected. Conductivity measurements predict that groundwater flows from the alluvium into the GAB.

The alluvium hosts a major groundwater resource recharged by rainfall, stream losses and overbank flooding. There is strong hydraulic connection between groundwater in shallow aquifers and surface water, particularly along the Macquarie River upstream of Narromine and Cudgegong River upstream of Mudgee. There is a very high demand for groundwater for irrigation, supply for town water, and stock and domestic use.

Bore yields are typically less than 25 L/s from shallow aquifers but can reach 180 L/s from deep aquifers in the lower valley palaeochannel areas. Water quality is almost always low salinity and is used for a wide variety of purposes.

The 11 groundwater sources within this catchment are described briefly in Table 15.



Highlights

- High bore yields are available across most alluvial areas.
- Groundwater is low salinity except in north-western areas of the Lower Macquarie water sources.
- Groundwater is used extensively for a large variety of uses; irrigation and town water supply are the most important consumptive uses.
- There is strong surface water – shallow groundwater connectivity along the regulated rivers particularly upstream of Narromine.
- There are riparian vegetation GDEs along most of the rivers in the mid-upstream catchment areas.

Table 15. Groundwater attributes of groundwater sources within the Macquarie–Castlereagh River catchments

Groundwater source	Range of aquifer depths (m)*	Typical bore yields (L/s)*	Salinity (mg/L TDS)*	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Bell Alluvial	10 to 25	5 to 20	Fresh	Stock and domestic Small scale irrigation	3,299	Riparian vegetation, and baseflow ecosystems
Castlereagh Alluvial	20 to 80	1 to 10	200-1,000	Stock and domestic Small scale irrigation Town supply	621	Riparian vegetation
Cudgegong Alluvial	5 to 25	1 to 30	200 to 600	Stock and domestic Small scale irrigation Town supply	2,533	Riparian vegetation, and baseflow ecosystems
Lower Macquarie Zone 1	15 to 120	10 to 150	200 to 1,000	Stock and domestic Irrigation Town supply	21,807	Riparian vegetation
Lower Macquarie Zone 2	15 to 130	10 to 120	400 to 2,000	Stock and domestic Irrigation	22,761	None known
Lower Macquarie Zone 3	15 to 180*	10 to 70*	500 to 1,500*	Stock and domestic Irrigation Town supply	9,752	Riparian vegetation
Lower Macquarie Zone 4	15 to 160*	10 to 70*	500 to 2,000*	Stock and domestic Irrigation	5,326	None known
Lower Macquarie Zone 5	15 to 160*	1 to 10*	1,000 to 5,000*	Stock and domestic	2,871	None known
Lower Macquarie Zone 6	15 to 100	10 to 70	200 to 1,000	Stock and domestic Irrigation	8,202	Riparian vegetation
Talbragar Alluvial	15 to 60	1 to 60	200 to 800	Stock and domestic Small scale irrigation Town supply	3,473	Riparian vegetation, and baseflow ecosystems
Upper Macquarie	15 to 90	1 to 60	200 to 800	Stock and domestic Small scale irrigation Town supply	17,935	Riparian vegetation, and baseflow ecosystems

*These depths, yields and salinities relate to the combined alluvial and GAB sandstone aquifers managed under these water sources.

The groundwater is mostly fresh close to the regulated rivers where there is a lot of river recharge. In the Lower Macquarie area, downstream of Narromine (particularly westwards in the Bogan River catchment), salinity increases to levels where it is only suitable for stock purposes.

Major irrigation use is for cotton and a variety of cereal crops in the Lower Macquarie. In the Upper Macquarie and tributary valleys, the irrigation of pasture and fodder crops such as lucerne, vegetables, wine grapes and orchards of various types is common.

There are numerous towns and villages across the catchment including Mudgee, Dubbo and Narromine that use groundwater as their sole or supplementary drinking water source.

GDEs are common across each of the groundwater sources in the upstream and mid catchment areas. These include terrestrial vegetation along riparian corridors and baseflow discharges in gaining sections of the regulated rivers. The dominant GDE vegetation communities include river red gum riparian woodlands, and other riparian forests and woodlands.

Irrigation and mining are likely to remain as the largest future drivers of demand. Population growth at large regional centres such as Bathurst, Mudgee, Orange and Dubbo, together with associated land use changes and economic development, may pose challenges to future groundwater availability and use as the alluvial groundwater sources are fully committed.

A medium sized monitoring network – more than 59 monitoring bores at 41 sites across the Lower Macquarie water source and 55 monitoring bores at 45 sites across the Upper Macquarie water source – monitors groundwater level and water quality trends. In addition, there are small monitoring networks in the Bell and Cudgegong valleys, and in the Castlereagh catchment. Maintenance and expansion of this network is the primary challenge because of increasing development and use. This is a priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Further reading:

Department of Planning, Industry and Environment 2018, *Macquarie–Castlereagh Alluvium Water Resource Plan – Groundwater Resource Description*.

Department of Planning, Industry and Environment 2020, *Groundwater Annual Report – Bell Alluvial Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Cudgegong Alluvial Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Macquarie Alluvial Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Macquarie Sandstone Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Talbragar Alluvial Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Macquarie Alluvial Groundwater Source*.

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0017/192221/macquarie–castlereagh-alluvium-appendix-a-water-resource-description.pdf

Image courtesy of Destination NSW. Calabria Family Wines, Griffith.

Southern inland

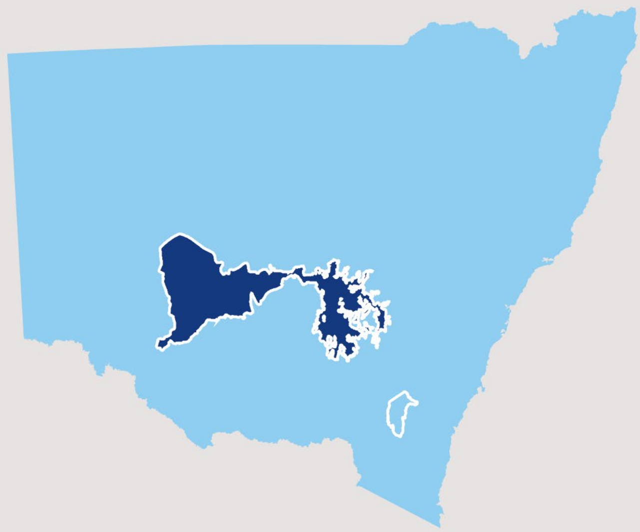
Lachlan

The Lachlan River catchment is another of the Murray–Darling Basin's major catchments in central western NSW. Large alluvial deposits occur along the floodplain areas of the Lachlan and Bland Creek catchments, together with shallower deposits along valley floors in the upstream Belubula River and Back Creek catchments. Alluvial thicknesses increase downstream, with 10 to 30 m of sediments in upstream catchments and more than 400 m of sediments in areas downstream of Hillston. The Lachlan Alluvium is the largest in the state with an approximate area of 54,000 km^2.

The alluvium hosts a major groundwater resource recharged by rainfall, stream losses and overbank flooding. There is strong hydraulic connection between groundwater in shallow aquifers and surface water particularly along the regulated Lachlan and Belubula rivers in upper and mid-catchment areas. There is a very high demand for groundwater for irrigation, water supply for town water, mining and stock and domestic use.

Bore yields are typically less than 20 L/s from shallow aquifers but can reach 150 L/s from deep aquifers in the palaeochannel areas, and 300 L/s from deep aquifers in the lower valley alluvial fan area. Water quality is almost always low salinity and is used for a wide variety of purposes.

The 3 alluvial groundwater sources within this catchment are described briefly in Table 16.



Highlights

- High bore yields are available across most alluvial areas.
- Aquifers generally have low salinity except those floodplains areas remote from regulated rivers and in the far western area of the Lower Lachlan water source.
- Groundwater is used extensively for a large variety of uses; irrigation and town water supply are the most important consumptive uses.
- There is strong surface water – shallow groundwater connectivity along the regulated rivers particularly upstream of Forbes.
- There are riparian vegetation and wetland ecosystem GDEs in the mid and upper catchment areas.

Table 16. Groundwater attributes of water sources within the Lachlan River catchment

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Belubula Valley Alluvial	10 to 40	1 to 20	200 to 600	Stock and domestic Small scale irrigation	2,883	Riparian vegetation, and baseflow ecosystems
Lower Lachlan	50 to 400	20 to 300	500 to 2,000	Stock and domestic Irrigation Town water	117,000	Riparian vegetation
Upper Lachlan Alluvial	30 to 150	20 to 150	200 to 2,500	Stock and domestic Irrigation Mining Town water	94,168	Riparian vegetation, and baseflow ecosystems

The groundwater is mostly fresh close to the rivers where there is a lot of river recharge. Variable water quality occurs in alluvial aquifers in the Bland Creek catchment because of limited vertical recharge from rainfall and long flow paths from upstream recharge areas. In the Lower Lachlan, in the western areas of the alluvial fan, salinity increases to levels where it is only suitable for stock purposes.

Groundwater is used mostly for irrigation of a broad range of crop types (mostly cereals and cotton) and for mining purposes. Many towns and villages, including Parkes, Forbes and Hillston, use groundwater as their drinking water source across the catchment.

GDEs are common across the upstream groundwater sources and, to a lesser extent, in the Lower Lachlan where water tables across the alluvial fan are much lower. GDEs include terrestrial vegetation along riparian corridors, occasional wetlands (such as Lake Cowal) and baseflow discharges in gaining sections of the major rivers. The dominant vegetation communities include river red gum riparian woodlands, other riparian forests and woodlands, and wetlands in the far south-western corner of the resource area near Booligal (Booligal wetlands) and Oxley (the Great Cumbung Swamp).

With the development of the Parkes Special Activation Precinct, some growth in agribusiness, logistics and industrial/commercial activities and associated water use is expected. Population growth in the Parkes-Forbes region and nearby mining operations will place additional demands on groundwater availability and use as the alluvial groundwater sources are fully committed. The NSW Groundwater Strategy aims to address the challenges of water supply and resource protection by working with these communities.

The Lachlan Alluvium contains one of the larger monitoring networks to monitor groundwater level and water quality trends: 189 monitoring bores at 90 sites across the Lower Lachlan water source and 309 monitoring bores at 160 sites across the Upper Lachlan and Belubula Valley water sources. These bores have been established progressively since the 1970s. Maintenance of this network is the primary challenge given its age and susceptibility to flood damage. This is a priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Further reading:

Department of Planning, Industry and Environment 2018, *Lachlan Alluvium Water Resource Plan – Groundwater Resource Description*.

Department of Planning, Industry and Environment 2020, *Groundwater Annual Report – Belubula Valley Alluvial Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Lachlan Groundwater Source*.

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Lachlan Alluvial Groundwater Source*.

Department of Planning and Environment 2022, *Upper Lachlan Alluvial Groundwater Source – 2021 Groundwater Level Review*.

Available for download at www.industry.nsw.gov.au/water/science/groundwater/document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0010/175969/Lachlan-alluvium-appendice-a-water-resource-description.pdf

Mapping:

Forbes 1:250,000 scale series available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Hydrogeology of the Murray Basin 1:250,000 scale series (Cargelligo, Booligal, Ivanhoe sheets) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

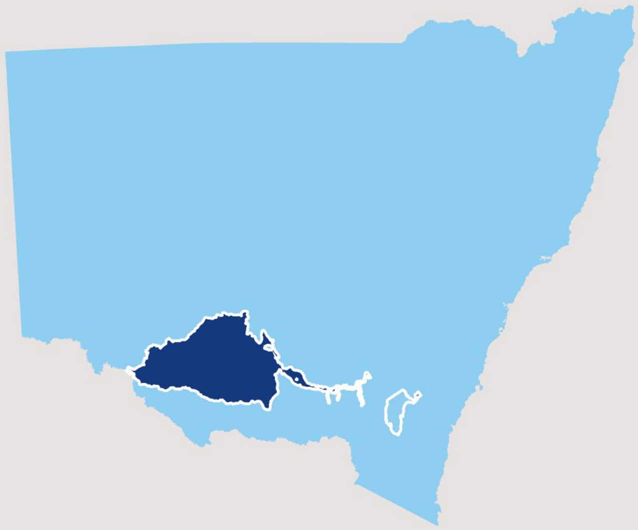
Murrumbidgee

The Murrumbidgee River catchment is the largest inland catchment of the Murray–Darling Basin in southern NSW. Extensive alluvial deposits occur along the floodplain areas of the Murrumbidgee Valley, together with shallower deposits along tributary valley floors in the upstream Tumut River and Kyeamba Creek catchments. Alluvial thicknesses increase downstream, with 10 to 40 m of sediment in tributary catchments and more than 400 m of sediment in areas downstream of Narrandera. The Murrumbidgee Alluvium is the second largest alluvium in the state with and approximate area of 47,000 km^2. A separate small alluvial groundwater source is located in the Lake George catchment north of the ACT where the alluvium is up to 50 m thick.

The alluvium hosts a major groundwater resource recharged by rainfall, stream losses and overbank flooding. There is strong hydraulic connection between groundwater in shallow aquifers and surface water particularly along the major rivers in upper and mid-catchment areas. There is a very high demand for groundwater for irrigation, as well as supply for town water, and stock and domestic use.

Bore yields are typically less than 30 L/s from shallow aquifers but can reach 200 L/s from deep aquifers in the palaeochannel areas, and 350 L/s from deep aquifers in the lower valley alluvial fan area. Water quality is almost always low salinity and is used for a wide variety of purposes.

The 7 alluvial groundwater sources within the Murrumbidgee catchment are described briefly in Table 17.



Highlights

- High bore yields are available across most alluvial areas.
- The highest bore yields in NSW are available in the Lower Murrumbidgee (deep) water source.
- Groundwater has low salinity in mid and upper catchment areas and in deep aquifers of the Lower Murrumbidgee water source.
- Groundwater is used extensively for a large variety of uses; irrigation and town water supply are the most important consumptive uses.
- There is strong surface water – shallow groundwater connectivity along the major rivers particularly upstream of Narrandera.
- There are riparian vegetation and wetland ecosystem GDEs in the mid and upper catchment areas.

Table 17. Groundwater attributes of water sources within the Murrumbidgee River catchment

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Bungendore Alluvial	10 to 50	1 to 15	200 to 500	Stock and domestic Small scale irrigation Town water	1,268	Riparian vegetation, and baseflow ecosystems
Gundagai Alluvial	10 to 30	1 to 30	300 to 1,000	Stock and domestic Small scale irrigation	1,926	Riparian vegetation, and baseflow ecosystems
Kyeamba Alluvial	10 to 40	1 to 30	300 to 1,000	Stock and domestic Small scale irrigation	723	Riparian vegetation, and baseflow ecosystems
Lower Murrumbidgee Deep	40 to 400	20 to 350	500 to 2,000	Stock and domestic Irrigation Town water	273,625	None
Lower Murrumbidgee Shallow	20 to 40	5 to 50	1,000 to 5,000	Stock and domestic Small scale irrigation	26,875	Riparian vegetation
Mid Murrumbidgee Zone 3 Alluvial	20 to 90	10 to 150	300 to 1,000	Stock and domestic Irrigation Town water	30,176	Riparian vegetation, and baseflow ecosystems
Wagga Wagga Alluvial	20 to 90	10 to 200	200 to 500	Stock and domestic Irrigation Town water	3,650*/ 16,998**	Riparian vegetation, and baseflow ecosystems

*Extraction limit for Basic Landholder Right (BLR) and access licences apart from local water utility access licences.

**Extraction limit for local water utility access licences.

The groundwater is fresh close to the major rivers, especially in the mid Murrumbidgee areas in the vicinity of Wagga Wagga. In the Lower Murrumbidgee (deep) aquifer, in the western areas of the alluvial sequence, salinity increases to levels where it is only suitable for stock purposes. Groundwater salinity in the overlying Murrumbidgee (shallow) aquifer, is brackish to slightly saline due to the nature of the soils, shallow soils and sediments and irrigation leakage.

Town water supply use from the mid Murrumbidgee water sources is the highest of anywhere in NSW, with many towns and villages using groundwater as their drinking water source. There are several large borefields operated by Goldenfields Water at Oura and Mt Arthur, and Riverina Water at several locations surrounding Wagga Wagga. These borefields and associated distribution systems service many centres in the mid Murrumbidgee and the adjoining Billabong Creek and Lachlan catchments.

There is also widespread use of groundwater for irrigation purposes, with lucerne and irrigated pasture in upstream areas and broadacre irrigation of annual crops such as cotton and cereals, and permanent plantings such citrus, stone fruit, nuts and wine grapes in lower alluvial floodplain areas.

GDEs are common across the upstream groundwater sources and, to a lesser extent, in the Lower Murrumbidgee where water tables across the alluvial fan are much lower. GDEs include terrestrial vegetation along riparian corridors and baseflow discharges in gaining sections of the regulated rivers. The dominant GDE vegetation communities include river red gum riparian woodlands, other riparian forests, woodlands and wetlands, and wetlands in the far western corner of the resource area near Balranald (mostly within the Yanga National Park and State Conservation Area).

Some growth in agribusiness, logistics and industrial/commercial water use is expected with the development of the Wagga Wagga Special Activation Precinct resulting from the Inland Rail project. Population growth, together with land use changes and economic development, may pose challenges to future groundwater availability and use as all alluvial groundwater sources are fully committed.

Groundwater level and water quality trends are monitored by a very large network of 264 monitoring bores at 152 sites across the Lower Murrumbidgee water source and 204 monitoring bores at 95 sites across the Mid and Upper Murrumbidgee water sources. There is a small monitoring network in the Bungendore water source area. Maintenance of this network is the primary challenge given its age and susceptibility to flood damage. This is a priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Further reading:

Department of Planning, Industry and Environment 2019, *Murrumbidgee Alluvium Water Resource Plan – Resource Description.*

Department of Planning, Industry and Environment 2020, *Groundwater Annual Report – Bungendore Alluvial Groundwater Source.*

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Murrumbidgee Groundwater Source,*

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Mid Murrumbidgee Alluvial Groundwater Source.*

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0017/313127/appendix-a-murrumbidgee-alluvium-wrp-groundwater-resource-description.pdf

Mapping:

Hydrogeology of the Murray Basin 1:250,000 scale series (Narrandera, Hay, Balranald sheets) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

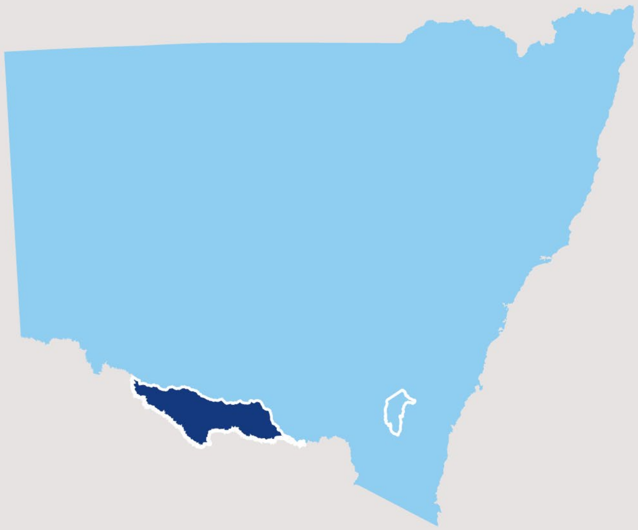
Murray

The Murray River catchment is another of the Murray–Darling Basin's major catchments in southern NSW. Only a portion of the alluvium and associated groundwater resource occurs in NSW. Extensive alluvial deposits occur beneath the floodplain areas of the Murray River, mainly downstream of Corowa. Upstream of Corowa and along Billabong Creek there is deep but less extensive alluvium. Alluvial thicknesses increase downstream, with more than 350 m of sediments in areas downstream of Corowa. The Murray Alluvium has an approximate area of 25,000 km^2.

The alluvium hosts a major groundwater resource recharged by rainfall, stream losses and overbank flooding. There is strong hydraulic connection between groundwater in shallow aquifers and surface water particularly along the regulated rivers. There is a moderate demand for groundwater for irrigation, town water supply, and stock and domestic use. There is also a small SIS in Billabong Creek north of Walla Walla that pumps deep groundwater to control water levels and saline discharges to the creek.

Bore yields are typically less than 20 L/s from shallow aquifers but can reach 120 L/s from deep aquifers in the palaeochannel areas, and 300 L/s from deep aquifers in the lower valley alluvial fan area. Water quality is almost always low salinity and is used for a wide variety of purposes.

The 4 groundwater sources within this groundwater resource are described briefly in Table 18.



Highlights

- High bore yields are available across most alluvial areas.
- Groundwater has low salinity except those floodplain areas remote from regulated rivers.
- Groundwater is used for a variety of uses including irrigation and town water supply.
- There is strong surface water – shallow groundwater connectivity along the regulated rivers particularly upstream of Corowa.
- There are important riparian vegetation and wetland ecosystem GDEs across the whole groundwater resource area.

Image courtesy of iStock. Developed agricultural farms with cultivated fields, Murray River area.

Table 18. Groundwater attributes of water sources within the Murray River catchment

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Billabong Creek Alluvial	20 to 100	5 to 40	500 to 2,000	Stock and domestic Small scale irrigation Town water Salt interception scheme	7,500	Riparian vegetation
Lower Murray Deep	20 to 350	20 to 300	500 to 2,000	Stock and domestic Irrigation	88,900	None
Lower Murray Shallow*	10 to 20	5 to 50	600 to 3,000	Stock and domestic Small scale irrigation	81,893	Riparian vegetation
Upper Murray	20 to 100	10 to 120	300 to 1,000	Stock and domestic Irrigation Town water	14,109	Riparian vegetation, and baseflow ecosystems

*The Lower Murray Shallow water source is split into eastern and western management zones, for more information, see the *Water Sharing Plan for the Murray Alluvial Groundwater Sources 2020* available at legislation.nsw.gov.au/view/whole/html/inforce/current/sl-2020-0344

The groundwater is fresh close to the regulated river. In the Lower Murray (deep) aquifer, in the western areas of the alluvial sequence, salinity increases to levels where it is only suitable for stock purposes. Groundwater salinity in the overlying Lower Murray (shallow) aquifer is brackish to slightly saline due to the nature of the soils, shallow soils and sediments and irrigation leakage.

A few small towns and villages, including Balldale and Culcairn, use groundwater as their drinking water source.

Groundwater is used for irrigation purposes with lucerne and irrigated pasture in upstream areas and broadacre irrigation of cotton and cereals in lower catchment areas. Irrigation is expected to be the driver for continued and expanded groundwater use.

GDEs are extensive along the Murray and Edward rivers downstream of Mulwala. GDEs include high value terrestrial vegetation (mostly river red gum communities) along riparian corridors, and associated swamps and wetlands that support significant aquatic ecosystems. These communities are generally characterised by having a high number of threatened species, endangered ecological communities, extensive connected riparian corridors and important vegetation species of black box, lignum and river red gums. The most important areas are the Millewa Forest within the Murray Valley National Park south of Deniliquin and within the Koondrook State Forest at Barham.

Groundwater level and water quality trends are monitored by a large monitoring network of more than 183 monitoring bores at 79 sites across the Lower Murray water source, and 69 monitoring bores at 41 sites across the Upper Murray and Billabong Creek water sources. Maintenance of this network is the primary challenge given its age and susceptibility to flood damage. This is a priority under the NSW Groundwater Strategy Priority 3 (Action 3.4).

Further reading:

Department of Planning, Industry and Environment 2019, *Murray Alluvium Water Resource Plan – Resource Description.*

Department of Planning, Industry and Environment 2020, *Groundwater Annual Report – Billabong Creek Alluvial Groundwater Source.*

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Lower Murray Groundwater Source.*

Department of Planning, Industry and Environment 2021, *Groundwater Annual Report – Upper Murray Groundwater Source.*

Available for download at www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and www.industry.nsw.gov.au/__data/assets/pdf_file/0004/230674/appendix-a-murray-alluvium-wrp-groundwater-resource-description.pdf

Mapping:

Hydrogeology of the Murray Basin 1:250,000 scale series (Jerilderie, Deniliquin sheets) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Other minor inland

The remaining alluvial areas across the inland catchments are mostly smaller and less productive alluvial systems, many of which have marginal or poor water quality suitable only for stock and limited domestic use.

Darling and major tributaries

There are variable thicknesses and extents of alluvium along the Darling River and its major tributaries, the Paroo and Warrego rivers. The alluvium ranges in width from 1 to 5 km from the river channel. Alluvial thicknesses are not well known because of low demand for shallow groundwater and minimal exploration activities.

There is currently one water sharing plan[15] to cover all the (near river) Darling River Alluvium plus the floodplain alluvium of these 2 tributaries.

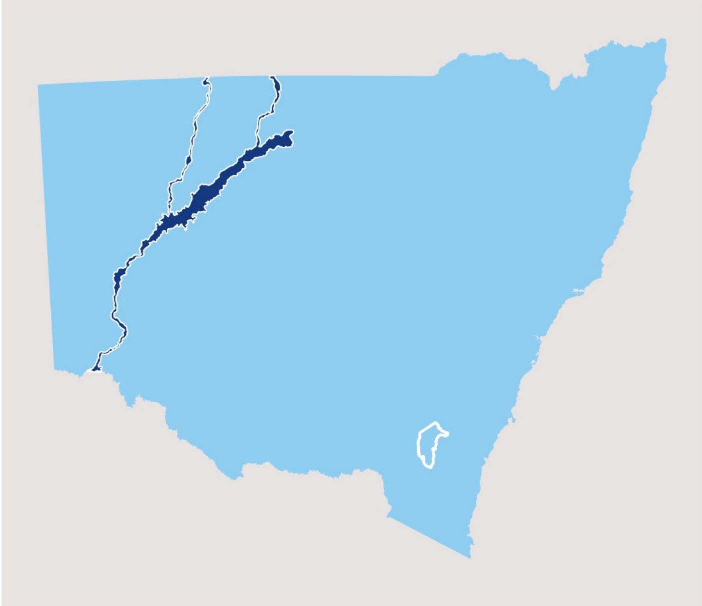
The alluvial sediments defined by the Lower Darling Alluvial water source occur from about 65 km upstream of Menindee to the junction with the Murray River near Wentworth. Within the alluvium is a freshwater lens,[16] overlying saline groundwater at depth.

The Upper Darling Alluvial groundwater source is located from just upstream of Bourke downstream to between Wilcannia and Menindee. It has similar characteristics to the Lower Darling Alluvial area.

The isolated occurrences of freshwater lenses located along the Darling Alluvium, close to the river are mostly recharged by high surface water flows. Achieving a better understanding of the size of these shallow pockets of freshwater and how they change over time in response to seasonal conditions has the potential to improve water security for nearby towns and other users.

The water from these groundwater sources is mainly used for stock and limited domestic purposes but also for town water supply at Wilcannia, Louth and Pooncarie. The freshwater lens located close to the river is targeted, where possible, for these consumptive uses. Most of the extraction from the Upper Darling Alluvial groundwater source is currently for the Upper Darling SIS, which is located 25 km south-west of Bourke along the Darling River.

The 4 water sources within this groundwater resource are described briefly in Table 19.



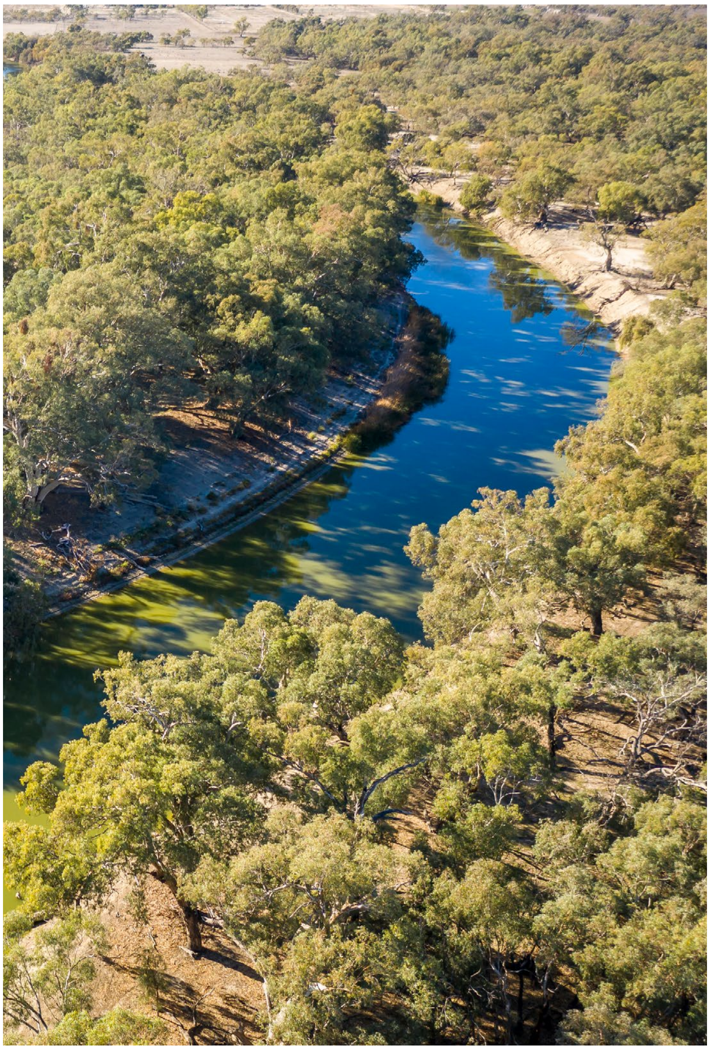


Image courtesy of John Spencer, Department of Planning and Environment. Darling River, Kinchega National Park.

15. *Water Sharing Plan for the Darling Alluvial Groundwater Sources 2020*, available at legislation.nsw.gov.au/view/html/inforce/current/sl-2020-0351
16. A freshwater lens is convex-shaped layer of fresh groundwater that floats above denser saltwater. Freshwater lenses rely on seasonal rainfall to recharge the aquifer and can change in thickness following drought or heavy rainfall.

Table 19. Groundwater attributes of water sources along the Darling River and Intersecting Streams

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Lower Darling Alluvial	10 to 35*	<1 to 10	300 to 2,500 (50,000*)	Stock and domestic Small scale irrigation Town water	2,230	Riparian vegetation
Upper Darling Alluvial	10 to 120*	<1 to 10	500 to 2,500 (100,000*)	Stock and domestic Town water Salt interception scheme	6,009	Riparian vegetation
Paroo Alluvial	Unknown	Unknown	Unknown	Stock and domestic	292	Riparian vegetation
Warrego Alluvial	Unknown	Unknown	Unknown	Stock and domestic	289	Riparian vegetation

*The deeper alluvial aquifers contain highly saline groundwater. The deeper groundwater salinities are shown in brackets.

Riparian vegetation along river banks is likely to be a seasonal GDE that relies on accessing groundwater from freshwater lenses when drier conditions prevail. In addition, a few important environmental assets are connected to the Darling Alluvium, including the Ramsar-listed Narran Lakes and Paroo Wetlands.

There is limited groundwater monitoring across the Lower and Upper Darling Alluvial water sources and no monitoring across the other water sources because of the minimal groundwater use.

Further reading:

Department of Primary Industries–OoW 2012, *Water Sharing Plan – Lower Murray–Darling Basin Unregulated and Alluvial Water Sources.*

Department of Primary Industries–OoW 2012, *Water Sharing Plan – Intersecting Streams Unregulated and Alluvial Water Sources.*

Department of Primary Industries–OoW 2012, *Water Sharing Plan – Barwon–Darling Basin Unregulated and Alluvial Water Sources.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Murray Basin 1:250,000 scale series (Mildura, Ana Branch, Pooncarie, Menindee, Manara sheets) available for download at www.industry.nsw.gov.au/water/science/maps/hydrogeological-maps

Hydrogeology of the Darling River Basin 1:1,000,000 scale available for download at ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/18733

Border Rivers

A small but locally important alluvial groundwater resource occurs along the NSW-Queensland border between Mingoola and Goondiwindi. This is known as the Border Rivers Alluvial groundwater resource. There are 4 water sources within the resource area in NSW. The most important and productive area is the Dumeresq River Valley upstream of Keetah Bridge.

Bore yields of up to 60 L/s from deep alluvial aquifers can be obtained upstream of Keetah Bridge. Yields are much lower in the tributary alluvium and there is no known deep aquifer in the floodplain area downstream of Keetah Bridge. In the upstream areas, the water quality is low salinity and is used for stock and domestic and irrigation purposes.

The 4 water sources within this groundwater resource are described briefly in Table 20.

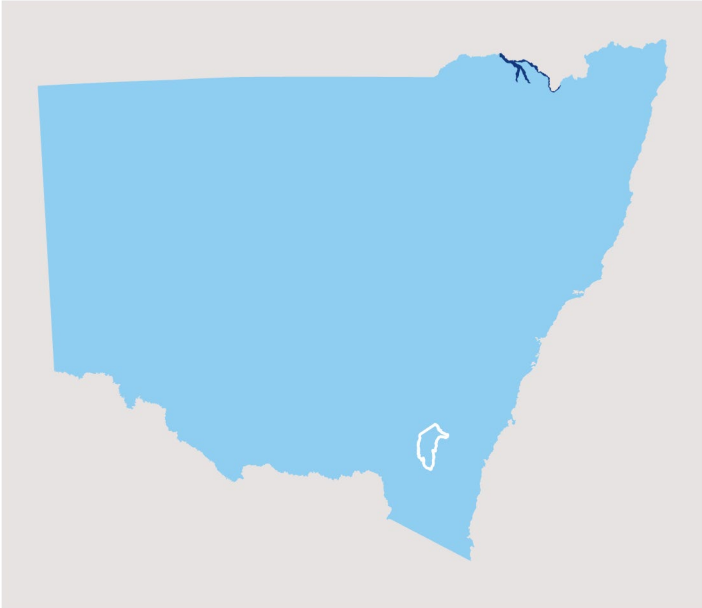


Table 20. Groundwater attributes of water sources along the Border Rivers

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
MacIntyre Alluvial	5 to 20	<1 to 5	500 to 2,500	Stock and domestic	373	Riparian vegetation and baseflow ecosystems
NSW Border Rivers downstream of Keetah Bridge Alluvial	10 to 20	<1 to 4	Unknown	Stock and domestic	316	Riparian vegetation
NSW Border Rivers microsiemens of Keetah Bridge Alluvial	10 to 75	1 to 50	500 to 1,000	Stock and domestic Irrigation	8,085	Riparian vegetation and baseflow ecosystems
Ottleys Creek Alluvial	5 to 20	<1 to 2	Fresh	Stock and domestic	30	Riparian vegetation and baseflow ecosystems

Within the Border Rivers region, GDEs include river red gum riparian woodland and Coolibah–River Coobah–Lignum woodland vegetation communities.

Irrigated crops include cereals and permanent pasture. Downstream of Goondiwindi, cotton is grown extensively; however, there is no groundwater resource in this area – irrigated crops are grown exclusively on surface water. Water for irrigation in upstream areas will be the driver for any future groundwater demand. No growth in demand for other uses is expected across these water sources as no population growth or no new industries are anticipated.

There is limited monitoring across the water sources upstream and downstream of Keetah Bridge to monitor groundwater level and water quality trends but no monitoring across the other water sources.

Further reading:

Department of Primary Industries–Water 2012, *Water Sharing Plan – NSW Border Rivers Unregulated and Alluvial Water Sources 2012 Background Document.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Darling River Basin 1:1,000,000 scale available for download at ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/18733

Image courtesy of Department of Planning and Environment. Windmill, Warialda.

GAB shallow

The remainder of the alluvium across inland NSW occurs in north-western NSW and provides a surface level cover over the GAB. The depth of productive alluvium is largely unknown but small bedrock channels filled with alluvium are likely to exist for the Culgoa, Narran, downstream Bogan and Castlereagh rivers, and Baradine Creek. Water quality is likely to be marginal to poor. The different water sources are either within the Murray–Darling Basin or in the Lake Eyre catchment in far north-western NSW. For management purposes, the resources covered in the GAB shallow WSP include all alluvium and the shallowest GAB porous rock, including:

- all geological formations to a depth of 60 m below the surface of the ground
- all alluvial sediments at any depth below the surface of the ground, within the boundaries of the groundwater sources.

Across this area, there are low bore yields and water quality is brackish to saline.

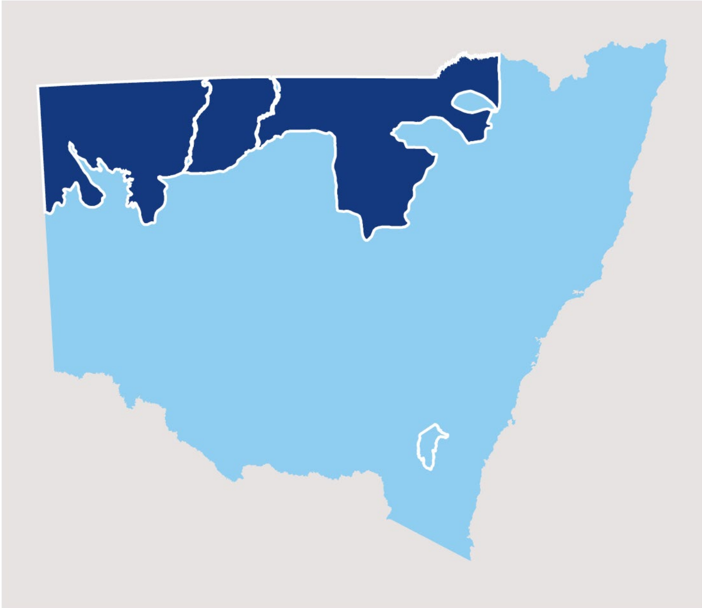


Image courtesy of Department of Planning and Environment. Water body with native plants and trees, Castlereagh.

The 4 water sources within this groundwater resource are described briefly in Table 21.

Table 21. Groundwater attributes of water sources across the GAB shallow area

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
GAB Central Shallow (MDB)	10 to 60	<0.5 to 4	2,500 to 10,000	Stock	8,830	Riparian vegetation
GAB Central Shallow (North Western)	10 to 60	<0.5 to 4	2,500 to 10,000	Stock	33,220	Riparian vegetation
GAB Surat Shallow	10 to 80*	1 to 15	500 to 10,000	Stock and domestic	15,500	Riparian vegetation
GAB Warrego Shallow	10 to 60	<0.5 to 4	2,500 to 10,000	Stock	33,400	Riparian vegetation

*Most aquifers are in the alluvium within this water source. For the other water sources, most aquifers are in shallow GAB rocks.

Riparian vegetation communities along ephemeral rivers and creeks are likely to be seasonal GDEs that rely on accessing groundwater from freshwater lenses in the shallow alluvial aquifers when drier conditions prevail. It is highly unlikely that any other terrestrial vegetation GDEs rely on groundwater from the shallow GAB aquifers.

Groundwater is only suitable for stock use and limited domestic use. No growth in water demand is expected across these water sources because of limited agricultural opportunities and no population growth.

There is no groundwater monitoring across these water sources.

Further reading:

Department of Planning, Industry and Environment 2019, *NSW Great Artesian Basin Shallow Water Resource Plan – Groundwater Resource Description.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status

Mapping:

Hydrogeology of the Darling River Basin 1:1,000,000 scale available for download at ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/18733

Coastal alluvium

The coastal alluvium includes small to medium size alluvial deposits along every coastal river catchment of NSW. There are basically 3 geographies where alluvial sediments are found:

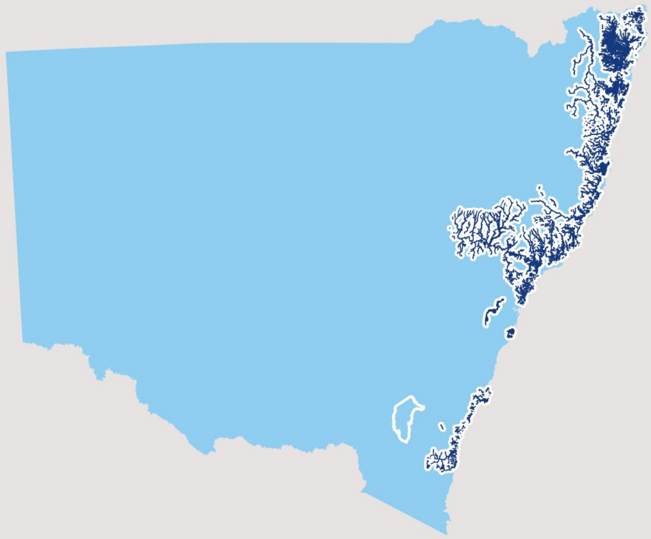
- upper catchment areas – headwater areas with thin and discontinuous pockets of coarse alluvium. The coarse alluvial material is usually within and immediately next to the stream
- mid catchment areas with small floodplains – these areas are above the tidal limit and have reasonable thickness of alluvial sediments beneath floodplain areas
- lower catchment areas with broad floodplains – these areas are mostly below the tidal limit and include a mixture of alluvium at depth and estuarine sediments near surface covered by fertile soils across the floodplain.

Most of the coastal alluvium is relatively young (less than 2 million years old) and hosts a single unconfined aquifer. The aquifer attributes are dependent on the geology of the catchment. For instance, the alluvium in the Bega/Brogo and Towamba rivers on the far south coast is all sand because of the granite catchment. Conversely in the Hunter Valley, the alluvial aquifers range from sand to cobbles based on a range of geologies across the upper and mid catchment areas.

Coastal floodplain alluvium upstream of the tidal limit (that is, in the mid catchment areas) typically has relatively high permeability resulting in high bore yields and low salinity. Strong surface water connectivity maintains water levels and quality. However, during droughts, storage volumes quickly deplete as river flows diminish.

In the lower catchment floodplain areas, the alluvium/estuarine sediments are low permeability and there are only thin aquifers that contain poorer quality water. Where bores tap freshwater lenses, these are vulnerable to saltwater intrusion.

Resource descriptions are provided below for North Coast Alluvium (catchments north of the Hunter), Central Coal Alluvium (Hunter and Hawkesbury-Nepean catchments) and South Coast Alluvium (catchments south of the Illawarra). Descriptions focus on the mid catchment areas where floodplain deposits produce the highest yields and the lowest salinity groundwater resources.



Highlights

- Limited information is available about many of these groundwater sources.
- High yields are available in some mid-catchment areas, and salinity is suitable for most purposes.
- Close to the tidal limit, saltwater intrusion is possible.
- Runoff from agricultural land, urban and industrial areas can impact groundwater quality.
- Groundwater is highly connected to nearby streams.
- Recharge is mostly from rainfall and leakage from nearby streams.
- Riparian vegetation and stream baseflows are important GDEs.

Northern coastal alluvium

There are 9 major coastal catchments north of the Hunter. The largest catchments with the most extensive alluvial deposits are the Richmond, Clarence, Macleay and Manning catchments, and floodplain areas in these catchments upstream of the tidal limit all contain useful alluvial aquifers. There are also important (smaller) alluvial aquifers in the Bellinger catchment along the Bellinger, Nambucca and Bowra rivers where borefields provide drinking water supplies for local communities.

As there is strong connectivity between surface water sources and shallow alluvial aquifers, groundwater and surface water are managed as one resource. In most instances, there are no separate extraction limits for groundwater.

Due to the large number of coastal alluvium water sources across the upper, mid and lower floodplain areas of each of these 9 catchments, brief descriptions of only a few catchments are provided in Table 22.

Most consumptive use in coastal alluvium is for stock, domestic and limited irrigation purposes. For several smaller towns located on rivers near the tidal limits (such as Bellingen and Kempsey), town water supply borefields have been established.

Growth in population in some centres along the North Coast of NSW will increase the water demand for towns and industry. The associated land use changes and economic development will pose challenges to future groundwater availability and use.

There are small groundwater monitoring networks in the Richmond, Manning, and Hasting River catchments to monitor groundwater level and water quality trends.

Image courtesy of Destination NSW. Bellbrook, Macleay Valley Coast.

Table 22. Groundwater attributes for coastal alluvium across several northern coastal catchments

Catchment	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Clarence	10 to 30	1 to 15	100 to 1,000	Stock and domestic Small scale irrigation	ND	Riparian vegetation and baseflow ecosystems
Macleay	10 to 30	1 to 15	150 to 1,000	Stock and domestic Small scale irrigation Town water	ND	Riparian vegetation and baseflow ecosystems
Nambucca	10 to 20	1 to 15	100 to 1,000	Stock and domestic Small scale irrigation Town water	ND	Riparian vegetation and baseflow ecosystems

ND – 'Not defined' because groundwater is managed with surface water – see respective water sharing plans.

Further reading:

DWE 2009, *Water Sharing Plan – Coffs Harbour Area Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–OoW 2010, *Water Sharing Plan – Tweed River Area Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Brunswick River Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Richmond River Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Clarence River Unregulated, Regulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Nambucca Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries 2016, *Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries 2019, *Water Sharing Plan for the Hastings Unregulated and Alluvial Water Sources – Background document.*

Department of Planning and Environment 2022, *Water Sharing Plan for the Bellinger River Area Unregulated and Alluvial Water Sources 2020 – Background document.*

Available for download at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/north-coast-region and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/far-north-coast-region

Central coastal alluvium

The largest alluvial deposits of any of the coastal catchments are found in the Hunter catchment. These are mostly upstream of Maitland along the Hunter catchment and along all major tributaries. Large alluvial deposits also occur across the Hawkesbury-Nepean catchment upstream of Cattai along the Hawkesbury and upstream of Penrith along the Nepean.

In the central coastal alluvium, groundwater is used extensively for irrigating market gardens and improved pasture, together with some commercial activities such as growing turf and sand-gravel quarrying.

Summary information for these 2 catchments is provided in Table 23.

Table 23. Groundwater attributes for coastal alluvium across central coastal alluvium catchments

Catchment	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Hunter	10 to 40	1 to 25	100 to 1,000	Stock and domestic Irrigation Extractive industry	ND	Riparian vegetation and baseflow ecosystems
Hawkesbury-Nepean	10 to 20	1 to 15	100 to 1,000	Stock and domestic Small scale irrigation Extractive industry	ND 2,456* 645**	Riparian vegetation and baseflow ecosystems

ND – Not defined because groundwater is managed with surface water apart from the 2 listed sources – see respective water sharing plans.
*The current extraction limit assigned to the Hawkesbury Alluvium groundwater source.
**The current extraction limit assigned to the Maroota Tertiary Sands groundwater source.

Growth in population in the Hunter and western Sydney may see more shallow groundwater used for industrial and commercial purposes and potentially small-scale irrigation. Groundwater use is unlikely to increase substantially.

There are small monitoring networks in the Hunter and Hawkesbury catchments to monitor groundwater level and water quality trends.

Further reading:

Department of Primary Industries–Water 2016, *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–OoW 2011, *Water Sharing Plan – Greater Metropolitan Groundwater Sources – Background document.*

EMM Consulting 2018, *Maroota Extractive Industry Groundwater Study.*

All available from water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/hunter-region, www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/greater-metropolitan-region

Southern coastal alluvium

There are 6 major coastal catchments south of the Illawarra. The largest catchments with the most extensive alluvial deposits are the Shoalhaven, Bega and Towamba catchments. The floodplain areas in these catchments upstream of the tidal limit all contain useful alluvial aquifers. There are also smaller alluvial aquifers in the other catchments but due to their limited size and the availability of surface water they have negligible use.

Most consumptive use is for stock, domestic and limited irrigation purposes. Town water supply borefields are established to supply towns in the Bega and Towamba catchments.

Summary information for several catchments is provided in Table 24.

There is a small monitoring network in the Bega catchment to monitor groundwater level and water quality trends.

Table 24. Groundwater attributes for coastal alluvium across several southern coastal alluvium

Catchment	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Shoalhaven	10 to 40	1 to 5	200 to 2,500	Stock and domestic Small scale irrigation	ND	Riparian vegetation and baseflow ecosystems
Bega	10 to 30	1 to 20	100 to 1,000	Stock and domestic Small scale irrigation Town water	ND	Riparian vegetation and baseflow ecosystems
Towamba	10 to 30	1 to 20	100 to 1,000	Stock and domestic Small scale irrigation Town water	ND	Riparian vegetation and baseflow ecosystems

ND – Not defined because groundwater is managed with surface water – see respective water sharing plans.

Further reading:

Department of Primary Industries–OoW 2011, *Water Sharing Plan – Bega and Brogo Rivers Area Regulated, Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–OoW 2010, *Water Sharing Plan – Towamba River Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for Clyde River Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for Deua River Unregulated and Alluvial Water Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for Tuross River Unregulated and Alluvial Water Sources – Background document.*

All available from water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/south-coast-region and www.industry.nsw.gov.au/__data/assets/pdf_file/0009/166860/murrah-wallaga_background.pdf

Coastal sands

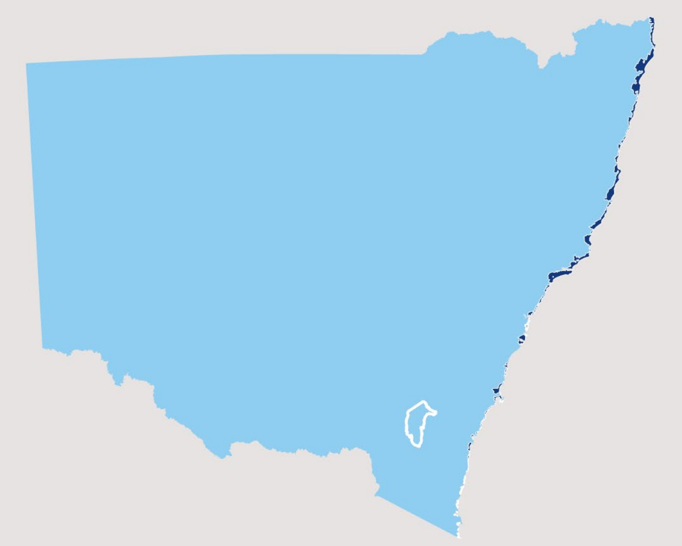
Coastal sands systems consist of aquifers located in dune and beach deposits along the coast. The largest coastal sand systems are located north of Sydney and include those at Tomago, Hawks Nest and South West Rocks.

These are recent landscapes that contain high value aquifers. The aquifers are mostly unconfined sand aquifers with occasional thin clay and peat lenses. Coastal sand systems are highly connected to the ocean, estuaries and associated lakes. High water levels are maintained by direct rainfall; however, levels can vary markedly due to tidal influences and drought.

These systems are used for a large variety of purposes including domestic, garden, extractive industries and town and city water supply, and sustain many GDEs, including terrestrial vegetation, freshwater swamps and brackish water marshes adjacent to estuaries.

Bore yields are typically less than 10–15 L/s (but can be as high as 50 L/s) and water quality is mostly low salinity except if close to adjacent saltwater features. These resources can be impacted by urban pollutants (such as nutrients and bacteria from stormwater, sewerage and sewerage exfiltration systems, chemical pollutants from industrial/commercial activities and landfill leachate) and agricultural activities (such as fertilisers and pesticides).

Brief descriptions of the 17 groundwater sources within this distributed resource are provided in Table 25.



Highlights

- Bore yields are high and salinity is fresh in all the coastal sand aquifers.
- Storage volumes are small and regular rainfall recharge is required to sustain these aquifers and their dependent ecosystems.
- Close to the tidal limit, saltwater intrusion is possible.
- Runoff and contaminants from urban and industrial areas can impact groundwater quality.
- Many coastal communities rely on these aquifers for their water supply.
- Terrestrial vegetation and wetlands located on and adjacent to these aquifer systems have a high reliance on groundwater.

Image courtesy of Destination NSW. Main Beach, Nambucca Heads.

Table 25. Groundwater attributes of coastal sand aquifers within the different water sources

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Bellinger-Nambucca Coastal Sands	10 to 40	1 to 40	100 to 750	Domestic	1,175	Terrestrial vegetation, wetlands, baseflows
Botany Sands	10 to 40	1 to 40	100 to 1,000	Domestic Industrial Recreation	14,684	Terrestrial vegetation, wetlands, baseflows
Clarence Coastal Sands	10 to 40	1 to 5	100 to 1,000	Domestic	4,200	Terrestrial vegetation, wetlands, baseflows
Coffs Harbour Coastal Sands	10 to 40	1 to 10	100 to 750	Domestic	3,110	Terrestrial vegetation, wetlands, baseflows
Great Lakes Coastal Sands	10 to 40	1 to 30	100 to 500	Domestic Recreation Town supply	16,000	Terrestrial vegetation, wetlands, baseflows
Hastings Coastal Sands	10 to 40	1 to 20	100 to 1,000	Domestic	7,100	Terrestrial vegetation, wetlands, baseflows
Hawkesbury to Hunter Coastal Sands	10 to 40	1 to 30	100 to 750	Domestic Recreation	20,445	Terrestrial vegetation, wetlands, baseflows
Macleay Coastal Sands	10 to 50	1 to 30	100 to 1,000	Domestic Town supply	11,300	Terrestrial vegetation, wetlands, baseflows
Manning-Camden Haven Coastal Sands	10 to 40	1 to 20	100 to 500	Domestic	3,300	Terrestrial vegetation, wetlands, baseflows
Metropolitan Coastal Sands	10 to 40	1 to 15	100 to 1,000	Domestic	27,206	Terrestrial vegetation, wetlands, baseflows

Table 25. Groundwater attributes of coastal sand aquifers within the different water sources (continued)

Groundwater source	Range of aquifer depths (m)	Typical bore yields (L/s)	Salinity (mg/L TDS)	Primary consumptive uses	Extraction limit (ML/yr)	GDEs
Richmond Coastal Sands	10 to 40	1 to 40	100 to 1,000	Domestic	19,000	Terrestrial vegetation, wetlands, baseflows
South East Coastal Sands	10 to 30	1 to 10	100 to 1,000	Domestic	5,600	Terrestrial vegetation, wetlands, baseflows
Stockton	10 to 40	1 to 10	100 to 500	Domestic Commercial	14,000	Terrestrial vegetation, wetlands, baseflows
Stuarts Point	10 to 40	1 to 10	100 to 1,000	Domestic Small scale irrigation Town supply	4,180	Terrestrial vegetation, wetlands, baseflows
Tomago	10 to 50	1 to 40	100 to 500	Domestic Small scale irrigation Town supply	25,000	Terrestrial vegetation, wetlands, baseflows
Tomaree	10 to 50	1 to 25	100 to 500	Domestic Town supply	6,000	Terrestrial vegetation, wetlands, baseflows
Tweed-Brunswick Coastal Sands	10 to 40	1 to 30	100 to 1,000	Domestic	19,000	Terrestrial vegetation, wetlands, baseflows

Many coastal communities (including those serviced by Hunter Water, Mid Coast Water and Rous County Council) rely on groundwater from these aquifers for their drinking water supply.

The largest systems used for water supply are operated by Hunter Water. The Tomago Sandbeds aquifer is used as a backup to Grahamstown Dam, potentially providing 20% of the Lower Hunter's water supply during drought periods. The Tomaree Sandbeds are the sole source of supply for the towns and villages on the Nelsons Bay peninsula.

There are some significant GDEs along coastal NSW supported by freshwater discharges from coastal sand aquifers. These include the Myall Lake wetlands complex, which covers an area of 450 km^2 north of Tea Gardens-Hawks Nest, and the Towra Point Nature Reserve in Botany Bay. Both are Ramsar-listed sites.

Challenges to future groundwater protection, availability and use will be:

- growth in population along the coast and associated increased water demand for towns and industry
- the necessity to protect recharge and discharge areas from urbanisation (particularly industrial and waste disposal activities) while accommodating land use changes and economic development.

The development of the Williamtown Special Activation Precinct in the centre of the Tomago Sandbeds faces challenges given historical contamination (such as nutrient, hydrocarbon and PFAS impacts) and the importance of this area for groundwater supply. There is also historical contamination across the Botany Sand aquifer due to widespread contamination from heavy industry, waste disposal practices and urban development.

There is a small monitoring network in the Botany Sands water source to monitor groundwater level and water quality trends. Several local and major water utilities have local monitoring networks around their borefield areas.

Further reading:

Department of Primary Industries–Water 2016, *Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources – Background document.*

Department of Primary Industries–Water 2016, *Water Sharing Plan for the South Coast Groundwater Sources – Background document.*

Department of Planning, Industry and Environment 2021, *Macleay Coastal Sands Groundwater Source – Groundwater Resource Description.*

Available at water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/north-coast-region and water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/south-coast-region and www.dpie.nsw.gov.au/water/science-data-and-modelling/groundwater-management-and-science/groundwater-document-library

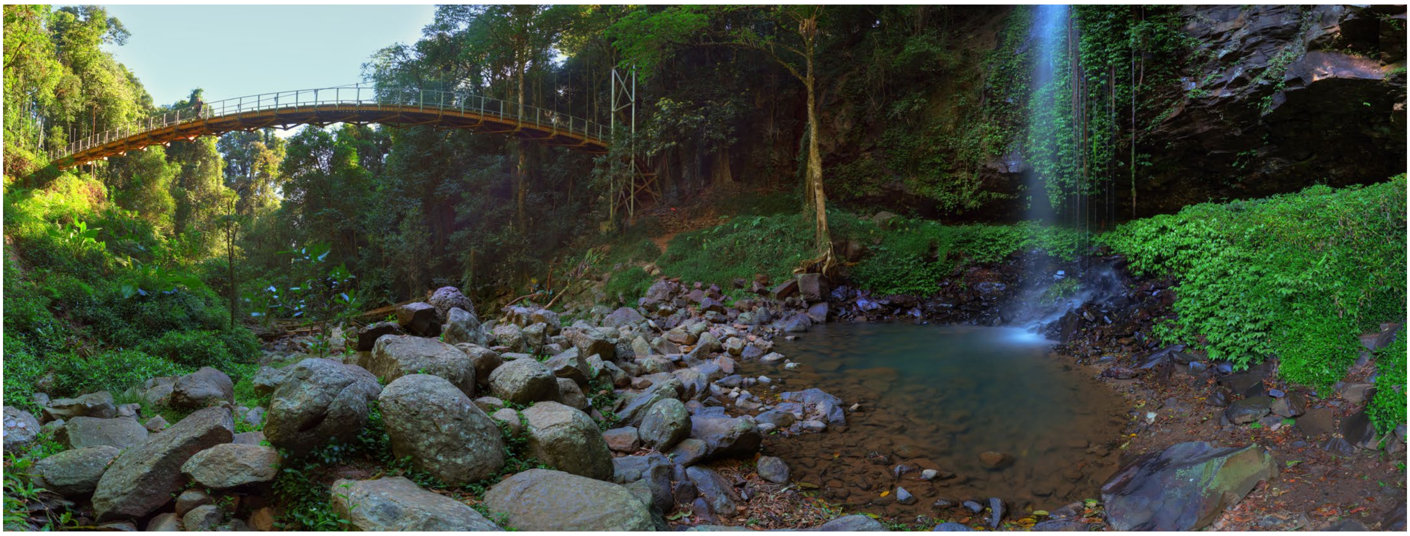


Image courtesy of Destination NSW. Dorrigo Crystal Shower Falls, Dorrigo National Park.

Groundwater access rights in NSW

4

Image courtesy of Destination NSW. Yarren Wines, Yenda.

In NSW, the state retains the rights to the control, use and flow of all groundwater. This includes all water in aquifers and occurring below the ground surface. There are a number of ways in which the government make it permissible to take water in NSW. These include:

- By conferring a **Basic Landholder Right (BLR)**. A BLR entitles:
  - the owner or occupier of a landholding to take groundwater from any aquifer underlying the land without the need for an access licence, for domestic consumption and stock watering only
  - a native title holder to take and use groundwater in the exercise of native title rights without the need for an access licence.
- By issuing an **access licence** (water access licence or WAL), which entitles their holder:
  - to specified shares in the available groundwater from a specified groundwater source
  - to take water:
    - at specified times, at specified rates or in specified circumstances, or in any combination of these
    - in specified areas or from specified locations.
- By allowing groundwater to be taken if specifically **exempt** from the requirement to hold an access licence under the *Water Management Act 2000* or the regulations.

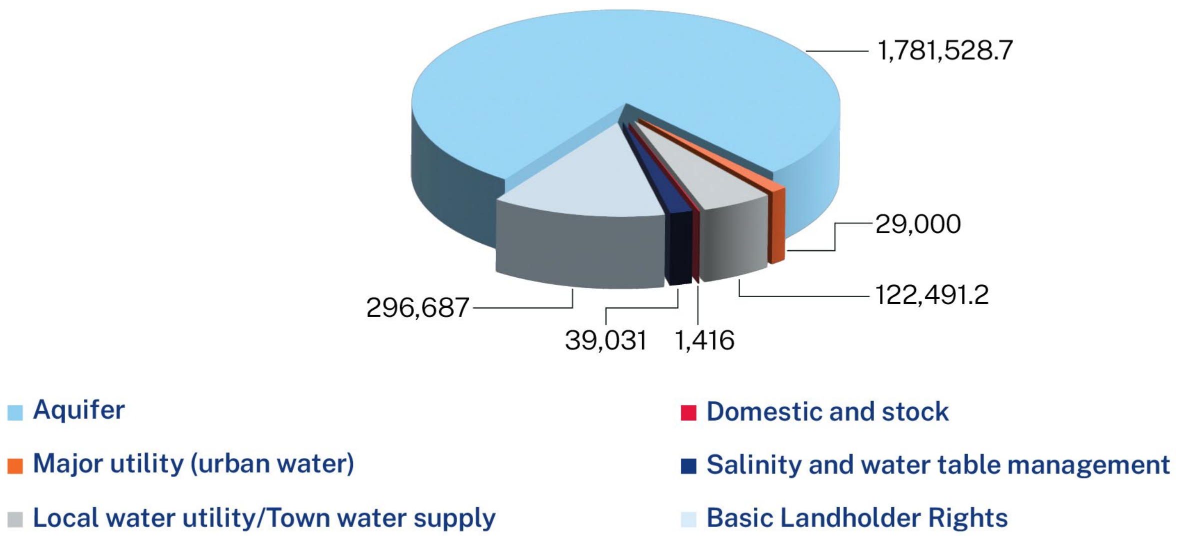
Within each of the state's groundwater sources there may be several categories or subcategories of WALs (or licences).[17] There are currently over 10,850 individual groundwater WALs in NSW. These broadly fall into 3 groups:

- Aquifer access licences, which are not purpose-based.
- Subcategories of aquifer access licences that are purpose-based – for Aboriginal cultural or community development or commercial purposes, for environmental or research purposes, or for temporary dewatering are also specific purpose access licence.
- Specific purpose access licence categories and subcategories – which stipulate the purpose for which the licence is issued. Examples include domestic and stock, town water supply, local water utility/town water supply, major utility and salinity and water table management access licences.

A breakdown of the NSW groundwater access rights (licensed entitlements and BLRs) is shown in Figure 13. Note that aquifer access licence entitlements are specified in 'unit shares' and all other access rights are specified in megalitres per year. For illustrative purposes we have assumed 1 unit share is equivalent to 1 ML/yr. Note also that the volume assigned to BLRs is an estimate only.

Figure 13 shows that most groundwater access rights are associated with aquifer access licences (79%), followed by entitlements associated with BLRs (13%). Less than 1% of access rights are held under domestic and stock access licences, however many people may use their BLRs to access groundwater for domestic and stock purposes.

Figure 13. Groundwater access rights across NSW – licensed and BLR



Source: From individual water sharing plans and Department of Planning and Environment.

17. Further information on groundwater licensing and approvals in NSW can be found in the *Guide to Groundwater Management* in NSW, available at water.nsw.gov.au/__data/assets/pdf_file/0007/518641/groundwater-management-in-nsw.pdf

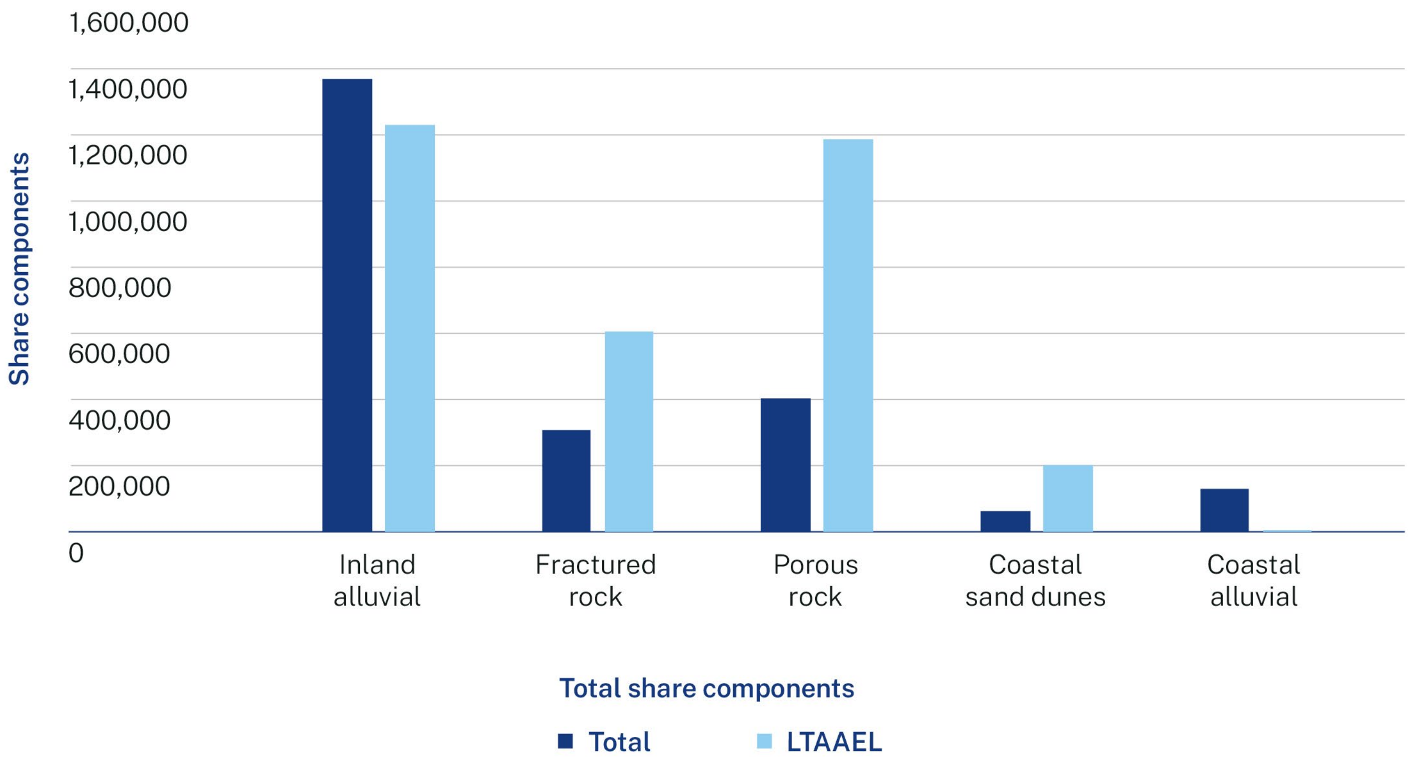
Access rights vary in different groundwater systems

Groundwater access rights vary across the different groundwater system types (see Figure 14). Most of the entitlements are held in the inland alluvial groundwater sources (around 60%), whilst the fewest are held in the much smaller coastal systems.

The largest proportion of groundwater available for extraction and use is located within the inland alluvial groundwater sources and porous rock groundwater sources (around 75% combined) (Figure 14).[18] It should be noted that there is no specific extraction limit for many coastal alluvial groundwater sources. In most of these coastal draining areas there is a single combined extraction limit for unregulated rivers and their associated alluvial groundwater.

The total groundwater access rights (the entitlements of both BLRs and access licences) is currently higher than the combined extraction limits in all inland alluvial groundwater systems. Figure 15 shows that current number of entitlement shares, in the inland alluvial groundwater systems exceed extraction limits (by around 10% above the combined extraction limit). The current groundwater access rights within the porous rock, fractured rock and coastal sands groundwater systems are currently around 50% or less of their respective extraction limits (Figure 14). Even though some water sources are fully committed, and use is high (such as some porous rock water sources within the Sydney Basin and the Tomago Sandbeds) there are others where the level of commitment is much lower than the extraction limits and there is the potential for increased use (such as the Clarence–Moreton Basin and the Lachlan Fold Belt). New entitlements can be granted in a few water sources, and these are made available periodically via controlled allocation orders (CAO).[19]

Figure 14. Groundwater access rights and extraction limits across NSW groundwater systems

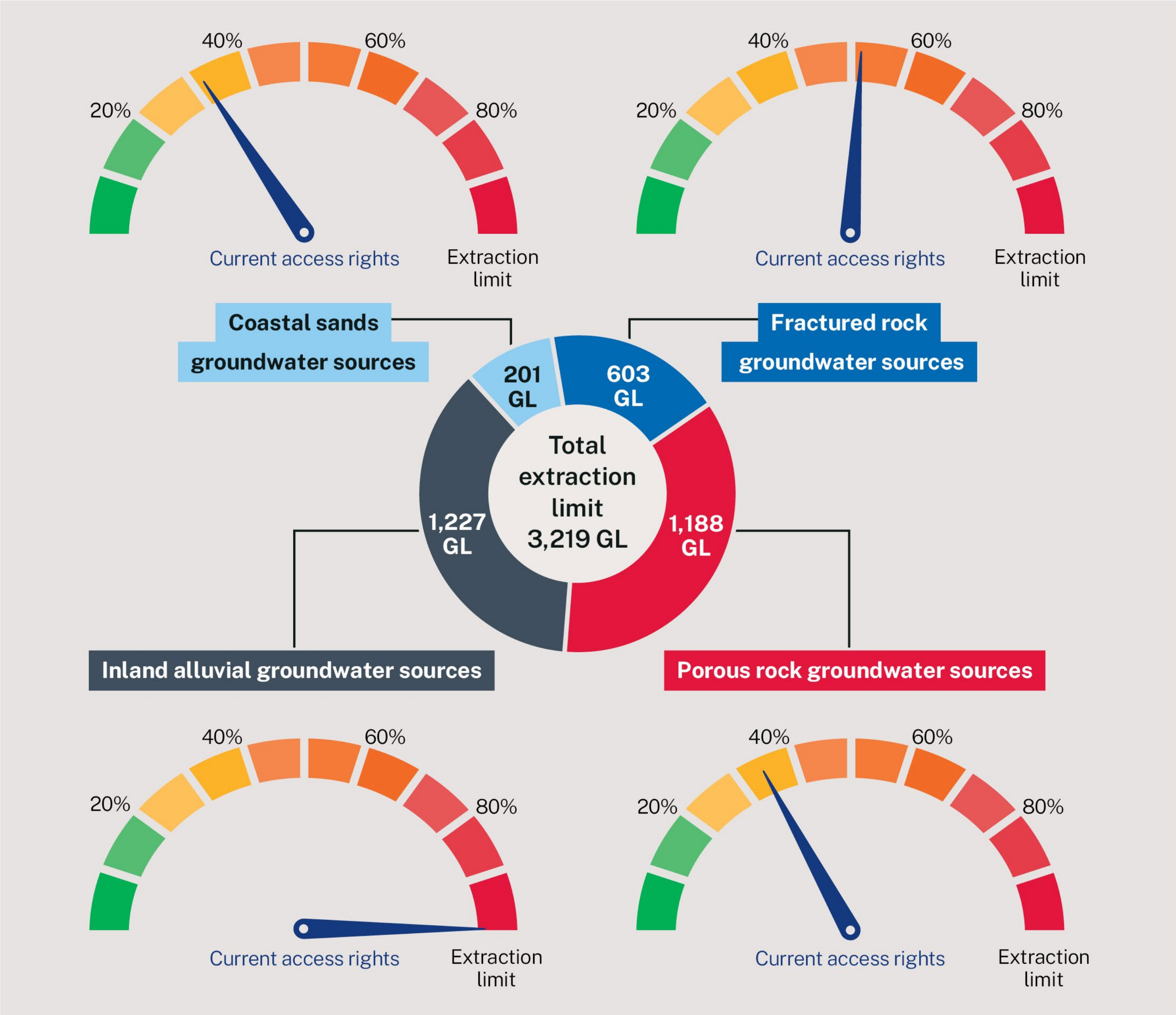


Note 1: Groundwater access rights include licenced and BLR. Extraction limits included show entitlement units.

Note 2: No extraction limit for coastal alluvial groundwater systems is shown as they are combined with those of the unregulated rivers in coastal draining catchments and are not separately quantified.

18. This is based on the extraction limits for each groundwater source set in the water sharing plans. Water sharing plans set a 'long term average annual extraction limit' (LTAAEL) for each groundwater source. Although the amount all water users extract varies each year, on average it cannot exceed this extraction limit. The Guide to Groundwater Management in NSW provides information about the water sharing plans and the process used to determine LTAAELs.
19. Refer to the *Guide to Groundwater Management in NSW* for further details on CAO processes. Available at water.nsw.gov.au/__data/assets/pdf_file/0007/518641/groundwater-management-in-nsw.pdf

Figure 15. Groundwater access rights (entitlements) as a proportion of extraction limits



Source: Individual water sharing plans and the Department of Planning and Environment water licensing database.

Entitlement levels = Basic Landholder Rights + Water access licences.

Coastal alluvials have not been included as their extraction limits are combined with those of unregulated rivers in coastal draining catchments and are not separately quantified. The total groundwater access rights in the coastal alluvial groundwater systems is 130 GL (assuming 1 unit share of entitlement is equivalent to 1 ML).

The largest proportion of aquifer access licence entitlement is in the inland alluvial groundwater sources (69%), as shown in Table 26. This table also show that largest proportion of BLRs is found in fractured and porous rock groundwater systems (81%).

A significant major utility (urban water) licence is held by Hunter Water Corporation in the Tomago Sand beds, which provides critical supply for the greater Newcastle area, particularly during drought time. Notably, local water utility (town water supply) licences are held within all groundwater system types. Again, these are a critical source of domestic supply during dry times or in areas where reliable surface water supplies are not available.

Salinity and water table management licences are in the southern MDB groundwater systems and are used to control rising water tables in the major irrigation districts, and to reduce the discharge of saline groundwater into the Murray River system.

Table 26. Groundwater access rights (entitlements and BLRs) across groundwater systems (entitlement units)

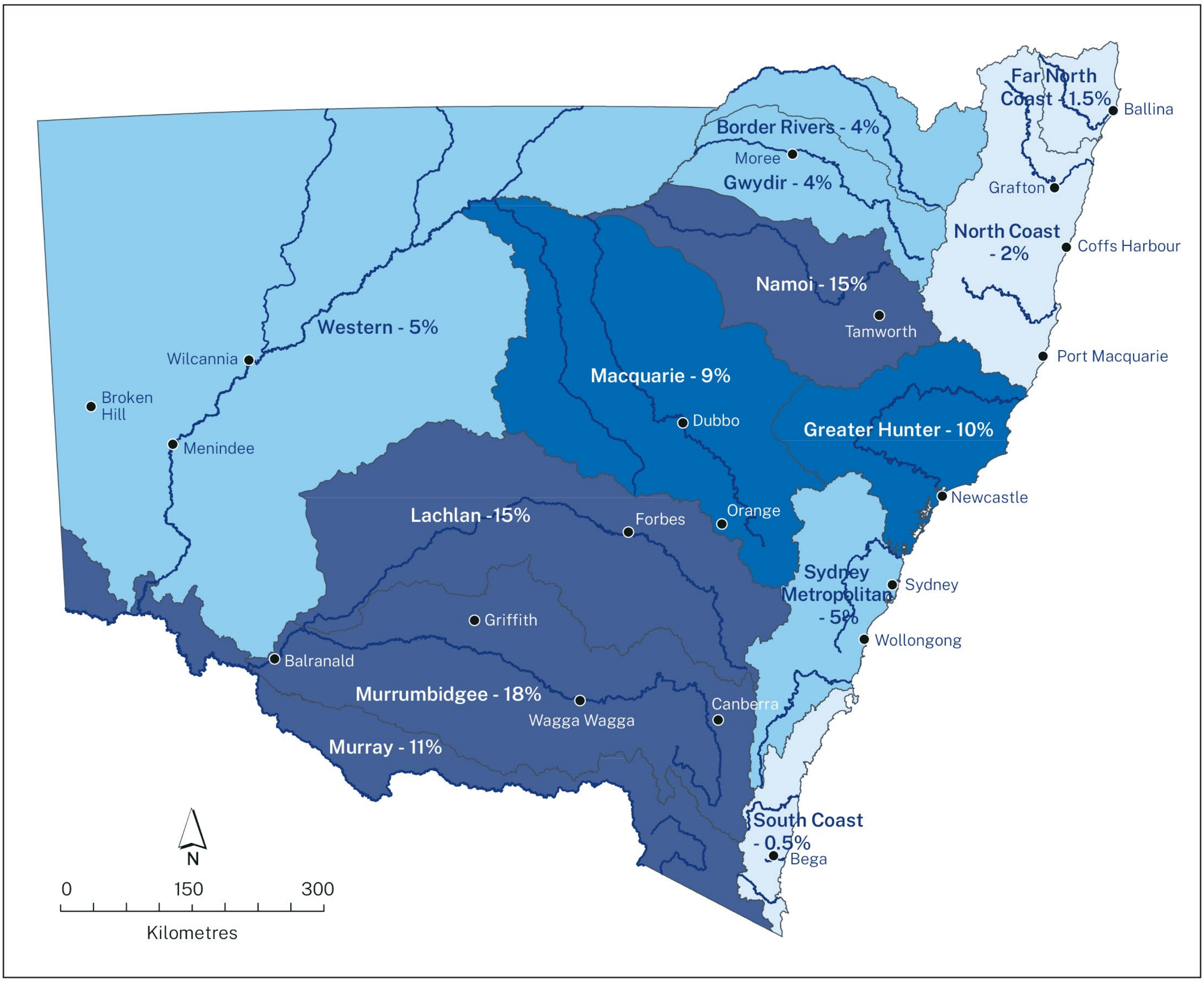
	Inland alluvial	Fractured rock	Porous rock	Coastal sand dunes	Coastal alluvial	Total
Aquifer	1,222,090	160,045	276,479	21,693	101,222	**1,781,529**
Major utility (urban water)	0	0	0	29,000	0	**29,000**
Local water utility/Town water supply	69,036	7,680	10,774	8,285	26,716	**122,491**
Domestic and stock	1,072	344	0	0	0	**1,416**
Salinity and water table management	24,810	236	13,985	0	0	**39,031**
BLR	51,108	137,889	101,693	4,241	1,756	**296,687**
Total	**1,368,116**	**306,194**	**402,931**	**63,219**	**129,694**	**2,270,154**

Source: Individual water sharing plans and the Department of Planning and Environment water licensing database.

Access rights vary across NSW

Regional water strategies delineate the state into 13 regional areas (Figure 16). The distribution of groundwater access rights by regional water strategy area is shown in Figure 16. Overall, the South Coast Regional Water Strategy area has the least number of entitlements (0.5%) and the Murrumbidgee Regional Water Strategy area has the most (18%).

Figure 16. Groundwater access rights by regional water strategy areas (% total)



Legend:

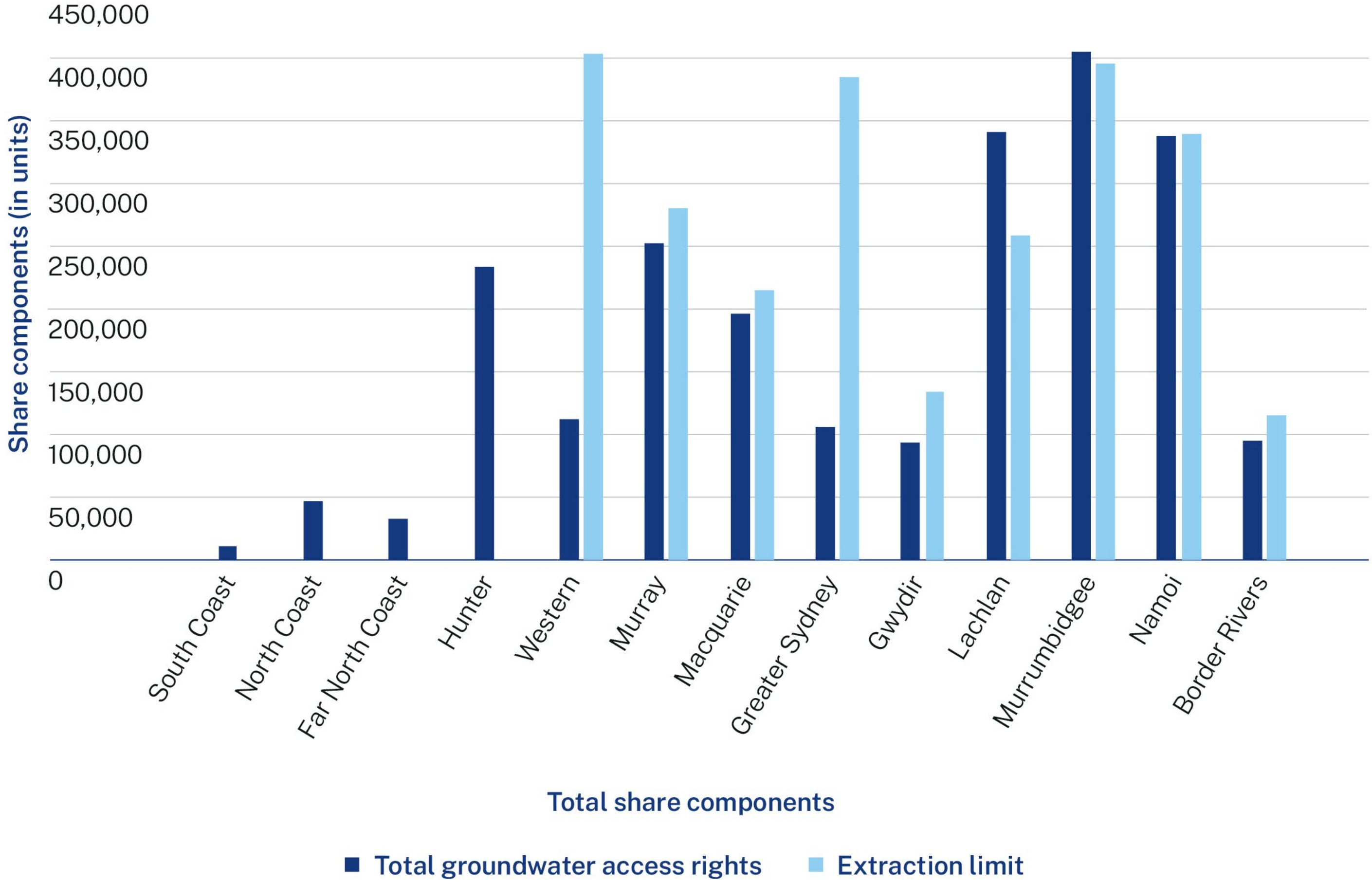
0% to 2% | 2% to 5% | 5% to 10% | 10% to 20%

Note: Groundwater access rights include entitlements and BLR.

Source: Individual water sharing plans and the Department of Planning and Environment water licensing database.

Current entitlements associated with access rights within the Lachlan and Murrumbidgee Regional Water Strategy areas exceed their extraction limits, while in the Namoi region they are very close to the extraction limit (Figure 17). On the other hand, extraction limits in the Western and Greater Sydney Regional Water Strategy areas are much greater than the total of current access rights entitlements. Coastal alluvial systems in Coastal Regional Water Strategy areas do not have extraction limits available for coastal alluvial systems (South Coast, North Coast, Far North Coast and the Hunter).

Figure 17. Groundwater access rights and extraction limits by regional water strategy areas



Note 1: Groundwater access rights include entitlements and BLRs, expressed in share components.

Note 2: No extraction limit for coastal regional water strategy areas have been provided as extraction limits for coastal alluvial systems are combined with those of the unregulated rivers in coastal draining catchments and are not separately quantified.

Source: Individual water sharing plans and the Department of Planning and Environment water licensing database.

In the large inland agricultural regions of the Murrumbidgee, Murray, Macquarie, Namoi and Lachlan aquifer access licence entitlements predominate (73%) (see Table 27). In the Hunter region, urban water supply strongly relies on groundwater, with Hunter Water Corporation holding about 10% of the total groundwater entitlements for the Greater Newcastle water supply.

Stock and domestic rights under BLRs in most areas also rely on groundwater, but particularly in the Western Regional Water Strategy due to its aridity and less reliable surface water supply (see Table 27). Meanwhile coastal areas have the least BLRs, due to their more dependable surface water supplies, although the North Coast does have many local water utility licences.

Table 27. Groundwater access rights (licensed and BLR) by regional water strategy areas (in entitlement units)

	Aquifer	Major utility (urban water)	Local water utility/ Town water supply	Domestic and stock	Salinity and water table management	BLR	Totals
South Coast	4,025	0	5,117	0	0	2,441	**11,583**
North Coast	18,440	0	21,385	0	0	7,244	**47,069**
Far North Coast	21,992	0	2,138	0	0	9,090	**33,220**
Hunter	181,979	29,000	10,206	0	0	13,494	**234,679**
Western	33,909	0	2,103	20	14,488	62,136	**112,656**
Murray	201,914	0	2,412	24	24,307	24,194	**252,851**
Macquarie	157,721	0	13,765	24	0	25,826	**197,336**
Greater Sydney	86,526	0	142	0	0	19,663	**106,331**
Gwydir	63,107	0	5,898	220	0	24,116	**93,341**
Lachlan	301,645	0	13,533	0	0	26,063	**341,241**
Murrumbidgee	350,439	0	28,991	535	236	25,994	**406,195**
Namoi	290,764	0	14,799	573	0	32,138	**338,274**
Border Rivers	69,066	0	2,003	20	0	24,288	**95,377**

Source: Individual water sharing plans and the Department of Planning and Environment water licensing database.

Appendix A

5

Image courtesy of David Barnes, Department of Primary Industries.
Stratford highwall.

Glossary

Term	Definition
Alluvial fan	A triangle-shaped deposit of alluvium usually created as flowing water interacts with mountains, hills, or the steep walls of canyons.
Alluvium	Unconsolidated sediments deposited by rivers or streams consisting of gravel, sand, silt or clay, and found in terraces, valleys, alluvial fans and floodplains.
Anabranches	Sections of a river or stream that diverts from the main channel of the watercourse and rejoins the main channel downstream.
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.
Aquifer, alluvial	A groundwater system whose geological matrix is composed of unconsolidated gravel, sand, silt or clay transported and deposited by rivers and streams.
Aquifer, confined	An aquifer which is bounded above and below by impermeable layers. Confined aquifers are typically under pressure so that when the aquifer is penetrated by a bore, the groundwater rises above the top of the confined aquifer.
Aquifer, fractured rock	A groundwater system that occurs in sedimentary, igneous and metamorphosed rocks that have been subjected to disturbance, deformation or weathering, and that allow water to move through joints, bedding planes, fractures and faults.
Aquifer, porous rock	A groundwater system typically associated with sedimentary basins containing consolidated sediments/cemented rocks with primary porosity where groundwater flow is predominantly through the pore spaces.
Aquifer, unconfined	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.
Aquifer, unconsolidated	A groundwater system whose geological matrix is composed of unconsolidated gravel, sand, silt or clay transported and deposited by rivers and streams (alluvium) or waves and wind (sand dunes).
Aquifer interference activity	Under NSW water legislation, an aquifer interference activity is one involving 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 • the disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Term	Definition
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.
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 feature.
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/Basement	A general term used for solid rock that underlies aquifers, soils or other unconsolidated material.
Bore (or well)	A small diameter hole (typically less than 500 mm) drilled into the ground.
Brackish water	Water with a salinity between 3,000 and 7,000 mg/L total dissolved solids.
Catchment	The land area draining to a point of interest, such as the confluence of 2 streams, or a water storage or monitoring site on a watercourse.
Conceptual model	Documentation or schematic of the understanding of groundwater recharge and discharge processes, flow within a groundwater system, and the interaction of groundwater with surface water and groundwater dependent ecosystems.
Connected water sources	Water sources that have some level of hydraulic connection.
Consumptive use	Use of water for beneficial and consumptive purposes including irrigation, industry, mining, urban and stock and domestic use.
Development (of a groundwater resource)	The commencement of extraction of significant volumes of water from a water source.
Dewatering	Process of removing groundwater which ensures construction work can occur safely, keeps water from seeping into the site which could affect engineering, and protects the ongoing integrity of the structure and surrounding area.
Discharge	Flow of groundwater from a groundwater source.
Drawdown	The difference between groundwater level/pressure before take and that during take.
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 25o C. 1 dS/m = 1,000 µS/cm.

Term	Definition
Evapo-transpiration	The part of the water cycle that removes liquid water from an area with vegetation and into the atmosphere by the processes of both transpiration and evaporation.
Extraction limit	See Long term average annual extraction limit (LTAAEL).
Fractured rock	Rocks with fractures, joints, bedding planes and cavities in the rock mass.
Greywacke	A type of hard sandstone
Groundwater dependent ecosystem (GDE)	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.
Geological sequence	A sequence of rocks or sediments occurring in chronological order.
Groundwater flow	The migration of water in aquifers and aquitards.
Groundwater level	The level of groundwater in an aquifer, typically measured in a water bore. In the case of an unconfined aquifer, the groundwater level is the water table level.
Groundwater 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.
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.
Hornfels	Metamorphic rock formed by the contact between clay-rich rock and a hot igneous material that represents a heat-altered equivalent of the original rock.
Hydraulic conductivity	The capacity of a porous medium to transmit water. Measured in metres/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.
Hydrogeology	The branch of geology that relates to the occurrence, distribution and processes of groundwater.
Igneous rock	Rocks which have solidified from a molten mass.
Infiltration	The movement of water from the land surface into the ground.
Inflow	Source of the water that flows into a specific body of water; for a lake, inflow could be a stream or river, and inflow for a stream or river could be rain.

Term	Definition
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.
Management zone	A defined area within a water source where a particular set of water sharing rules applies.
Metamorphic rock	Rocks that result from partial or complete recrystallisation in the solid state of pre-existing rocks under conditions of temperature and pressure.
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.
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.
Palaeochannel	A sub-surface inactive river or stream channel feature (usually carved into the adjacent bedrock) that is backfilled with sediment or buried by younger sediment.
Permeability	The capacity of earth materials to transmit a fluid.
Porosity	The percentage of the soil or rock volume that is occupied by pore space, void of material; defined by the ratio of voids to the total volume of a specimen.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings in the rock (such as joints, cleats and/or fractures).
Ramsar	The Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat is an international treaty for the conservation and sustainable use of wetlands (named after the city of Ramsar in Iran where the convention was signed).
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.
Regulated river	River on which a licensed entitlement regime exists with centralised allocation, and from which orders may be placed for upstream release of a licensed allocation from a dam.
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.

Term	Definition
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).
Spring	A discharge location where groundwater emerges from the ground and becomes surface water.
Standing water level	Depth to groundwater below a datum point or reference point, usually from the top of casing or natural surface.
Stygofauna	Aquatic animals that live in groundwater systems.
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.
Unregulated river	A river where there is no entitlement system at all or where there is an entitlement system that does not allow orders to be placed for upstream release of a licensed allocation.
Unsaturated zone	Area above the water table where soil spaces, pores, fractures and voids are not completely filled with water.
Water access entitlement/licence (WAL)	A perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant WRP or WSP.
Water balance	A calculation of all water entering and leaving a system.
Water bore	A bore means any work constructed: • for the purpose of finding an aquifer • for the purpose of testing the production capacity or water quality of an aquifer • for the purpose of taking water from, or discharging anything into, an aquifer • for any other purpose prescribed by the regulations, being a bore that has been artificially created, widened, lengthened or modified by means of drilling, boring, augering, digging or jetting (*Water Management Act 2000*).
Water resource	All natural water (surface water or groundwater) and alternative water sources (such as recycled or desalinated water) that has not yet been abstracted or used.
Water resource plan (WRP)	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 2012.
Water sharing plan (WSP)	A plan made under the *Water Management Act 2000* that 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.

Term	Definition
Water source	Under NSW water legislation, water source means the whole or any part of: • one or more rivers, lakes or estuaries • one or more places where water occurs on or below the surface of the ground (including overland flow water flowing over or lying there for the time being), and includes the coastal waters of the state (*Water Management Act 2000*).
Water table	Upper surface of groundwater at atmospheric pressure, below which the ground is saturated.
Water year	Twelve month period from 1 July to 30 June.
Well	A large diameter hole (typically greater than 500 mm) drilled, excavated or dug into the ground.
Yield	The amount of water that can be supplied by a water supply works over a specific period.

Acronyms and abbreviations

Acronym/Abbreviation	Explanation
ANZECC	Australian and New Zealand Environment and Conservation Council
AWD	Available Water Determination
BLR	Basic landholder rights
BP	Before present
CAO	Controlled allocation order
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EC	Electrical Conductivity (a measure of salinity)
GAB	Great Artesian Basin
GDE	Groundwater Dependent Ecosystem
GL	Gigalitre (a billion litres)
GL/yr	Gigalitres per year
LFB	Lachlan Fold Belt
LTAAEL	Long Term Average Annual Extraction Limit
L/s	Litres per second
m	Metre
mm	Millimetre
MDB	Murray–Darling Basin
ML	Megalitre (a million litres)
ML/d	Megalitres per day
ML/yr	Megalitre per year
NEFB	New England Fold Belt

Acronym/Abbreviation	Explanation
PFAS	Per- and poly-fluoroalkyl substances
SIS	Salt interception scheme
WAL	Water access licence
WRP	Water resource plan
WSP	Water sharing plan

Geological timescale

Era	Period	Epoch	Approximate million years before present (BP)
Cainozoic	Quaternary	Recent	Less than 0.012
		Pleistocene	0.012 to 2.6
	Neogene	Pliocene	2.6 to 5.3
		Miocene	5.3 to 23
	Paleogene	Oligocene	23 to 33.9
		Eocene	33.9 to 56
		Palaeocene	56 to 66
Mesozoic	Cretaceous		66 to 145
	Jurassic		145 to 201
	Triassic		201 to 252
Palaeozoic	Permian		252 to 299
	Carboniferous		299 to 359
	Devonian		359 to 419
	Silurian		419 to 444
	Ordovician		444 to 485
	Cambrian		485 to 541
Proterozoic	Pre-Cambrian		Greater than 541

Appendix B

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Image courtesy of Department of Planning and Environment.
Drilling rig.

Groundwater system type, resources and water sources

Table 28. Fractured rock groundwater systems, resources and sources

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Fractured Rock	Lachlan Fold Belt	Goulburn/Coxs River Fractured Rock Groundwater Source
		Lachlan Fold Belt Coast Groundwater Source
		Lachlan Fold Belt MDB Groundwater Source
		Lachlan Fold Belt North Western Groundwater Source
		Yass Catchment Groundwater Source
		Young Granite Groundwater Source
	New England Fold Belt	New England Fold Belt Coastal Groundwater Source
		New England Fold Belt MDB Groundwater Source
		Peel Fractured Rock Water Source
	Other minor Fold Belt Rocks	Adelaide Fold Belt MDB Groundwater Source
		Adelaide Fold Belt North Western Groundwater Source
		Kanmantoo Fold Belt MDB Groundwater Source
		Kanmantoo Fold Belt North Western Groundwater Source
	Basalts*	Alstonville Basalt Plateau Groundwater Source
		Comboyne Basalt Groundwater Source
		Dorrigo Basalt Groundwater Source
		Inverell Basalt Groundwater Source
		Liverpool Ranges Basalt Coast Groundwater Source
		Liverpool Ranges Basalt MDB Groundwater Source
		North Coast Volcanics Groundwater Source
		Orange Basalt Groundwater Source
		Warrumbungle Basalt Groundwater Source

*Not all basalts across NSW are separated out into individual groundwater sources. Where not listed they are incorporated into the underlying fold belt groundwater sources.

Table 29. Porous rock groundwater systems, resources and sources

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Porous Rocks	Great Artesian Basin	Central Groundwater Source Eastern Recharge Groundwater Source Southern Recharge Groundwater Source Surat Groundwater Source* Warrego Groundwater Source
	Oxley Basin	Gunnedah–Oxley Basin MDB Groundwater Source Oxley Basin Coast Groundwater Source
	Clarence Morton Basin	Clarence Moreton Basin Groundwater Source
	Sydney Basin[20]	Kulnura Mangrove Mountain Groundwater Source Sydney Basin–North Coast Groundwater Source Sydney Basin–South Coast Groundwater Source Sydney Basin West Groundwater Source Sydney Basin Central Groundwater Source Sydney Basin MDB Groundwater Source Sydney Basin Nepean Groundwater Source Sydney Basin North Groundwater Source Sydney Basin South Groundwater Source
	Gunnedah–Bowen Basin	Gunnedah–Oxley Basin MDB Groundwater Source
	Murray Basin	Western Murray Porous Rock Groundwater Source
	Darling Basin	No separate water sources at this time. Part of the Lachlan Fold Belt MDB Groundwater Source and the Kanmantoo Fold Belt MDB Groundwater Source
	Other minor basins	Bulahdelah Sandstone Groundwater Source Gloucester Basin Groundwater Source Lorne Basin Groundwater Source Oaklands Basin Groundwater Source

*Surat Groundwater Source does not include the GAB sandstone aquifers within Groundwater Source Zones 1 to 5 of the Macquarie–Castlereagh Water Sharing Plan.

20. Water sources are subject to change with the introduction of the updated water sharing plan, currently in Draft status, water.dpie.nsw.gov.au/plans-and-programs/water-sharing-plans/status/greater-metropolitan-region

Table 30. Unconsolidated sediments – alluvium groundwater systems, resources and sources

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Unconsolidated sediments (alluvium)	Inland alluvium – Northern (Gwydir, Namoi and Macquarie)	Bell Alluvial Groundwater Source
		Castlereagh Alluvial Groundwater Source
		Cudgegong Alluvial Groundwater Source
		Currabubula Alluvial Groundwater Source
		Lower Gwydir Groundwater Source
		Lower Macquarie Groundwater Sources (Zones 1 to 6)* (6)
		Lower Namoi Groundwater Source
		Manilla Alluvial Groundwater Source
		Peel Alluvium Groundwater Source
		Quipolly Alluvial Groundwater Source
		Quirindi Alluvial Groundwater Source
		Talbragar Alluvial Groundwater Source
		Upper Gwydir Alluvial Groundwater Source
		Upper Macquarie Groundwater Source
		Upper Namoi Groundwater Sources (Zones 1 to 12) (12)
	Inland alluvium – Southern (Lachlan, Murrumbidgee and Murray)	Belubula Valley Alluvial Groundwater Source
		Billabong Creek Alluvial Groundwater Source
		Bungendore Alluvial Groundwater Source
		Gundagai Alluvial Groundwater Source
		Kyeamba Alluvial Groundwater Source
		Lower Lachlan Groundwater Source
		Lower Murray Deep Groundwater Source
		Lower Murray Shallow Groundwater Source
		Lower Murrumbidgee Deep Groundwater Source
		Lower Murrumbidgee Shallow Groundwater Source
		Mid Murrumbidgee Zone 3 Alluvial Groundwater Source
		Upper Lachlan Alluvial Groundwater Source
		Upper Murray Groundwater Source
		Wagga Wagga Alluvial Groundwater Source

*Zones 1 to 5 groundwater sources include the GAB Surat Basin sandstone aquifers to basement.

Table 30. Unconsolidated sediments – alluvium groundwater systems, resources and sources (continued)

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Unconsolidated sediments (alluvium)	Inland alluvium – Darling, Border Rivers and major tributaries	GAB Central Shallow (MDB) Groundwater Source** GAB Central Shallow (North Western) Groundwater Source** GAB Surat Shallow Groundwater Source** GAB Warrego Shallow Groundwater Source** Lower Darling Alluvial Groundwater Source MacIntyre Alluvial Groundwater Source NSW Border Rivers Downstream Keetah Bridge Alluvial Groundwater Source NSW Border Rivers Upstream Keetah Bridge Alluvial Groundwater Source Ottleys Creek Alluvial Groundwater Source Paroo Alluvial Groundwater Source Upper Darling Alluvial Groundwater Source Warrego Alluvial Groundwater Source
	Coastal alluvium – upper and mid catchment	Maroota Tertiary Sands Groundwater Source In addition, there are 287 upriver alluvial segments in coastal surface water sources. The majority of these are unnamed and are referred to by the surface water body above them. These are not individually listed in this table. The reader should refer to individual water sharing plans.

**These water sources cover (i) all geological formations (mostly shallow GAB aquifers) to a depth of 60 m below the surface of the ground, and (ii) all alluvial sediments to any depth below the surface of the ground.

Table 30. Unconsolidated sediments – alluvium groundwater systems, resources and sources (continued)

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Unconsolidated sediments (alluvium)	Coastal alluvium and estuarine sediments – lower floodplain	There are 81 lower floodplain alluvial/estuarine segments in coastal surface water sources. Seventy of these are unnamed and identified only by the surface water source above them. The 10 that are named are: • Bellinger River Coastal Floodplain Alluvial Groundwater Water Source • Brunswick River Coastal Floodplain Alluvial Groundwater Source • Clarence River Coastal Floodplain Alluvial Groundwater Source • Coastal Macleay Floodplain Alluvial Groundwater Source • Coastal Nambucca Floodplain Alluvial Groundwater Source • Coopers Creek Alluvial Groundwater Source • Hastings River Coastal Floodplain Alluvial Groundwater Source • Hawkesbury Alluvium Groundwater Source • Hunter Coastal Floodplain Alluvial Groundwater Source • Hunter Regulated River Alluvial Water Source • Richmond Regulated Alluvial Water Source The reader should refer to individual water sharing plans.

Table 31. Unconsolidated sediments – sands groundwater systems, resources and sources

Groundwater system type	Groundwater resource	Groundwater sources under current WRPs and WSPs
Unconsolidated sediments (dune and beach sands)	Coastal sands	Bellinger–Nambucca Coastal Sands Groundwater Source
		Botany Sands Groundwater Source
		Clarence Coastal Sands Groundwater Source
		Coffs Harbour Coastal Sands Groundwater Source
		Great Lakes Coastal Sands Groundwater Source
		Hastings Coastal Sands Groundwater Source
		Hawkesbury to Hunter Coastal Sands Groundwater Source
		Macleay Coastal Sands Groundwater Source
		Manning-Camden Haven Coastal Sands Groundwater Source
		Metropolitan Coastal Sands Groundwater Source
		Richmond Coastal Sands Groundwater Source
		South East Coastal Sands Groundwater Source
		Stockton Groundwater Source
		Stuarts Point Groundwater Source
		Tomago Groundwater Source
		Tomaree Groundwater Source
		Tweed-Brunswick Coastal Sands Groundwater Source
	Inland sands	No separate water sources at this time
		Part of the Western Murray Porous Rock Groundwater Source

Image courtesy of Destination NSW.
Nambucca River, Nambucca Heads.

Department of Planning and Environment