

NSW Groundwater Strategy

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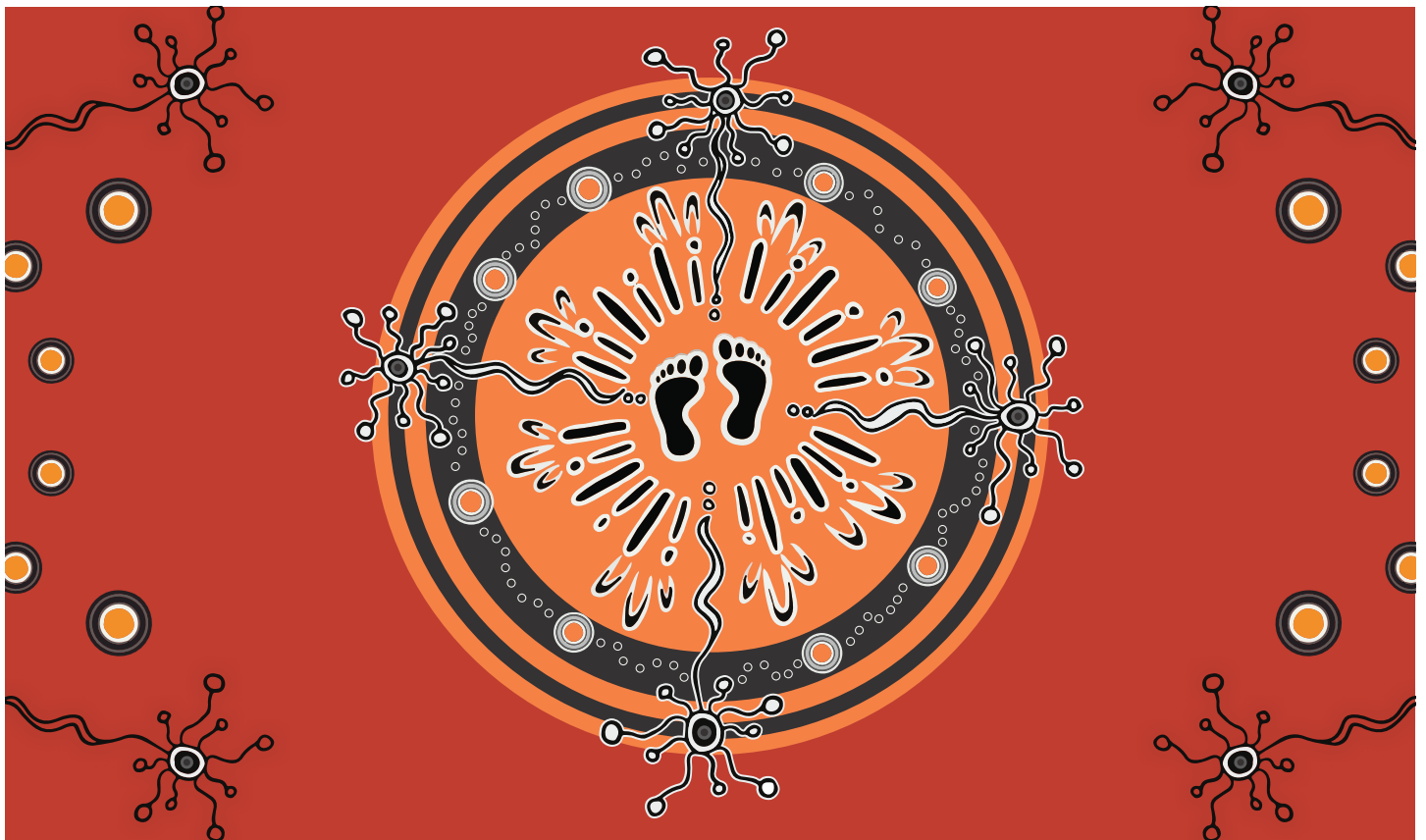
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More information www.dpie.nsw.gov.au/groundwater-strategy

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Acknowledgment 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.

Minister's foreword



Kevin Anderson MP
Minister for Lands and Water

The NSW Government is using new knowledge and evidence to improve the management of water resources across the state and better prepare communities for future droughts and a more variable climate. The NSW Groundwater Strategy is part of a suite of state-wide regional and metropolitan strategies aimed at ensuring we have resilient water services and resources in NSW in the decades ahead.

Groundwater is a vital resource for NSW. It is a source of water supply for many communities and industries. Activities supported by groundwater directly contribute close to \$1 billion to the NSW economy each year. Equally important is the role groundwater plays in supporting ecosystems and maintaining water in our rivers, streams, and wetlands. With most surface water resources now fully allocated, groundwater is an increasingly critical supply source – particularly during dry times.

Although NSW has a strong framework and robust policies in place to manage the extraction and use of groundwater, the highly vulnerable resource is coming under increased pressure from climate change, growing demand, urban development and changing land uses. We have to protect and secure our groundwater resources so they continue to support the environment, communities and industries into the future. That requires taking stock of the current condition of these resources, looking at the challenges we face and applying new knowledge and science to adopt the right approaches, policies and tools to manage groundwater sustainably.

We also need to learn from Aboriginal people's knowledge in managing groundwater and better recognise and provide for Aboriginal people's rights to, and interests in, groundwater. The NSW Government is working with Aboriginal communities to develop a state-wide Aboriginal Water Strategy and increase the participation and employment of Aboriginal people 'on the ground' in maintaining the health of our waterways. This approach will extend to groundwater, where Aboriginal communities could secure new economic opportunities from better access to groundwater.

Unlike our rivers, lakes, wetlands and other surface water bodies, groundwater is largely a 'hidden' resource. This means we understand and know less about groundwater than we do about surface water. The NSW Groundwater Strategy has a strong focus on collecting and sharing better data and evidence about groundwater resources across NSW so all of us – including government, water utilities, environmental managers, industries and landholders – can make well-informed decisions about how to manage and use these resources.

The strategy also gives priority to protecting groundwater sources and the ecosystems that depend on them as well as ensuring the long-term security and quality of groundwater supply to towns, cities and industries. We are also exploring how we can do more with less groundwater in a more variable climate, such as potentially increasing our use of marginal groundwater sources through innovative solutions.

In a first for NSW, this new strategy sets out a logical, evidence-based framework for the sustainable use of our groundwater resources over the next 20 years. Importantly, it actively encourages collaboration, participation and partnerships to create a sense of shared ownership, trust and responsibility in caring for, protecting and managing these vital resources for the benefit of all of us – including the generations that will come after us.



Image courtesy of Jake Turi. Killen Falls.

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Strategy at a glance



Vision

Groundwater supports cultural and social values, dependent ecosystems and resilient towns and industries



Outcomes



Our groundwater resources and dependent ecosystems are protected to support current and future uses



Through sustainable groundwater use, water dependent aspirations of Aboriginal people are supported, water resilience for urban populations is improved and development opportunities are realised



Better groundwater management and investment decisions are made based on improved information and knowledge



Actions

Refresh, consolidate and expand our groundwater policy framework

page 46

Support Aboriginal people's rights, values and uses of groundwater

page 60

Develop the groundwater components of a water knowledge plan

page 72

Improve protection of groundwater dependent ecosystems and baseflows to streams

page 47

Support towns and cities that use groundwater to improve their urban water planning

page 63

Better share and integrate groundwater information

page 73

Review and update approaches to sustainable groundwater extraction

page 50

Support resilient groundwater dependent industries in NSW

page 65

Improve our understanding of groundwater resources

page 76

Protect groundwater quality within natural limits

page 54

Expand and target our groundwater data collection

page 78

Better integrate groundwater management with other land and water management processes

page 56

Facts about groundwater in NSW



Aboriginal communities have a deep connection to groundwater

Important **cultural values** are associated with wetlands, springs, caves and other groundwater dependent ecosystems



NSW groundwater resources are extensive

There are over **500 groundwater sources** capable of supplying up to 3,200 GL per year



Many communities depend on groundwater

Over 250 regional towns with a combined population close to **300,000** depend on groundwater fully or partially



Groundwater is at risk from climate change

It is projected that groundwater recharge will decrease by **15%** on average across the state by 2060



NSW has rich and extensive groundwater dependent ecosystems

They cover over **6.5 million ha** in NSW (8% of NSW's land surface)
There are more than **1,000** unique groundwater dependent plant types in NSW, **69** of which are threatened



Groundwater contributes to the NSW economy

Close to **\$1 billion** in direct value is generated from activities using groundwater



Groundwater supports a variety of uses

Agriculture represents over **70%** of all groundwater use, followed by industry with **10%** and towns with **5%**



Groundwater extraction is highly concentrated

Over **70%** of groundwater extraction occurs in the Murrumbidgee, Lachlan and Namoi regions



Demand for groundwater will increase

The use of groundwater for industrial activities may increase by up to **60%** by 2042



Demand by towns may significantly increase

The demand for groundwater by towns is expected to increase by close to **300%** by 2042



Groundwater is a strategic resource during drought

Groundwater can represent up to **70%** of the total water used by agriculture during drought



Trade is increasing

Over the last 10 years permanent trade of groundwater entitlements has increased by **300%** and temporary trading by **170%**



The value of trade

In 2019–20, the value of permanent groundwater trades was **\$45m** and **\$55m** for temporary trades

Introduction



Image courtesy of Department of Primary Industries.
Bore and overhead tank in Merebene Section, Pilliga West.

Across NSW – from our towns to our cities, from our coasts to the outback – healthy groundwater resources sustain our unique ecosystems and wildlife, maintain vital industries and support our way of life and well-being.

Over the course of the past century, our management of groundwater has evolved from exploiting our resources to introducing sustainable extraction limits and focusing on ecosystem protection. Now, we need to take another step towards sustainability and ensure we can adapt to future challenges.

With this strategy, the NSW Government is acting to protect the reliability, quality and resilience of our groundwater. We are making sure this critical resource is managed sustainably so that the environment, towns, communities and industries have access to the groundwater they need to thrive – now and in the future.



Image courtesy of Department of Primary Industries. Bore located at Millie, Moree Plains Shire.

The need for a groundwater strategy

Groundwater is a vital and strategic natural resource for NSW, critical for towns and villages, agriculture and other industries. Without groundwater, many towns and villages would run out of water during drought. Groundwater keeps many of our rivers flowing in times of low rainfall and provides vital refuges in river pools for animals and vegetation. Many of our wetlands and a wide range of other ecosystems also rely on groundwater.

Our knowledge of groundwater and the ecosystems it supports continues to grow and our notion of achieving sustainability is evolving.¹ Community perceptions of what constitutes fair access to groundwater are also evolving, particularly concerning access for Aboriginal people.

However, our groundwater resources are vulnerable. A more variable climate is affecting rainfall patterns, decreasing surface water flows and reducing groundwater recharge and availability. These risks are heightened as population growth, land use practices and increased demand from communities and industries place a strain on our groundwater resources. Apparent gaps in our knowledge and data about the resource and its quality make managing these risks challenging. Without better management, ecosystems, regional towns and cities, communities and valuable economic activities that depend on groundwater are threatened.

A renewed effort is required to sustainably manage this important natural resource so that it can underpin long-term community and economic development and support the services and opportunities on which our society relies. Put simply, if we do not continue to adapt and manage our groundwater resources wisely, we will create unacceptable risks to the critical values and uses they support – both today and in the coming decades.

Figure 1. Evolution of groundwater management in NSW



1. The United Nations (UN) identified groundwater sustainability as a global challenge in 2022 and the UN Sustainable Development Goals (SDGs) adopted in 2015 consider ecosystem protection and water and food security as essential components of a sustainable future. This includes particularly SDG 6, Ensure availability and sustainable management of water and sanitation for all. See UN 2022, *Groundwater: Making the invisible visible*, *World Water Development Report 2022*, www.unwater.org/un-world-water-development-report-2022/

Our vision is that groundwater resources in NSW support cultural and social values, dependent ecosystems and resilient towns and industries.

To deliver on this vision, we will focus on 3 strategic priorities:

1. Protect groundwater resources and the ecosystems that depend on them
2. Build community and industry resilience through sustainable groundwater use
3. Improve groundwater information and knowledge.

These strategic priorities set the direction for our groundwater management investments and efforts over the next 20 years.



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

Strategic context

The NSW Government is delivering a suite of water strategies for the state. These include the *NSW Water Strategy*,² this NSW Groundwater Strategy, 12 regional water strategies, 2 metropolitan water strategies and an Aboriginal Water Strategy.

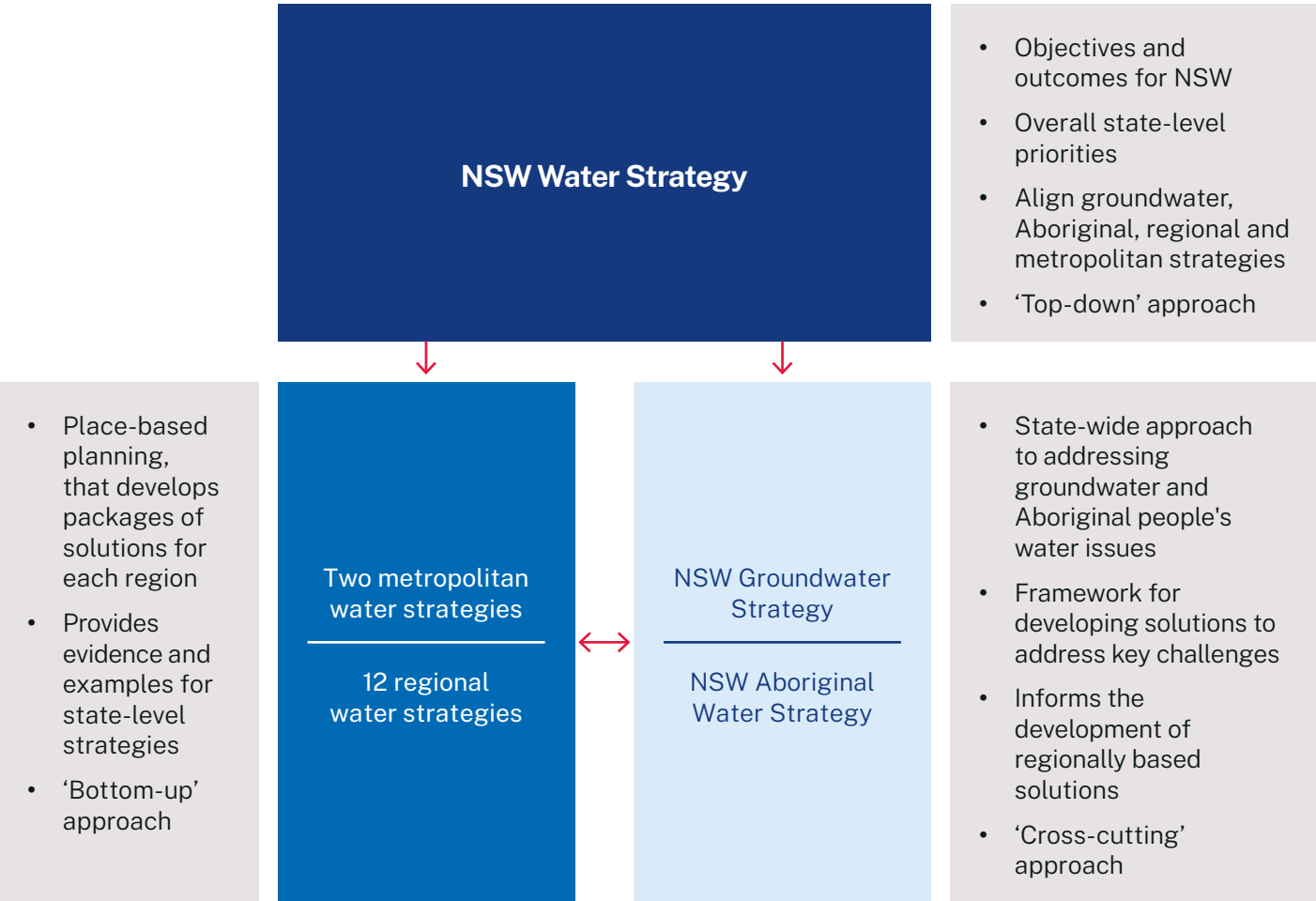
The NSW Groundwater Strategy is an element of the 2021 *NSW Water Strategy* – a 20-year strategy that aims to improve the security, reliability, quality and resilience of the state’s water resources (Figure 2). The *NSW Water Strategy* is a long-term ‘roadmap’ of actions to deliver the following key objectives:

- protect public health and safety
- ensure liveable and vibrant towns and cities
- protect our water sources, floodplains and ecosystems
- protect and respect cultural values
- provide for the orderly fair and equitable sharing of water
- contribute to a strong economy.

The NSW Groundwater Strategy, developed through a process of evidence building and engagement across the state over the past 3 years, is designed to achieve these high-level objectives for the state’s groundwater resources. It also draws together solutions to common state-wide challenges articulated in the regional water strategies. The NSW Groundwater Strategy needs to be finalised before many local actions from the regional water strategies can proceed.

The alignment of regional-scale actions with state-scale actions is pivotal in creating clarity during implementation. Having a clear alignment of proposed actions will better prepare us for long-term projects with appropriate delivery plans and timely actions that result in more efficient use of government and community resources.

Figure 2. The NSW Groundwater Strategy is part of a suite of long-term strategies being developed by the NSW Government



2. water.dpie.nsw.gov.au/plans-and-programs/nsw-water-strategy/toward-2050

Groundwater in NSW



Image courtesy of Department of Planning and Environment. Production bore extraction site.

There are 2 companion documents that support this NSW Groundwater Strategy: the *Guide to Groundwater Resources in NSW* and the *Guide to Groundwater Management in NSW*. This part of the strategy gives a broad overview of these 2 documents. For more detailed information on the state's groundwater resources and current groundwater management framework, please refer to these supporting documents.

If you wish to skip this background and start reading about the challenges we face, go to Chapter 4 (page 44), or to read about the strategic priorities themselves, please go to Chapter 5 (page 82).

Figure 3. Chapter summary – Our groundwater resources and their management

Our groundwater resources		page 16
	Groundwater resources are extensive across NSW	
	Groundwater is a vital resource for our State	
	Groundwater extraction varies across NSW	
Our groundwater management		page 24
	Strategies, legislation and implementation tools exist to manage groundwater sustainably in NSW	
	Management responsibility is shared with the Australian government, our neighbouring states and local councils	
For further reading:		
	<i>Guide to Groundwater Resources in NSW</i>	
		<i>Guide to Groundwater Management in NSW</i>

Our groundwater resources

Extensive groundwater resources can be found throughout NSW. Not only does this groundwater sustain environmental values and supply water for towns, but a variety of commercial users from agriculture and grazing to mining and quarrying depend on the resource. Groundwater use has increased over the last decade and some groundwater sources are under stress. In other places, underutilised groundwater sources have the potential to support economic activities and additional growth.

Characteristics of groundwater

Groundwater is water below the land surface in the saturated zone. It moves slowly between open spaces in sediment and the cracks (or fractures) of rocks. It enters the ground in recharge areas and leaves via discharge areas.

Groundwater is contained in aquifers, which are underground geological formations with the capacity to store and provide 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 naturally discharge at permanent water features in the landscape such as springs, streams and wetlands. This process can take days where aquifers are shallow and highly connected to surface water features, or more than a million years in large, deep and confined aquifers such as the Great Artesian Basin.

Water bores, mines and underground infrastructure such as tunnels and basements are some of the human activities that can divert or impact groundwater flows. The quantity and quality of groundwater resources can be impacted by activities such as land clearing, intensive agriculture and some urban and industrial activities.

Groundwater also directly contributes to the health of dependent ecosystems (both underground and in discharge areas) called groundwater dependent ecosystems (GDEs).

Although groundwater occurs everywhere below the ground's surface, its quantity and quality can vary. The amount of groundwater stored in an aquifer, the ability to get that water out of the ground (i.e. yield) and the quality of the water (which can be affected by various contaminants such as salinity) depends on the geology, the nature of the overlying soils and recharge/flow characteristics.

Quantity

The quantity of groundwater available for use is a key characteristic of a groundwater source. Yields of water bores are highly variable and are mostly determined by the geology and the permeability of the groundwater system. Because of this variability, there are several classifications for groundwater aquifers. Unconsolidated sand and gravel aquifers have the highest yields of any groundwater system in NSW (typically in the range of 5 to 300 litres per second (L/s)) while fractured rock aquifers have the lowest yields (typically less than 5 L/s).

Quality

The quality of groundwater determines the suitability of the water for a particular purpose. There are several important attributes that determine suitability, but salinity is the most critical. Groundwater in aquifers across NSW can vary from as fresh as rainwater to saltier than seawater. Groundwater salinity is determined by the length of time water spends in the groundwater system, the type of sediment, porous or fractured rock that hosts the groundwater system and the length of the flow path.

Groundwater dependent ecosystems

Groundwater sustains surface and sub-surface ecosystems and habitats that depend on this water to survive and thrive. Typical groundwater dependent ecosystems include springs, permanent streams, lakes, caves, wetlands and deep-rooted vegetation. These ecosystems can be compromised by severe changes to groundwater sources caused by droughts and human activities.

Surface water – groundwater interaction

As water flows along a stream, water may flow out of or seep into underlying groundwater system. When the height of water in a stream is above the groundwater table, water from the stream flows to the underlying aquifer as recharge. When the water table in the underlying aquifer is higher than the streambed, groundwater flows to the stream and is discharged as baseflow.

The most connected groundwater sources are the alluvial aquifers located beneath floodplains close to rivers. In inland alluvial areas, surface water and groundwater are managed separately. For smaller coastal alluvial areas where groundwater systems are often shallow and porous enough for a strong connection between surface water and groundwater, all water is managed as one resource. Further details are provided in the *Guide to Groundwater Management in NSW*.

Groundwater resources are extensive across NSW

Groundwater is an important water source for NSW. The average total allowable extraction is close to 3,350 GL per year, which is about 3/4 the total amount stored at Lake Eucumbene – the largest surface water reservoir in NSW.³ Even more groundwater is reserved for the environment.

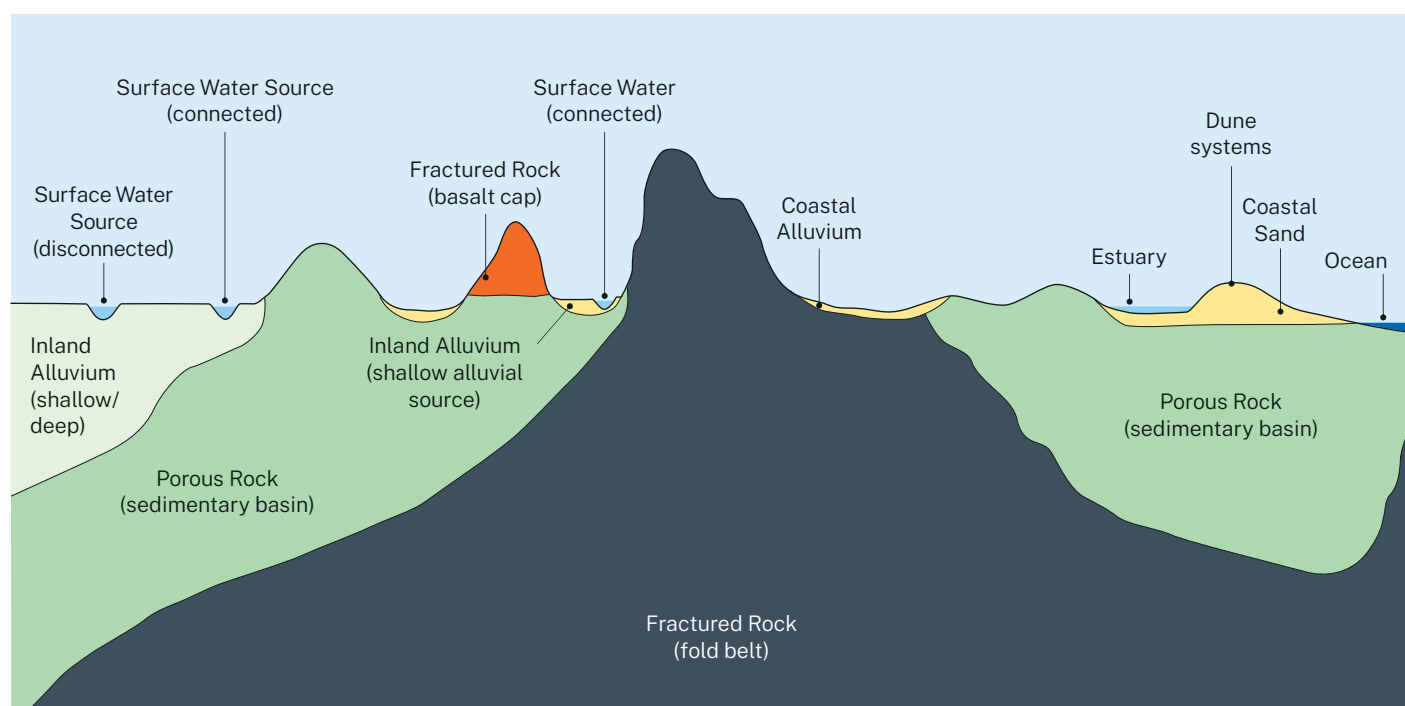
The presence of groundwater is closely linked to the area's geology because groundwater accumulates in the open spaces or cracks and fractures in sediment or rocks.

There are fundamentally 3 types of groundwater systems in NSW:

- fractured rock groundwater systems (basement fold belts and basalts)
- porous rock groundwater systems (sedimentary basins)
- unconsolidated groundwater systems (shallow alluvial and sand dune/beach deposits).

An overview of groundwater resource types in NSW is shown in Figure 4.

Figure 4. Overview of the groundwater resource types in NSW



3. This consists of the sum of Long-Term Average Annual Extraction Limits across the state, plus current entitlements in coastal unregulated and alluvial systems.

Fractured rock groundwater systems

Fractured rocks are found in the regional fold belt areas (predominantly the Lachlan Fold Belt and the New England Fold Belt) and form the basement rocks (and host the base-layer groundwater systems) across the whole of NSW. 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). Basalts contain important fractured rock groundwater systems found in multiple plateau areas across eastern NSW.

Groundwater does not flow through the solid rock itself. Rainfall seeps into the water table and then moves slowly through fractures and faults in the rock. Bore yields are generally low (on average less than 2–3 L/s) and water quality is brackish to saline unless in areas with high rainfall. Fractured rock groundwater sources are not typically used as primary water supply sources, but they are an important back-up water source during times of drought and other emergencies.

Porous rock groundwater systems

Porous rocks systems are comprised of consolidated deposits of sandstone, siltstone, claystone, conglomerates, shale and coal and form both young and old sedimentary basins across NSW. These basins are much younger than the fractured rocks in the basement fold belts. The largest and most important basins with known groundwater resources are the Great Artesian Basin and the Sydney Basin. Porous rock groundwater systems in NSW overlie fractured rock and extend across more than 60% of the state.

Due to their ubiquity and depth, porous rock groundwater systems store large amounts of groundwater. Sandstone and coal seams are the most common aquifers, and their length can extend for tens to hundreds of kilometres.

Artesian supplies of 50–60 L/s are possible from deep sandstone aquifers in the Great Artesian Basin. The older Sydney and Gunnedah-Bowen Basins have highly variable yields and water quality. The other sedimentary basins across NSW have mostly low yields (typically less than 5 L/s) and variable quality groundwater.

Unconsolidated sediment groundwater systems

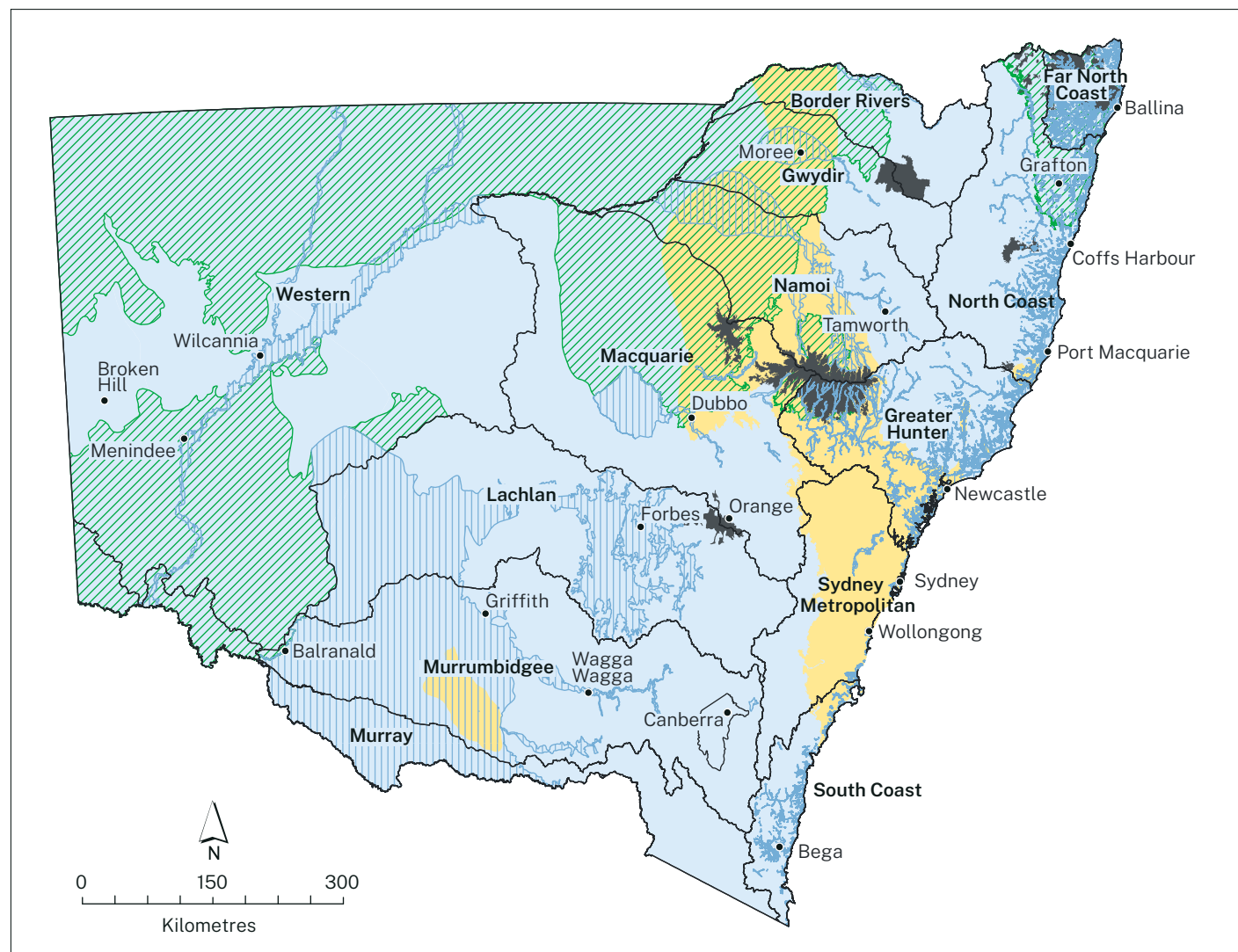
Unconsolidated sediment includes river-deposited alluvium (sand, gravel, silt and clay) and dune and beach sands. These sediments overlie both regional fold belts and sedimentary basins and host the groundwater resources nearest to the surface.

Alluvium is associated with past and present rivers and floodplains in the major inland catchment of the Murray–Darling Basin. Some of these are buried deep below the ground surface and follow ancient river and floodplain pathways. Others are shallower and reflect the location of current rivers and floodplains. Along coastal NSW, the valley alluvium is thin and surficial and merges with estuarine sediments in the tidal and coastal areas.

The groundwater contained in the alluvial deposits of the 6 major inland catchments (Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee and Murray) are the most productive and economically important groundwater resources in NSW. Bores with the highest yields (some more than 300 L/s) are usually located at depth in highly permeable sand and gravel aquifers. Along coastal NSW, most of the thin alluvial aquifers yield less than 20 L/s. Recharge areas with high rainfall levels and regulated rivers yield groundwater that is fresh and of good quality.

Coastal sand systems consist of aquifers located in dune and beach aeolian (e.g., created by the wind) deposits along the coast. Bore yields are typically less than 10 L/s (but can be as high as 50 L/s) and water quality is mostly fresh unless it is close to saltwater features.

Figure 5. Location of primary groundwater resource types in NSW



Legend:

- | | | |
|--|--------------------------|--------------------|
| Water strategy boundary | Fractured rock (Basalts) | Older porous rocks |
| Alluvials, coastal sands and other sediments | Younger porous rocks | Fractured rocks |

Groundwater access rights and demand in NSW

Groundwater access rights

NSW grants rights to individuals or entities to take groundwater mainly through either access licences or non-licensed basic landholder rights.⁴ The current number of rights to extract groundwater in NSW is approximately 2.27 million shares, with about 1.97 million of these held under approximately 10,850 individual licences. The remaining 300,000 entitlement units are authorised for unlicensed basic landholder rights for domestic and stock use. Groundwater access rights vary in their distribution across the state – less than 20% of access rights are east of the Great Dividing Range.

To protect our groundwater resources, existing rights and ecosystems dependent on groundwater, statutory water sharing plans limit the amount of extraction that can occur on an average annual basis. The sum of volumetric rights (e.g. basic landholder rights and special purpose access licences) plus access licences appears to exceed the combined volumetric extraction limits for inland alluvial groundwater systems (Figure 6).

However, most access rights are expressed in shares rather than by volume, which enables extraction from a groundwater source to be managed within the limits specified in a water sharing plan.

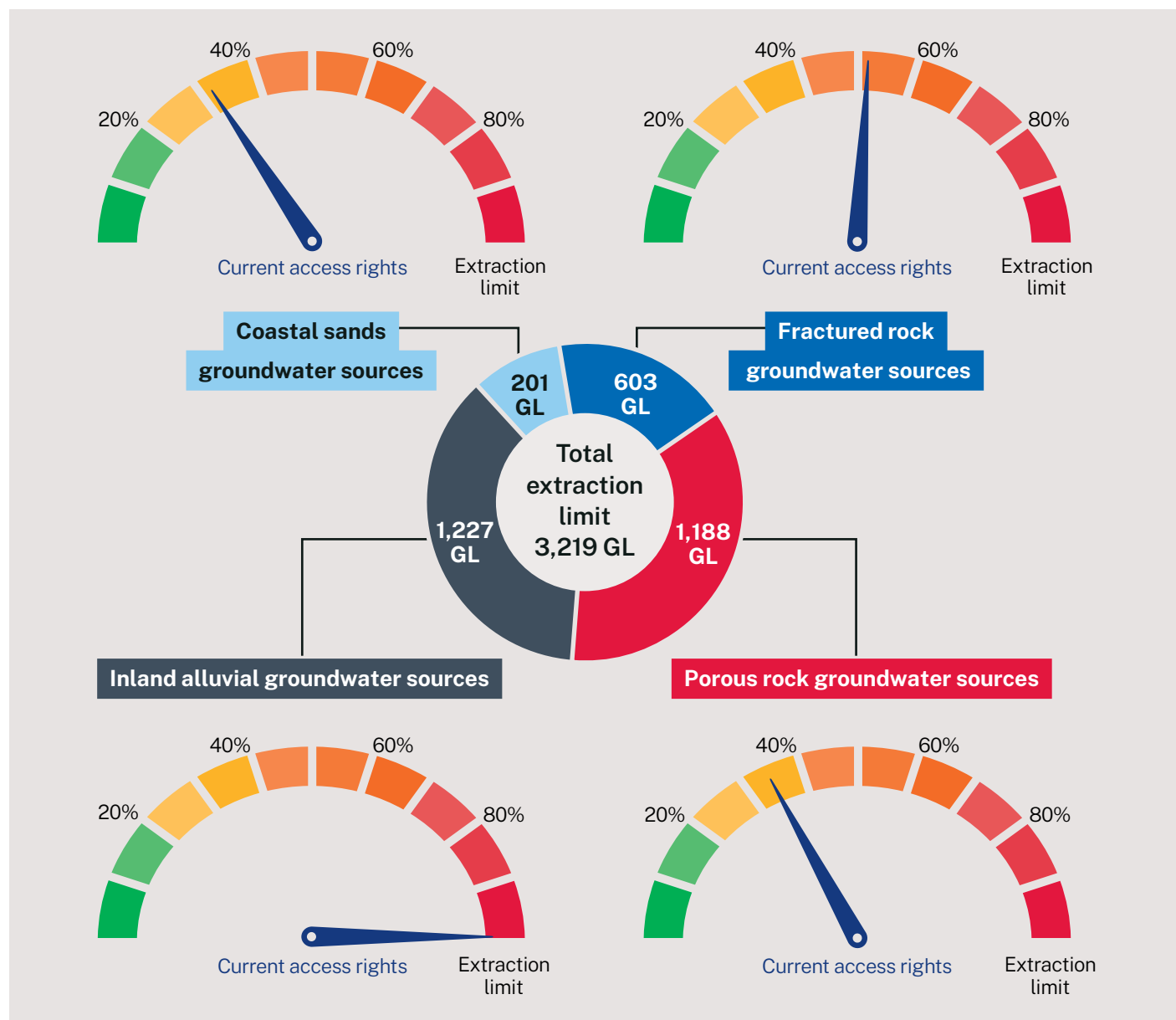
In the porous rock, fractured rock and coastal sands groundwater systems, groundwater access rights are currently around 50% or less of their respective extraction limits (Figure 6). Even though some individual water sources are fully committed and use is high (such as some porous rock water sources 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 licenses can be granted in a few water sources and these are made available by government periodically via Controlled Allocation Orders (see the *Guide to Groundwater Management in NSW* for more details).



Image courtesy of Glen McPherson. Thollo old bore tank.

4. A native title holder has the right to take and use groundwater in the exercise of native title rights. Similarly, an owner or occupier of a landholding is entitled to take groundwater from an aquifer underlying their land and to use that water for domestic consumption and stock watering, but not for any other purpose. A water licence is not required to exercise these basic landholder rights.

Figure 6. Groundwater access rights (entitlements) as a proportion of extraction limits



Source: Department of Planning and Environment data.

Entitlement levels = estimate for 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).

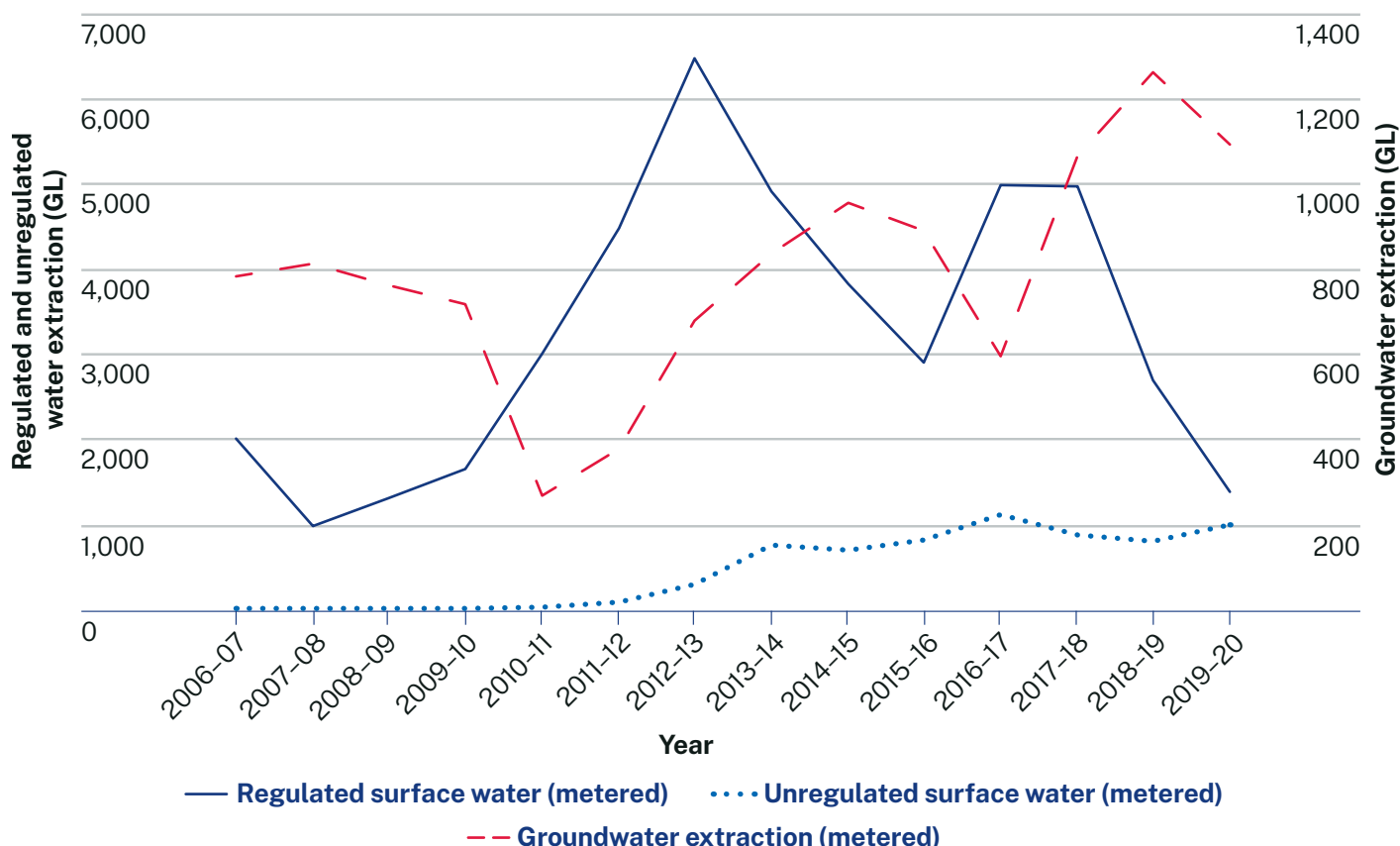
Groundwater use and demands

Many sectors of the NSW economy depend on groundwater to thrive. It is important for the agricultural and urban sectors and often supplement or replace traditional surface water sources during periods of drought.

Over the last decade, extraction volumes⁵ have ranged from just below 500 GL in a wet year to about 1,550 GL in the extreme drought year of 2018–19 (Figure 7). This is likely an underestimate because not all extraction associated with licensed groundwater is metered or recorded.

Groundwater extracted from productive alluvial aquifers across the agricultural regions of the Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee and Murray catchments in the Murray–Darling Basin account for most groundwater used in NSW – as much as 75% of all groundwater extraction and up to 90% of currently metered extraction occurs in these regions. It is mostly used to irrigate annual cereal and fibre crops, such as sorghum and cotton, and a variety of fruit and nut plantations. It is also sometimes used to improve pasture for livestock.

Figure 7. Groundwater provides supply security when surface water flows decrease



Note: Groundwater extraction data based on metered bores only.

Source: Department of Planning and Environment data.

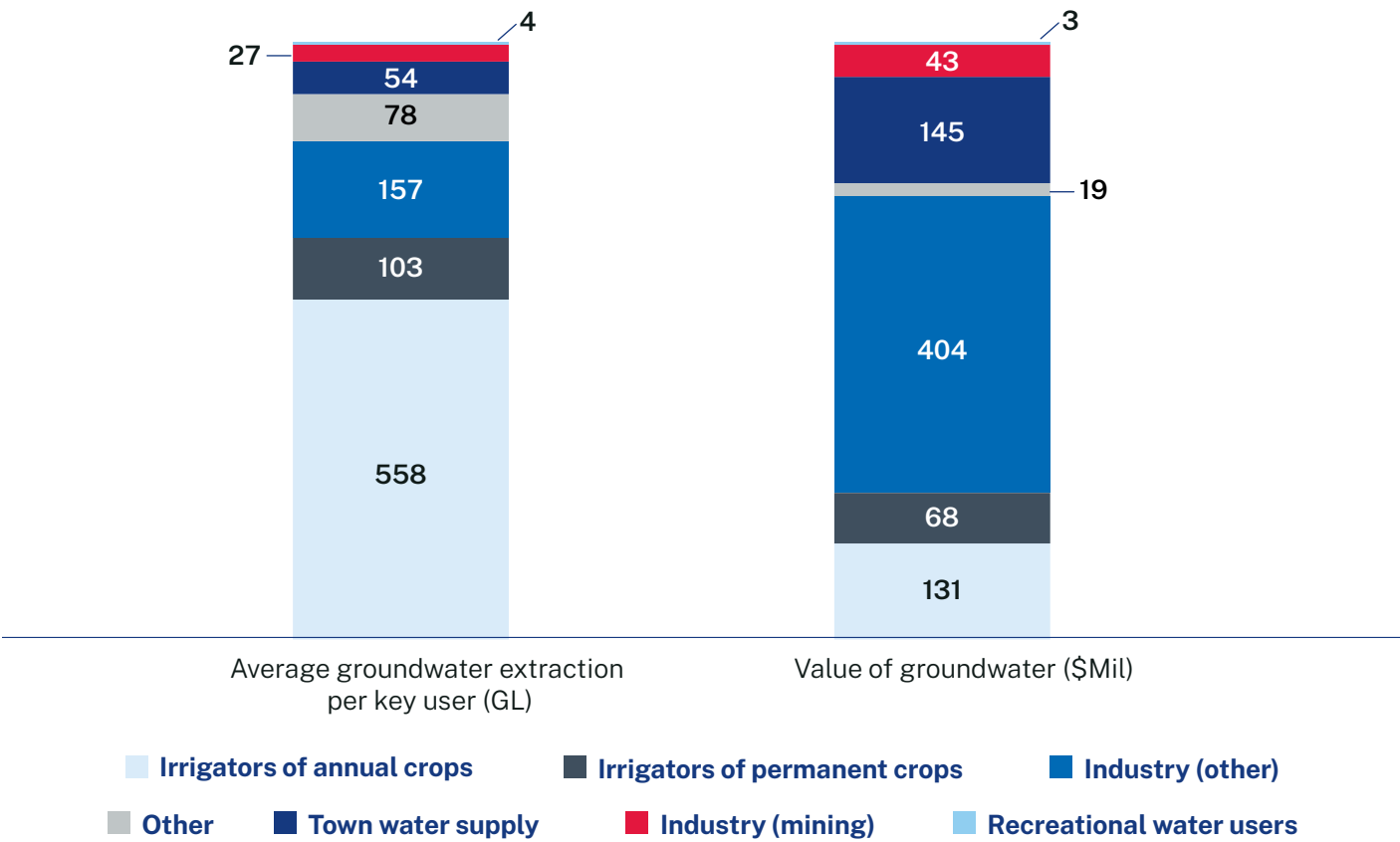
Analysis indicates the agricultural sector is the largest user of groundwater and accounts for 75% of all licensed groundwater use across the state.⁶ Mining and other industrial sectors account for another 10–15% of use.

The remaining water is mostly extracted by water supply authorities for domestic use – more than 250 cities and towns use groundwater from 52 different groundwater sources (Figure 8).

5. Measured by metered usage plus estimates for use from unlicensed basic landholder rights.

6. Department of Planning and Environment 2022, *Economic users of alluvial groundwater sources for Gwydir, Lachlan, Macquarie, Murray, Murrumbidgee, and Namoi regional water strategy*. Report prepared by The Centre for International Economics for Department of Planning and Environment – Water Group. Also Department of Planning and Environment (2021a) *Understanding NSW's economic dependency on groundwater*. Report prepared by The Centre for International Economics for Department of Planning and Environment – Water Group.

Figure 8. Average annual metered groundwater extraction by key user category



Note: Based on metered data. This figure shows preliminary economic analysis results, subject to further review.
Source: Department of Planning and Environment data

Future Projections

Growth in the demand for groundwater is expected to increase by more than 22% over the next 20 years, largely driven by substantial population growth and increased climate variability resulting in less reliable surface water resources (especially in the Murray–Darling Basin). Demand is expected to increase across all sectors that rely on groundwater, except for recreational use.

Most population growth is predicted to occur, 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 in the next 20 years.

With growth comes the associated demand for more water and improved water supply resilience, which will be exacerbated during climate emergencies such as drought, floods and bushfires. As a result, demand for groundwater from the urban sector is expected to increase by 290% by 2040.

Irrigation will continue to be the dominant consumptive use of groundwater and a 27% increase in demand is forecasted by 2040. Demand for groundwater from mining and extractive industries is also expected to increase by 13% over the next 30 years, despite a predicted decline in the production of thermal coal. Growth in intensive rural industries is difficult to predict – modelling suggests demand could increase by more than 50% over this period.

Our groundwater management

NSW has a robust, world-leading approach to groundwater management that aims to ensure vital groundwater sources support the environment, communities and the economy.

The First peoples of NSW have been water managers for millennia. Rights and a moral obligation to care for water is a part of their culture. Following European occupation in 1788, Aboriginal people were largely excluded from water management activities.

From the late 1800s to the 1980s, management of groundwater in NSW primarily supported economic development by finding and exploiting groundwater sources. The *Water Act 1912* introduced the first water licences for Great Artesian Basin bores and were granted in perpetuity. In the 1960s, licence requirements were expanded to all bores in NSW and were issued without volumetric entitlement or restriction for productive uses. Little consideration was given to the environmental impacts of groundwater extraction, the importance of conserving and protecting the resource, or the values and needs of Aboriginal people.

Rapid expansion of irrigated agriculture, increased competition for water resources and periods of extended drought in the 1980s were affecting the reliability of water supplies in inland NSW. As a result, volume-based groundwater entitlements were introduced as a means to set limits on extraction.

By the 1990s, it was generally accepted that land and water management practices were contributing to natural resource degradation and needed to change. Reforms introduced in NSW through the *Water Management Act 2000* reflected the shift underway across Australia towards more sustainable water management. Today, NSW has a robust, multifaceted groundwater management framework focused on sustainable groundwater use (Figure 9).

The groundwater management framework is implemented collaboratively by local, state and federal governments and the people, communities and industries that rely on groundwater. The NSW Government, through the Department of Planning and Environment, has primary responsibility for managing the state's water resources, including groundwater. Elements of NSW's state groundwater management responsibilities are shared with the Australian Government and local governments. Metropolitan water utilities, Water NSW and non-government irrigation corporations also play significant roles in managing groundwater resources.



Image courtesy of Department of Primary Industries. Murrawombie Pit Girilambone, Cobar.

Figure 9. The NSW groundwater management framework

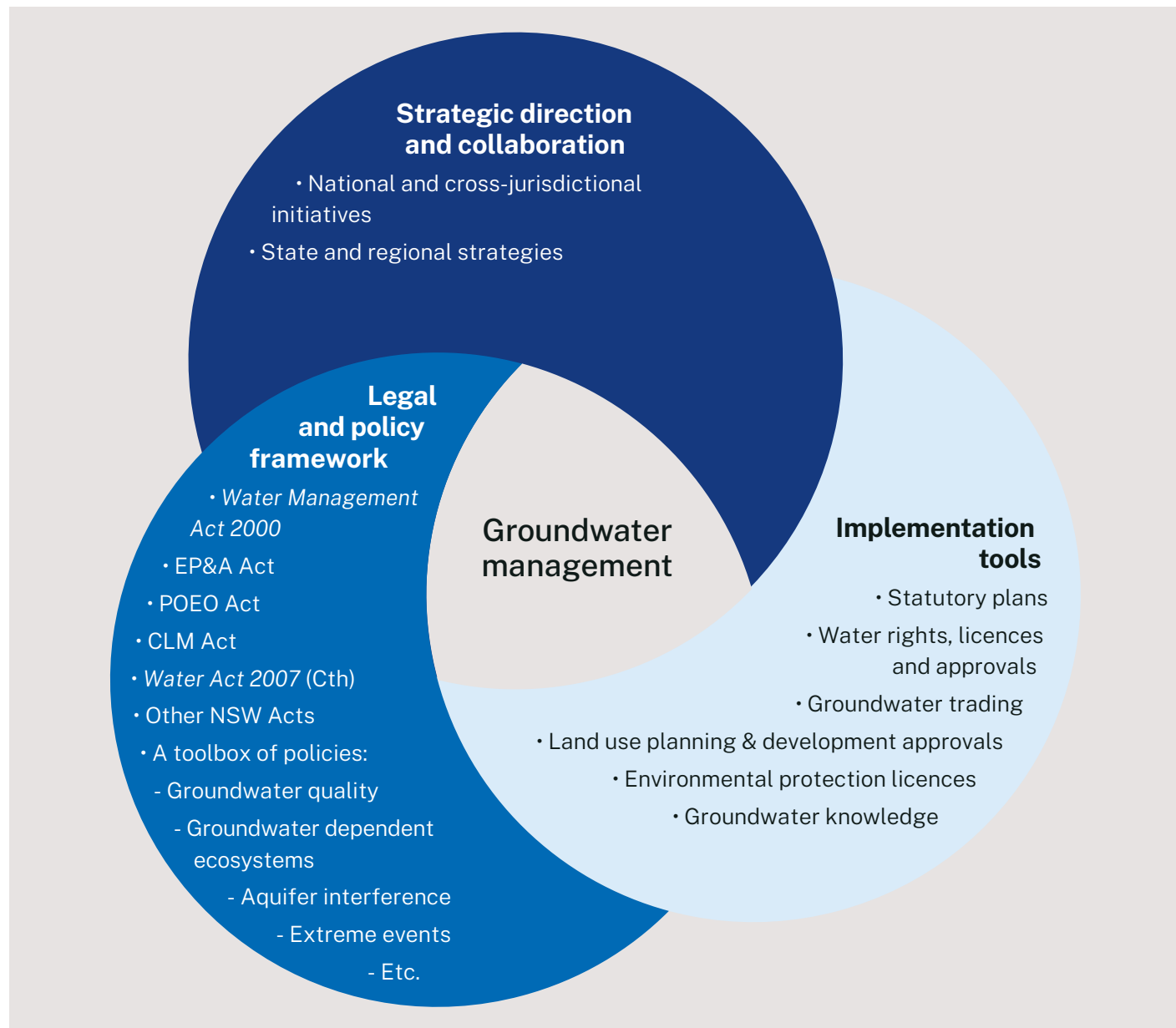


Image courtesy of Orange City Council. Ploughmans Creek Stormwater Harvesting Scheme.

Strategic direction and collaboration

Groundwater management in NSW is guided by the *NSW Water Strategy* – a 20-year state-wide strategy to improve the security, reliability and quality of the state's water resources. The *NSW Water Strategy* addresses key challenges and opportunities for water management and service delivery across the state and sets the direction for the NSW water sector over the long term. The *NSW Water Strategy* prioritises the development and implementation of this NSW Groundwater Strategy to improve groundwater management across NSW.

The *NSW Water Strategy* is supported by 12 regional⁷ and 2 metropolitan water strategies. These bring together the latest climate evidence with a wide range of tools and solutions to plan and manage surface water and groundwater needs in each NSW region over the next 20–40 years.

When groundwater management issues extend beyond the state's borders, NSW works with the Australian Government and other states and territories to provide a consistent management approach.

The National Water Initiative is the national blueprint for water reform and provides an overarching framework and principles for the sustainable management of water resources in Australia.⁸ Agreed on by the Council of Australian Governments (COAG) in 2004, it represents a shared commitment by all Australian governments to improve how water resources are managed, planned for, measured, priced and traded in Australia.

A National Groundwater Strategic Framework⁹ was developed by Australian, state and territory governments in 2017 that provides a 10-year vision for a nationally coordinated approach to manage and secure Australia's groundwater systems. This framework has 3 priority action areas:

1. sustainable extraction and optimal use
2. provide confidence for investment through improved regulation
3. planning and managing now and for the future.

The Murray–Darling Basin is the largest and most complex river basin in Australia, covering one million square kilometres of south-eastern Australia. Sharing groundwater and surface water in the basin states of NSW, QLD, VIC, SA and the ACT is subject to the requirements of the *Australian Water Act 2007* and *Basin Plan 2012*.

The Great Artesian Basin is one of the largest and deepest underground freshwater resources in the world. It extends across NSW, QLD, SA and the NT (Box 5). The Great Artesian Basin Strategic Management Plan provides a coordinated framework for governments, Aboriginal people, water users and other stakeholders to achieve economic, environmental, cultural and social outcomes for the Great Artesian Basin and its users.¹⁰



Image courtesy of Jess Thompson. Mascot Spring, Great Artesian Basin.

7. water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/final

8. www.dcceew.gov.au/water/policy/policy/nwi

9. www.dcceew.gov.au/sites/default/files/sitecollectiondocuments/water/national-groundwater.pdf

10. www.dcceew.gov.au/water/policy/national/great-artesian-basin/strategic-management-plan

Legal and policy framework

The *Water Management Act 2000* is the key legislation for managing groundwater in NSW. The act establishes principles for managing groundwater resources and provides for the development of enforceable plans to share water between water users, including the environment. The act requires NSW to protect a groundwater source and its dependent ecosystems as the highest priority, then to provide water for basic landholder rights.¹¹ Extraction of groundwater by other licence holders is managed by the long-term average extraction limits in water sharing plans and by specific conditions on approvals for works which are set after a local impact assessment has been done.

In the Murray–Darling Basin, the *Australian Water Act 2007* and *Murray–Darling Basin Plan 2012* also apply to groundwater sources. To meet the requirements of these instruments, NSW has developed 11 water resource plans for its Murray–Darling Basin groundwater resources. These plans, once accredited, will ensure that state water management rules meet Basin Plan objectives and outline how each designated area aims to achieve community, environmental, economic and cultural outcomes. The water resource plans will include current water-sharing plan arrangements and incorporate new arrangements that strengthen water management at a local level.

In NSW, environmental and planning laws play a key role in managing the impacts of land use and development on groundwater. The *Environmental Planning and Assessment Act 1979*, (EP&A Act) is the principal sustainable land use planning legislation in NSW, requires assessments of the impacts on groundwater from urban and industrial development and land use change and identification of groundwater availability to meet future demand through land use planning. The *Protection of the Environment Operations Act 1997* and the *Contaminated Land Management Act 2007* are the key tools for ensuring our groundwater is not polluted and for remediating groundwater contamination if it does occur.

Several state policies support the legislative framework for managing groundwater in NSW. These provide guidance on issues such as maintaining groundwater quality by avoiding contamination and protecting groundwater dependent ecosystems. There are also specific policies covering how groundwater is shared during prolonged droughts and other extreme events, the construction of groundwater bores, obligations for developers to report on groundwater at building sites and the licensing and assessment requirements for activities that interfere with an aquifer.

Knowing how much water licensed users take is critical for understanding and managing our groundwater resources. The NSW Government's non-urban water metering policy introduced in 2018 sets requirements for licensed groundwater users to monitor their take. These requirements differ depending on the groundwater source and the capacity of the water pumping infrastructure, and they do not apply to bores or works only used to take water under basic landholder rights. The metering rules are rolling out in stages, with licence holders extracting from all non-urban groundwater sources required to comply with the rules by the end of 2024 .

11. A native title holder has the right to take and use groundwater in the exercise of native title rights. Similarly, an owner or occupier of a landholding is entitled to take groundwater from an aquifer underlying their land and to use that water for domestic consumption and stock watering, but not for any other purpose. A water licence is not required to exercise these basic landholder rights.

Implementation tools

NSW water sharing plans

Water sharing plans are 10-year statutory plans made under the *Water Management Act 2000*. These plans set the priorities and rules for sharing groundwater across NSW between water users and different categories of water use, allocating flows for the environment and managing risks and impacts to groundwater. The plans are the primary mechanism for implementation of federally mandated water resource plans in the NSW parts of the Murray–Darling Basin. Consistent with the provisions, principles and priorities established in the *Water Management Act 2000*, and the directions set out in relevant state policies, all water sharing plans:

- commit water for fundamental ecosystem health or other specified environmental purposes that cannot, to the extent committed, be taken or used for any other purpose (planned environmental water)
- set sustainable extraction limits for each water source in the plan area and the rules for managing access within these
- protect water for basic landholder rights – Native Title and domestic and stock uses
- set rules to manage access to water – including making water ‘available’ on occasion for different access licence categories and carrying groundwater entitlement allocation forward
- set rules to manage the impacts of extraction on groundwater dependent ecosystems, other users, water quality and Aboriginal people’s cultural sites
- set the opportunities and limitations on water trading (the buying and selling of water licences and annual water allocations)
- set the conditions that apply to access licences and bores in the plan area.

The location of water sharing plans and an explanation of each of the elements outlined above, including the methods used to determine and enforce extraction limits are detailed in the *Guide to Groundwater Management in NSW*.

Water licences and approvals

Water access licences and approvals issued under the *Water Management Act 2000* are the main mechanisms used in NSW to regulate groundwater within the sustainable framework set by the water sharing plans and to define the rights and responsibilities of water users.

In most circumstances, people or entities wanting to use groundwater in NSW will need the following:

- a water access licence (WAL) to take water from a particular water source
- a water supply work approval to construct, replace or modify and operate a specified water supply work (i.e., a bore, excavation or spearpoint) at a specified location
- a water use approval to use water for a particular purpose at a particular location.

A water access licence is required to take water from any groundwater source in NSW, except for water taken under basic landholder rights or where an exemption applies.¹² Each year, ‘available water determinations’ are made for most groundwater sources and for each licence category according to water sharing plan rules. An available water determination credits each water access licence account with an amount of water that can be taken from the groundwater source. Available water determinations can vary year to year to keep extraction from the groundwater source within an extraction limit or to avoid unacceptable impacts.

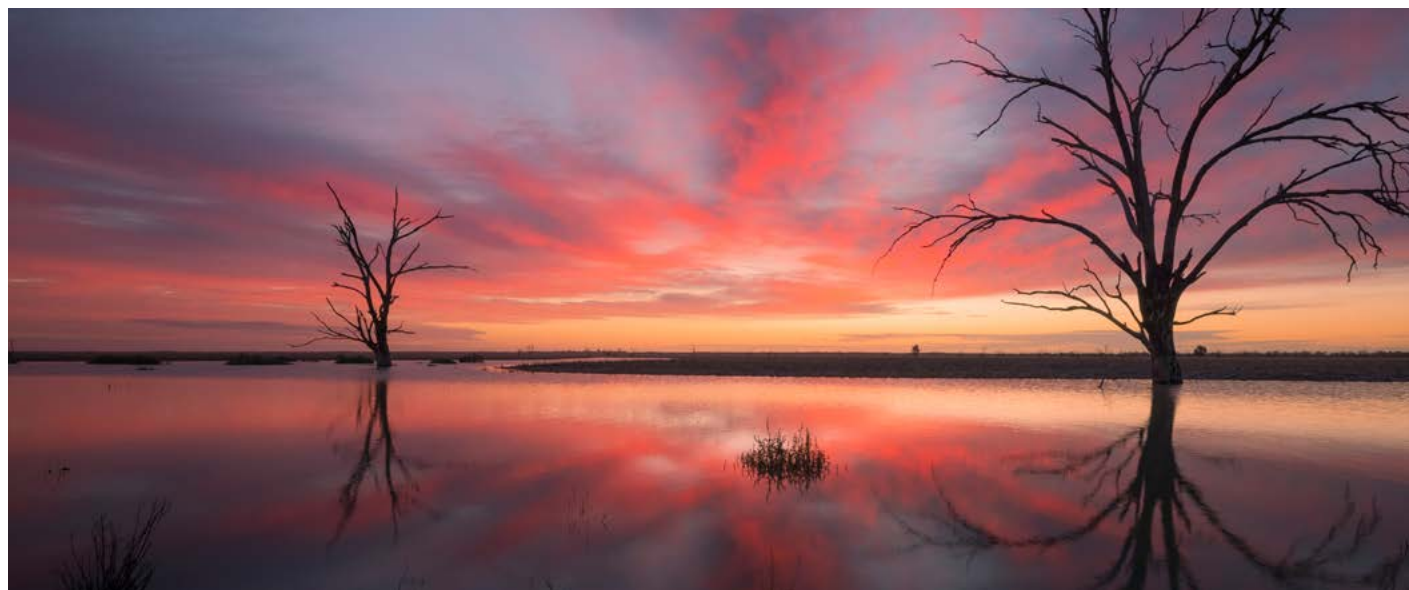


Image courtesy of Destination NSW. Menindee Lakes, Menindee.

12. Licence exemptions and other aspects of our licencing and approvals system are detailed in the *Guide to Groundwater Management in NSW*.

In most groundwater systems in NSW the available groundwater is fully allocated, so purchasing water extraction licences or annual allocations in the market is the only way to secure water for new or expanding commercial purposes. In areas where groundwater is not fully allocated, there may be groundwater available for new licences. In these systems, new aquifer licences can be issued from the unassigned water (the portion of the extraction limit not allocated) under a competitive controlled allocation tender process.

Like NSW's surface water resources, access to groundwater priorities change during extreme events such as a prolonged drought. During normal circumstances, the highest priority access is protecting the water source

and dependent ecosystems followed by basic landholder rights. If a water sharing plan, or part thereof, is suspended due to an extreme event, the highest priority becomes critical human water needs, including basic landholder rights for domestic uses and town water supply.

Water licence and approval compliance and enforcement is overseen in NSW by the Natural Resources Access Regulator (NRAR). NRAR is the independent regulator responsible for the enforcement of water laws through licensing, monitoring compliance and education. It investigates alleged breaches of water law and takes compliance action including issuing directions and penalties where appropriate when water users have not complied with water laws (see Box 1).

Box 1. NRAR's advances in enforcement and compliance

Groundwater has been a specific target for NRAR. Several campaigns focussing on compliance with extraction limits and reducing over-extraction in bores have been launched.

Operation Drawdown focused on large inland alluvial groundwater sources around Griffith, Leeton, Coleambally and Darlington Point. Audits revealed:

- 9% non-compliant aquifer access licences accessing the Lower Murrumbidgee groundwater source (out of 218 licences)
- 11 instances of potential excess of groundwater extraction in the Lower Lachlan groundwater source (out of 226 licences).

New metering regulations for water users that require a tamper-proof, accurate meter validated by a certified professional will improve compliance.

To increase knowledge about water rules and regulations, NRAR's Know the Rules campaign focuses on helping water users to understand how they can access and use water within the rules by providing information through media articles, videos and other internet resources.

Despite the best efforts of NRAR, further work is needed. Almost 70% of water licence holders report feeling 'fairly confident' about their knowledge of water laws currently, but less than half (49%) of the state's public understand the consequences of breaching these laws.

Water trading

Trading is the buying and selling of a water licence entitlement (the share component of a water access licence) or water allocation (a volume of water credited to a water access licence in a year). All or part of an entitlement or water allocation can be traded, subject to the rules in water sharing plans, the *Access Licence Dealings Principles Order 2004* and an assessment of the potential impacts of a proposed trade. Prices are determined by the market and fluctuate depending on supply and demand.

Water trading enables a more efficient and effective use of groundwater resources. It provides the opportunity for new or expanding commercial users to obtain access to water, particularly where groundwater sources are fully committed and where no further entitlements can be granted. It also allows licence holders who are not using all or part of their licences to realise the capital value of their water asset.

Modelling, monitoring and science

The NSW Government collects information about groundwater quality, water table levels and groundwater use through a network of more than 4,000 monitoring bores and by measuring licensed groundwater take. The data collected is used in a range of ways to support groundwater modelling and other government and non-government groundwater management decisions. Models informed by the data use and produce extensive and detailed information on water levels, quality, availability and use for a range of climatic, groundwater pumping and regulatory scenarios. Data collected by the NSW Government is made available to the community, water users and prospective developments through different websites, databases, reports and mapping portals to support water users in making informed decisions.

Drivers and challenges

3

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

Four broad factors are driving the need to evolve our groundwater management framework. As the effects of climate change impact the replenishment of groundwater, the availability and quality of these resources continue to be threatened. These risks are heightened as demand for and potential impacts on groundwater continue to rise due to population growth, demographic changes, economic development and decreased reliability of surface water sources. Simultaneously, our knowledge of groundwater continues to grow and community notions of sustainability and fair access to groundwater, particularly for Aboriginal people, have evolved. As a result, we know that our groundwater resources and the ecosystems that depend on them are under increasing pressure and the resilience of communities and industries using groundwater is at risk.

The NSW Groundwater Strategy provides direction to tackle these challenges and deliver sustainable groundwater management for environments, communities and industries.

Figure 10. Chapter summary – Drivers of change and key challenges

Drivers			page 32
<ol style="list-style-type: none"> 1. Our climate is changing, and groundwater recharge and demands will be affected by this 2. The risks to groundwater of development and land use change are increasing 3. Community notions of sustainability and fair access to groundwater have evolved over time 4. Our understanding of groundwater, its behaviour and use is improving 			
Challenges			page 38
Groundwater resources and the ecosystems that depend on them are under pressure	Community and industry resilience is at risk	Better information is needed to manage groundwater resources sustainably	
<ul style="list-style-type: none"> • Our policy framework for groundwater management needs to be refreshed and expanded to respond to emerging changes and future challenges • Our groundwater management framework needs to be better integrated with surface water and land management • Ecosystems that depend on groundwater face increased threats • Threats to groundwater quality are growing and need to be addressed 	<ul style="list-style-type: none"> • Growing population and decreasing surface water availability will continue to drive higher demand for groundwater for towns • Aboriginal rights to and interests in groundwater are not adequately recognised • New and expanding industries must consider groundwater opportunities and constraints 	<ul style="list-style-type: none"> • Being underground and difficult to investigate, information about groundwater is lacking • There are gaps in our scientific knowledge and research capabilities • Our groundwater monitoring network is ageing and has limited coverage 	

Drivers of change

NSW has been at the forefront of sustainable groundwater management for the past 30 years. Our approach has served us well, particularly for managing extraction. But our groundwater management approaches need to evolve, mature and adapt to new and emerging challenges. The 4 key drivers of this need to change include a changing climate, increased risk from land use and development, changed community perceptions on sustainable and equitable access and a better understanding of groundwater.

Our climate is changing, and groundwater recharge and demands will be affected by this

In NSW, droughts are expected to be longer, more severe and more frequent due to climate change.¹³ The effect will be twofold. First, it will reduce groundwater recharge and, as a result, decrease the availability of groundwater in the long term. Second, drought will drive up groundwater demand in the short term as surface water becomes less reliable and available.

The NSW Government has commissioned CSIRO to undertake cutting edge analysis of Paleoclimate informed climate data.¹⁴ Preliminary results of this research indicate that diffuse recharge (the widespread movement of water from the surface of the earth to the water table below ground) will decrease by 15% on average across the state over the next 40 years.¹⁵ In some groundwater sources, recharge could drop by more than half (Box 2). The analysis will be published in 2023.¹⁶

This new modelling also suggests large reductions in localised recharge from streams to shallow and connected aquifers and overbank flooding (where the recharge occurs across the floodplain) in the Murray–Darling Basin. A decline in flood days under a ‘dry future climate change’ scenario could reduce overbank flooding recharge by around 80% in the Lachlan region and 50% in the Namoi.¹⁷

If we do not act, these significant reductions in groundwater recharge are expected to affect:

- groundwater availability and groundwater base flows to rivers and streams
- groundwater dependent ecosystems
- the security of groundwater licences and available entitlements
- competition between groundwater users leading to potential increases in the cost of groundwater
- economic activities and towns, cities and communities that rely on groundwater.

Changes in climate sometimes manifest slowly in groundwater, so the effects from current activities may be delayed. For example, sea-level rise can cause saltwater intrusion into coastal groundwater sources. This means it is critical to start planning to avoid the potentially damaging impacts of climate change on groundwater in the future.

13. Office of Environment and Heritage 2014, *New South Wales Climate Change Snapshot*; IPCC 2021, ‘Summary for Policymakers’ in *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

14. NSW 2020, *New climate analysis informs NSW’s regional water strategies*, water.dpie.nsw.gov.au/data/assets/pdf_file/0004/500728/nsw-climate-model-report.pdf

15. Results based on a ‘dry future climate change’ scenario. The department has used climate change projections to understand future climate risks. We have chosen one of the driest future scenarios to give us an idea of what the most extreme risks could look like and will help us stress test the resilience of any identified options. For more information see, water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/climate-data-and-modelling

16. Crosbie RS, Charles SP, Rojas R, Dawes W, Fu G, Rassam D, Barry K and Pickett T 2021, *Impact of climate change on groundwater in NSW—Preliminary assessment of the sensitivity of recharge and groundwater resources to a projected drying climate*, CSIRO, Australia.

17. Crosbie RS, Charles SP, Rojas R, Dawes W, Fu G, Rassam D, Barry K and Pickett T 2021, *Impact of climate change on groundwater in NSW—Preliminary assessment of the sensitivity of recharge and groundwater resources to a projected drying climate*, CSIRO, Australia.

Box 2. How climate change affects groundwater recharge

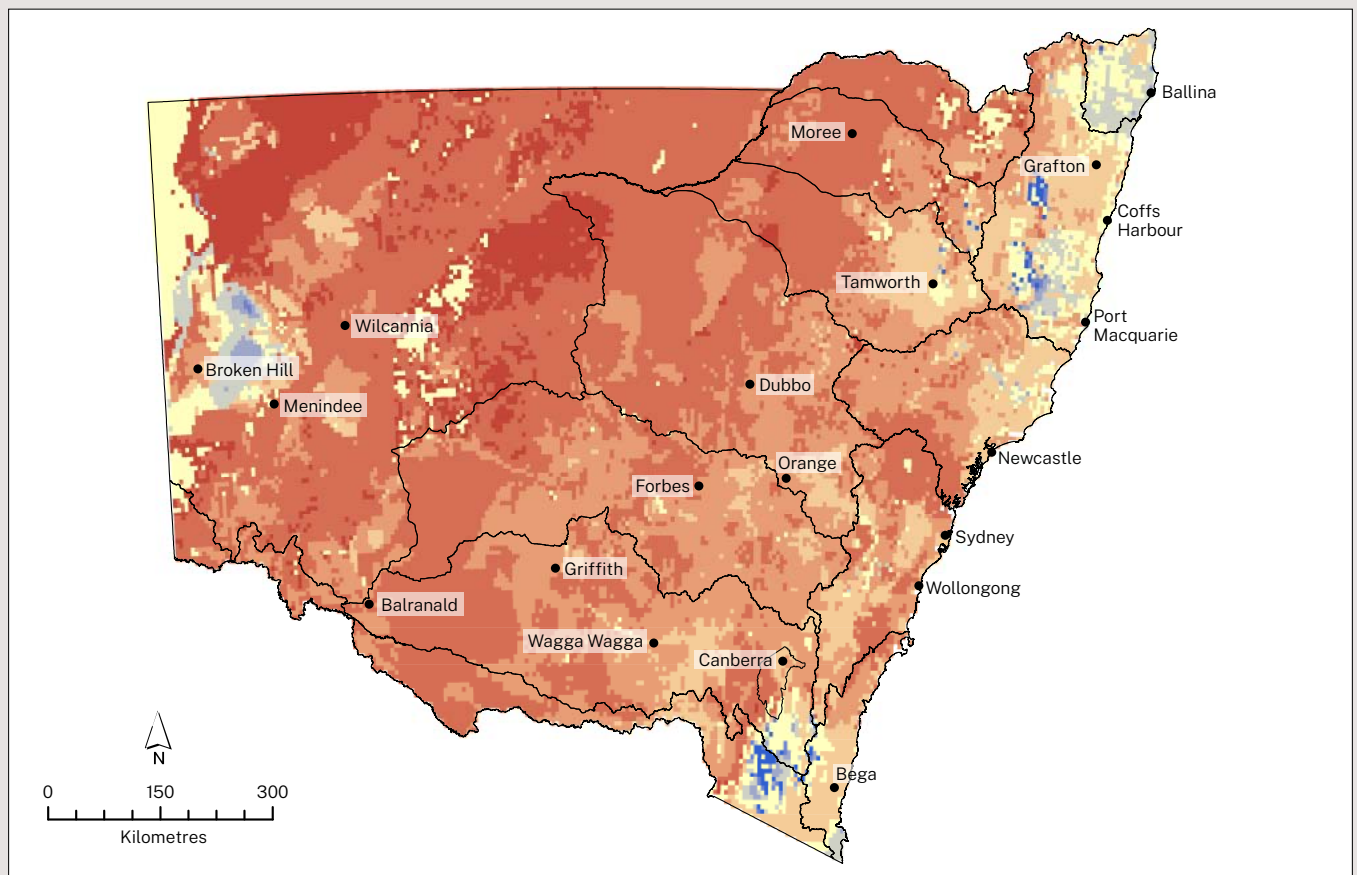
NSW's water strategies use new climate data and modelling to give a more accurate picture of how a more variable climate and extreme climate events could affect our water resources in the future. To inform the NSW Groundwater Strategy, the Department of Planning and Environment commissioned CSIRO to assess the potential impacts of a drier climate on the ability of our groundwater resources to recharge.

CSIRO used a 'dry future climate change' scenario to assess the most extreme potential risks to groundwater resources and examined the impacts of this scenario on diffuse and localised recharge of groundwater. The dry future climate change scenario¹⁸ represents a high carbon emissions scenario, so results project higher than expected climate change impacts.¹⁹ This is not a forecast of how climate change is expected to eventuate, but it is one possible outcome.

While further work is needed, the CSIRO's modelling indicates substantial reductions in groundwater recharge both on average and across the state (Figure 11). Although the future impacts of climate change on groundwater across NSW are not fully known, this research can inform our strategic water planning and highlights key water challenges we may need to focus on in the future.

While using a comparison between current climate and an extreme, far future climate scenario is appropriate to identify risks to our groundwater resources, it is not a fit for purpose method to make decisions about sharing or allocating groundwater. Further work will be required to determine how we can apply the new climate information to these decisions.

Figure 11. Predicted change in future annual average groundwater recharge (%)



Legend:

Water strategy boundary

Change in recharge (%)

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

Note: This figure shows preliminary modelled results for changes in diffused groundwater recharge. These results are under further review. Source: Crosbie et al, 2021.

18. The scenario uses the regionally downscaled factors from the NARClIM 1.0 Project to adjust the long-term past climate scenario rainfall and evapotranspiration data. Further information on NARClIM 1.0 Project is available at www.climatechange.environment.nsw.gov.au/climate-projections-used-adaptNSW

19. archive.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

The risks to groundwater from development and land use change are increasing

Using groundwater sustainably to support economic growth will present significant challenges for which we must be prepared, from both policy and technical perspectives.

By 2040, the population of NSW is expected to grow by 1.7 million people (Figure 12).²⁰ Growth is predicted in all parts of the state except for the far south coast, the far west and the northwest. The coastal population growth north of Jervis Bay will be significant.

This will create more demand for water, especially in coastal urban areas and expanding regional centres. Overall, demand for groundwater to supply towns is forecasted to increase by nearly 300% over the next 20 years.²¹ Demand for industrial uses is also expected to increase.

Growth in regional populations and industries also threatens our groundwater quality. Shallow, high-value and fresh groundwater reserves in coastal areas can be compromised if not protected from potentially contaminating industries and activities, including residential development.

As we prepare for emerging pressures on our groundwater resources caused by population and industry growth, we need to simultaneously manage legacy groundwater issues associated with existing and retiring industries. For example, we need to transition from fossil fuels to a low carbon economy.²² Groundwater issues associated with closure and rehabilitation of these large coal mining operations, particularly in the Greater Sydney, Hunter and North West regions, are complex and will be carefully managed.



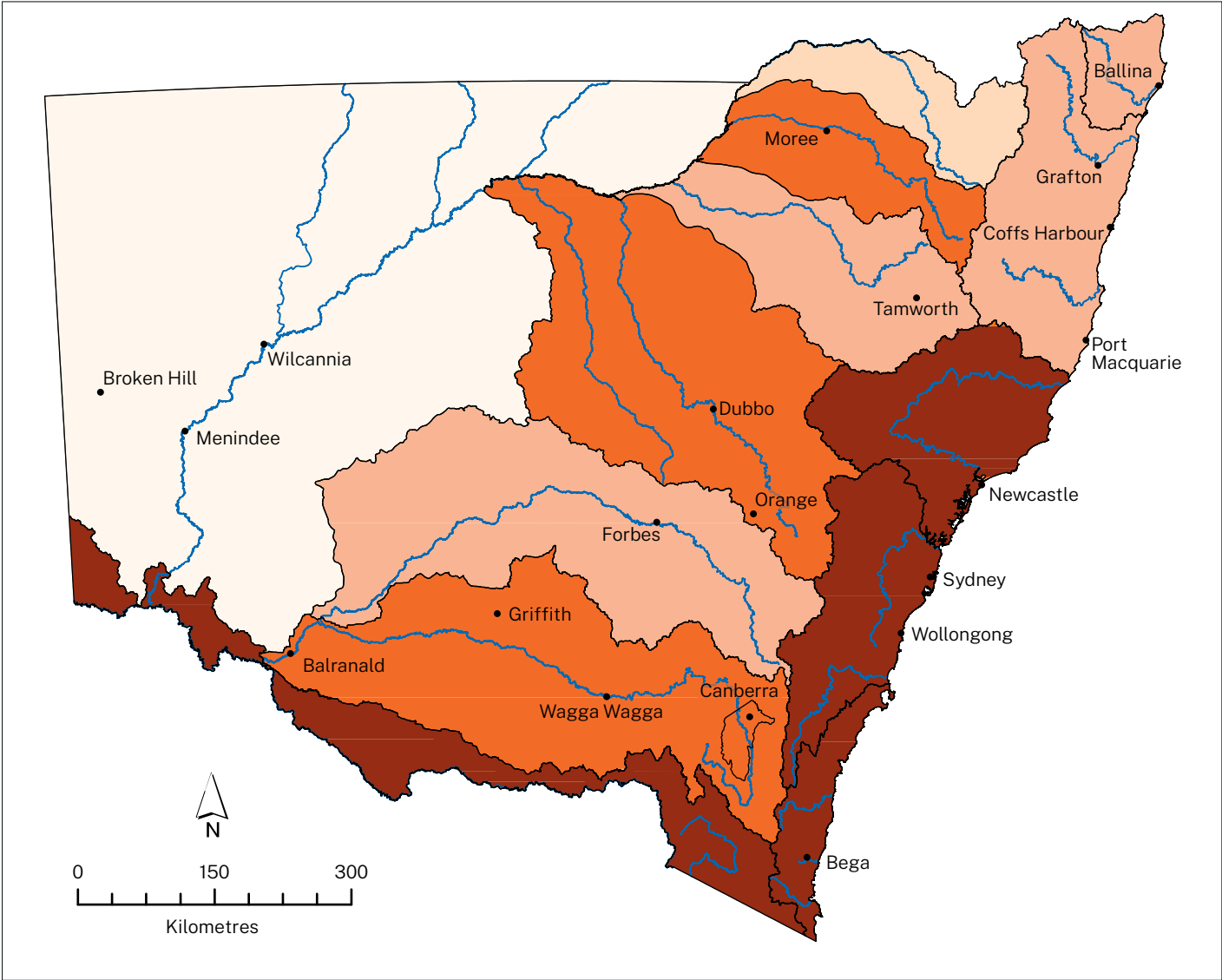
Image courtesy of Destination NSW. Township, Narrandera.

20. The population of NSW is projected to reach about 9.8 million by 2041. NSW Government population projections 2022, www.planning.nsw.gov.au/Research-and-Demography/Population-projections/Projections

21. Department of Planning and Environment 2021, *Groundwater supply and demand for NSW, Project completion summary report*

22. www.regional.nsw.gov.au/meg/nsw-resources/coal

Figure 12. 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.

Community notions of sustainability and fair access to groundwater have evolved over time

Our perception and values towards sustainability and environmental protection have changed over the years. The term 'sustainability' and its use has evolved from its first recognition in 1987 by the United Nations in the Brundtland Report, *Our Common Future*,²³ to becoming part of our daily vocabulary. Shifting values, public awareness and concerns about environmental degradation have also increased, along with demands for accountability and transparency. As Australia's water resources continue to face increasing pressure, the need to better protect the environment for present and future generations has become an established expectation for governments and communities alike. Notions such as water stewardship are also becoming mainstream, emphasising local and catchment-based actions to improve water management that include all stakeholders.

We must also ensure our groundwater management system is fairer and more inclusive of First Nations people. Underpinning this is the recognition of rights linked to water access and the fair distribution of the resource among users to support essential cultural functions and socio-economic development.

Our understanding of groundwater, its behaviour and use is improving

Groundwater is difficult to measure – unlike surface water, groundwater remains out of sight. Historically, we had to infer groundwater dynamics from limited monitoring bore holes, the geology of the area, our best understanding of hydrogeology and the actual response of our groundwater systems to extraction. But science, available analytical techniques and modelling capabilities have improved and continue to evolve. Likewise, our understanding of groundwater dependent ecosystems, the nature of their dependence and their tolerances to fluctuating water levels and quality is rapidly growing. We also have a much better appreciation of why, how and when communities and industries are using groundwater – particularly the criticality of this water supply particularly in dry times.

We need to incorporate this new knowledge into our groundwater management approaches. But we also need to grow our knowledge of groundwater through research, supporting programs and tools to respond to current and emerging sustainability and water supply issues. This knowledge infrastructure will support robust, informed and transparent decision-making by governments, the community and industry.



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

23. United Nations 1987, *Our Common Future*, sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf



Image courtesy of Destination NSW. Menindee Lakes, Menindee.

Challenges

In response to these broad drivers of change, we have defined 3 main challenges for sustainable management of the state's groundwater resources. We know that groundwater resources and the ecosystems that depend on them are under pressure, community and industry resilience is at risk and better information is needed to manage groundwater sustainably. These 3 challenges set the priorities and subsequent actions for this NSW Groundwater Strategy.

Challenge 1: Groundwater resources and the ecosystems that depend on them are under pressure

Our policy framework for sustainable groundwater management needs to be refreshed and expanded to respond to emerging changes and future challenges

Our policy framework for managing groundwater over the past 20 years has served us well. But it needs to be updated to be more agile, responsive and adaptive. We need to recognise changing policy principles and directions, keep abreast of new groundwater management approaches and foster innovation in response to changing demands and knowledge. Reviewing our policy relating to stewardship of our groundwater resources – including protecting groundwater quality and dependent ecosystems and defining approaches for sustainable use – needs to be a constant key focus.

Ecosystems that depend on groundwater face increased threats

Groundwater supports a wide range of terrestrial, aquatic and subterranean ecosystems, such as spring systems, habitats in rivers and along riverbanks, wetlands, floodplain habitats, coastal lakes, marshes and caves. Groundwater baseflows feed into streams and rivers during dry periods and support the species and ecosystems within them (Box 3).

Groundwater's contribution to terrestrial and aquatic ecosystem processes is complex and often poorly understood. We do know that these delicate ecosystems are highly vulnerable to threats such as land use changes, the effects of climate change, pollution from human activities and overextraction of water.

Box 3. Our groundwater supports rich biodiversity

Groundwater dependent ecosystems rely on groundwater to meet all or some of their water requirements. Some ecosystems continuously rely on groundwater and some seasonally or only during drier times when surface water is limited or unavailable. Groundwater dependent ecosystems cover approximately 8% of land in NSW (around 6.5 million ha) – those considered as 'high priority' are found across 5% of the state. More than 1,000 unique groundwater-dependent plant types have been identified.

Groundwater not only supports diverse terrestrial and riverine plant and animal species, but also their associated ecological processes such as water storage, nutrient recycling and flood mitigation. Aquifers themselves can also be important habitats for macro- and micro-organisms and bacteria which provide important functions such as water purification, bioremediation and water infiltration.

Currently, over 200,000 ha of groundwater dependent ecosystems and about 70 unique plant types are under threat in NSW. Some of the important groundwater-fed ecosystems include the Gwydir Wetlands, the hanging swamps of the Blue Mountains and the Narran Lakes east of Brewarrina and the systems of artesian springs in the Great Artesian Basin.

Our groundwater management framework needs to be better integrated with surface water and land management

While our current groundwater management approach is relatively robust, groundwater continues to be overlooked by many land managers, development proponents and others in many urban and regional land use planning processes. Too often the impacts of land use activities on groundwater are an afterthought in development processes because groundwater is out of sight and out of mind. A high-level and coordinated approach is required to develop effective management of groundwater in land use planning and development. Working closely with local land management authorities such as councils will be crucial for better integrating groundwater management with land management.

From a water supply perspective, groundwater is often seen as a last resort when surface water sources fail and is forgotten in times of surface water abundance. This was observed over the 2018–2020 drought when towns, villages and agricultural and other industries were scrambling to find emergency groundwater supplies.²⁴ A more robust, planned and integrated approach to groundwater and surface water supply is urgently needed.

Agricultural practices and urban and industrial development can change landscapes and therefore affects runoff and groundwater recharge rates. The risks of pollution and the potential to compromise high quality fresh groundwater resources are ever present. This is not new – we are now dealing with the legacy of past failures to consider groundwater and its vulnerability to contamination (see threats to groundwater quality below).

We need to get better at planning ahead and considering groundwater as an integral part of our water supply and land and water use management systems. We need to better recognise the opportunities groundwater provides and its inherent vulnerabilities.

Threats to groundwater quality are growing and need to be addressed

Current risks to groundwater quality in NSW include:

- diffuse pollution, where a pollutant or contaminant is introduced slowly over a large area and cannot be easily attributed to one source. Poor agricultural practice can be a key source of diffuse pollution due to inappropriate application of fertilisers and pesticides, but urban land, forestry, atmospheric deposition and rural dwellings can also be significant sources
- point-source pollution comes from a single, identifiable source. Examples include polyfluoroalkyl substances (PFAS)²⁵ from industrial sites and airports, fuel tank leaks from petrol stations and leaching from waste dumpsites
- soil and water salination from intensive changes to land use practices that mobilise naturally occurring salts. This can be a result of rapid urbanisation along the coast with its associated land use changes
- mixing of saline and fresh groundwater where connections between groundwater sources are created by pumping or from extraction through poorly constructed bores
- saltwater intrusion in shallow and sandy coastal groundwater sources due to intensive pumping or sea-level rise from climate change.

If the quality of groundwater deteriorates, its current and future beneficial uses may be limited or precluded altogether. The impacts of this could be significant on human health, the environment, urban and domestic use and industrial and agricultural productivity could be significant.



Image courtesy of Jess Thompson. Bingawilpa Spring.

24. Based on Department of Planning and Environment data, applications for groundwater trades and new bores increased threefold over this period.

25. Substances used in a range of applications including manufacturing, food packaging and in some types of firefighting foam. PFAS can affect human health and the environment due to their toxicity. See www.pfas.gov.au/ for further information.

Challenge 2: Community and industry resilience is at risk

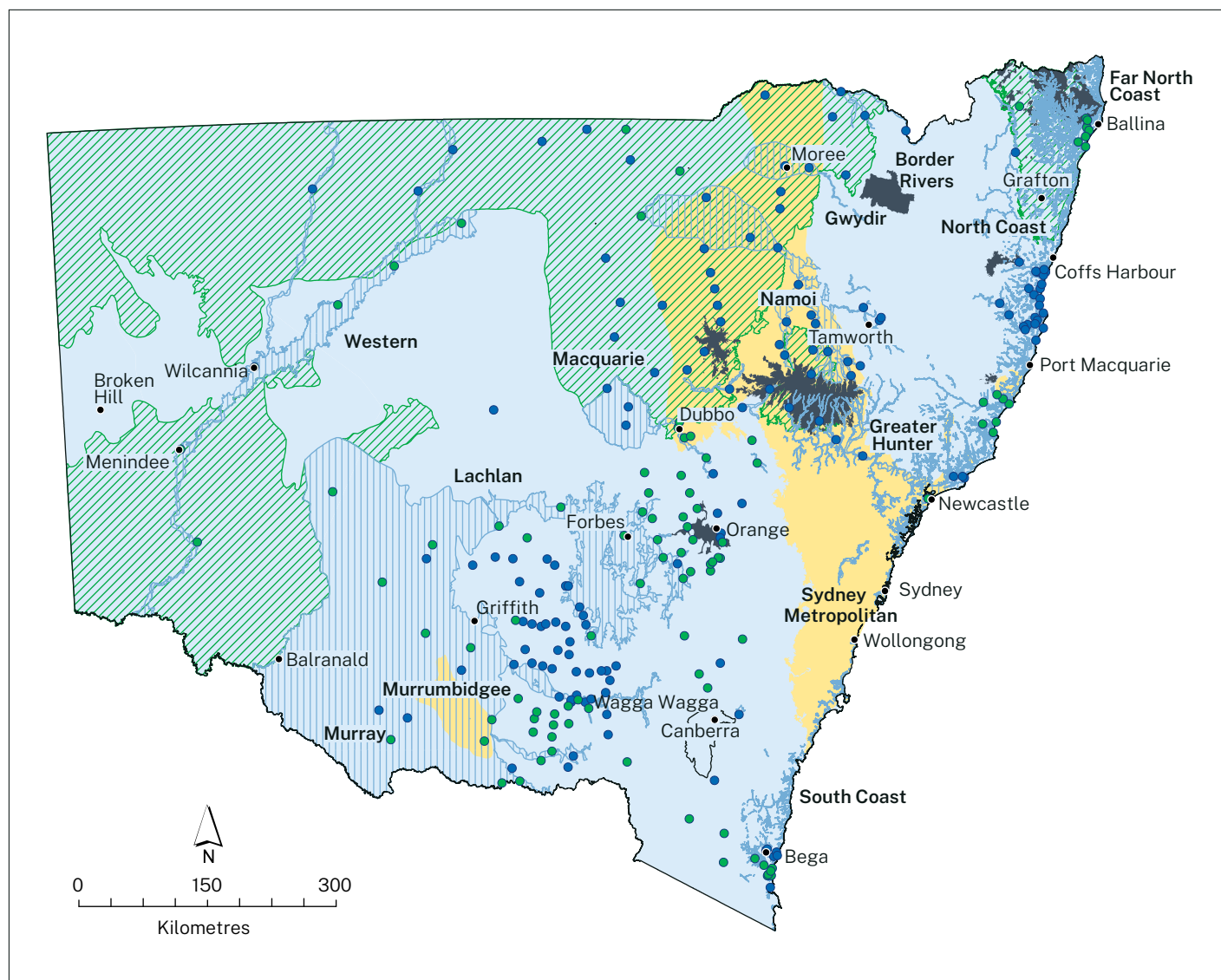
Increasing groundwater demand for town water supply and other domestic use

Growing cities, communities and industries need reliable access to increasing amounts of good quality groundwater. For many communities in NSW, being

able to access groundwater increases the resilience of their water supply systems. Currently, close to 300,000 people in over 250 regional towns depend fully or partially on groundwater for their drinking water supply (Figure 13).

As demand grows, we face challenges in planning for and securing a reliable supply of groundwater in times of surface water scarcity when river flows have dwindled and communities require alternative supplies.

Figure 13. Regional towns and cities in NSW that rely on groundwater



Legend:

- | | | |
|--|--------------------------|--------------------|
| Alluvials, coastal sands and other sediments | Fractured rock (Basalts) | Older porous rocks |
| Younger porous rocks | Fractured rocks | |

Town water supplied by:

- | | |
|-------------|---------------------------------------|
| Groundwater | Surface water with groundwater backup |
|-------------|---------------------------------------|

Source: Department of Planning and Environment data.

Providing an adequate supply of quality groundwater that suits different requirements (including drinking water for towns and households not connected to urban water supply schemes) is becoming more challenging. Over the last 10 years, total groundwater demand for towns has increased by almost 340%.²⁶ While variable climatic conditions mean that shifts in groundwater extraction are often quite drastic on a year-by-year basis, a growing population and decreasing surface water availability are likely to continue to drive higher overall demand for groundwater.

New and expanding industries need to consider groundwater opportunities and constraints

Groundwater-dependent economic activities generate close to \$1 billion in direct value every year for NSW.²⁷ The future of industry is linked to secure and reliable water supply and greater water-use efficiency, with all sectors facing uncertainty due to increased rainfall variability and reduced surface water flows resulting from the effects of climate change. As an example, groundwater demand from agriculture is expected to increase by nearly 30% in the next 20 years. Groundwater demand from the mining sector is expected to increase by nearly 15% over the same period.²⁸

Currently, many new and expanding industries and economic activities do not consider groundwater availability in their planning. This can lead to unexpected costs and unsustainable investment as groundwater might be harder and more expensive to access than initially assumed. It can also mean missed opportunities. As climate change increases pressure on water resources, industry will need to consider groundwater availability and protection in early planning and development phases to manage risks and identify the right conditions for investment.

Providing opportunities for groundwater-dependent investment and development is also important. It ensures that access to available groundwater is shared fairly, and the most productive and efficient use is made of our limited resources.

As the effects of climate change unfold, we will need to do more with less groundwater. An array of technologies and innovative solutions – from sensors and drones to desalination and managed aquifer recharge – can be leveraged to make the best use of our groundwater resources, increase groundwater availability and secure supply to communities and industries.²⁹

Aboriginal people's rights to groundwater are not adequately recognised

Groundwater-fed springs, wetlands and waterways have supported Aboriginal people's drinking water and cultural, social and spiritual functions throughout NSW for tens of thousands of years. Some groundwater dependent ecosystems are also sacred places for Aboriginal communities. To date, Aboriginal people's values concerning groundwater have not been adequately recognised and protected and there have been few opportunities for Aboriginal communities to influence and participate in groundwater management decisions.

Aboriginal people have been disadvantaged by water licensing schemes since they were developed as licences were traditionally allocated based on colonial land tenure. In the NSW section of the Murray–Darling Basin, Aboriginal people's organisations hold just 556 ML of groundwater entitlements.³⁰ Many of the state's groundwater systems are fully committed and the costs to Aboriginal people for buying back these rights for cultural purposes or economic development are prohibitively high.

26. Department of Planning and Environment 2021, *Groundwater supply and demand for NSW*, Project completion summary report.

27. Department of Planning and Environment 2021, *Understanding NSW's economic dependency on groundwater*, Internal project document.

28. Department of Planning and Environment 2021, *Groundwater supply and demand for NSW*, Project completion summary report.

29. Productivity Commission, *National Water Reform 2020: Draft Report*, February 2021.

30. Hartwig, LD. and Jackson, S 2020, *The status of Aboriginal water holdings in the Murray–Darling Basin*, ARI Report No. 2020/004, Australian Rivers Institute, Griffith University, Australia.

Challenge 3: Better information is needed to manage groundwater resources sustainably

Information about groundwater is lacking because it is underground and difficult to investigate

Accurate, timely and robust data and information are critical to mitigate potential risks to our groundwater resources and ensure the effective delivery of water sharing and water resource plans.

To share groundwater effectively and efficiently we need better information and insights into the complex socio-ecological interactions³¹ involved with groundwater extraction. This includes not only understanding how groundwater resources respond to extraction (such as how links to surface water or dependent ecosystems change) but also water user behaviour and how this may evolve into the future.

We need this information across different scales (from local to regional) to give groundwater users confidence while making management, business and investment decisions.

Our current understanding is limited by models that do not fully account for the long-term dynamics and feedback between human activities and our natural environment or allow us to manage local matters such as groundwater level decline or borefield issues. Developing multidisciplinary models that better integrate human behaviour with the affects those behaviours have on the environment will enable us to manage groundwater in a more holistic way that considers the social, economic and technical context in which groundwater problems arise.

As demand for groundwater increases, it is critical that we gather the right data with sufficient accuracy, use it in best-practice models and make it widely available and in formats that are easy to understand.³²

There are gaps in our scientific knowledge and research capabilities

Our understanding of groundwater resources needs to continually evolve to align with new demands and challenges. Currently, there are significant gaps in our scientific knowledge and in our groundwater research capacity and capabilities, across both the public and private sectors. These shortcomings in groundwater science – including the social and economic aspects of groundwater use – are a challenge across Australia and globally.

Our groundwater monitoring network is ageing and has limited coverage

Good groundwater management requires accurate, timely and reliable data about water levels, water quality, bore location and extraction volumes. In NSW, this data comes from a network of government monitoring bores, installed meters on licensed extraction bores and industry monitoring bores required as a condition of development approval.

Monitoring groundwater resources, particularly those that are intensively used, helps us manage the risks of overextraction and the consequent risks to water quality, dependent ecosystems, the structure of the aquifers themselves and to sustainable community and industry groundwater access. Monitoring provides the critical evidence to support robust decision making and the fundamental inputs to our modelling and ultimately our understanding and conceptualisation of the resource.

However, more than 50% of our monitoring bores are more than 30 years old.³³ This ageing network is also limited in its coverage, which makes it difficult to obtain a complete picture of the condition of groundwater resources across the state.³⁴ We need to understand where monitoring needs to improve to directly inform and improve our management of the resource. We need to expand the coverage of the bore monitoring network to include more of our fractured rock, minor alluvial and coastal sand systems because there is not sufficient information to manage these systems under current extraction levels and predicted demand growth.

31. Socio-ecological systems have a highly interconnected relationship between society (human activities) and ecosystems.

32. NSW Chief Scientist and Engineer 2020, *Review of water-related data collections, data infrastructure and capabilities*, www.chiefscientist.nsw.gov.au/_data/assets/pdf_file/0003/337503/Water-Data-Review.pdf

33. Department of Primary Industries 2016, *Groundwater monitoring program review*, Draft Report.

34. NSW Chief Scientist and Engineer 2020, *Review of water-related data collections, data infrastructure and capabilities*, www.chiefscientist.nsw.gov.au/_data/assets/pdf_file/0003/337503/Water-Data-Review.pdf



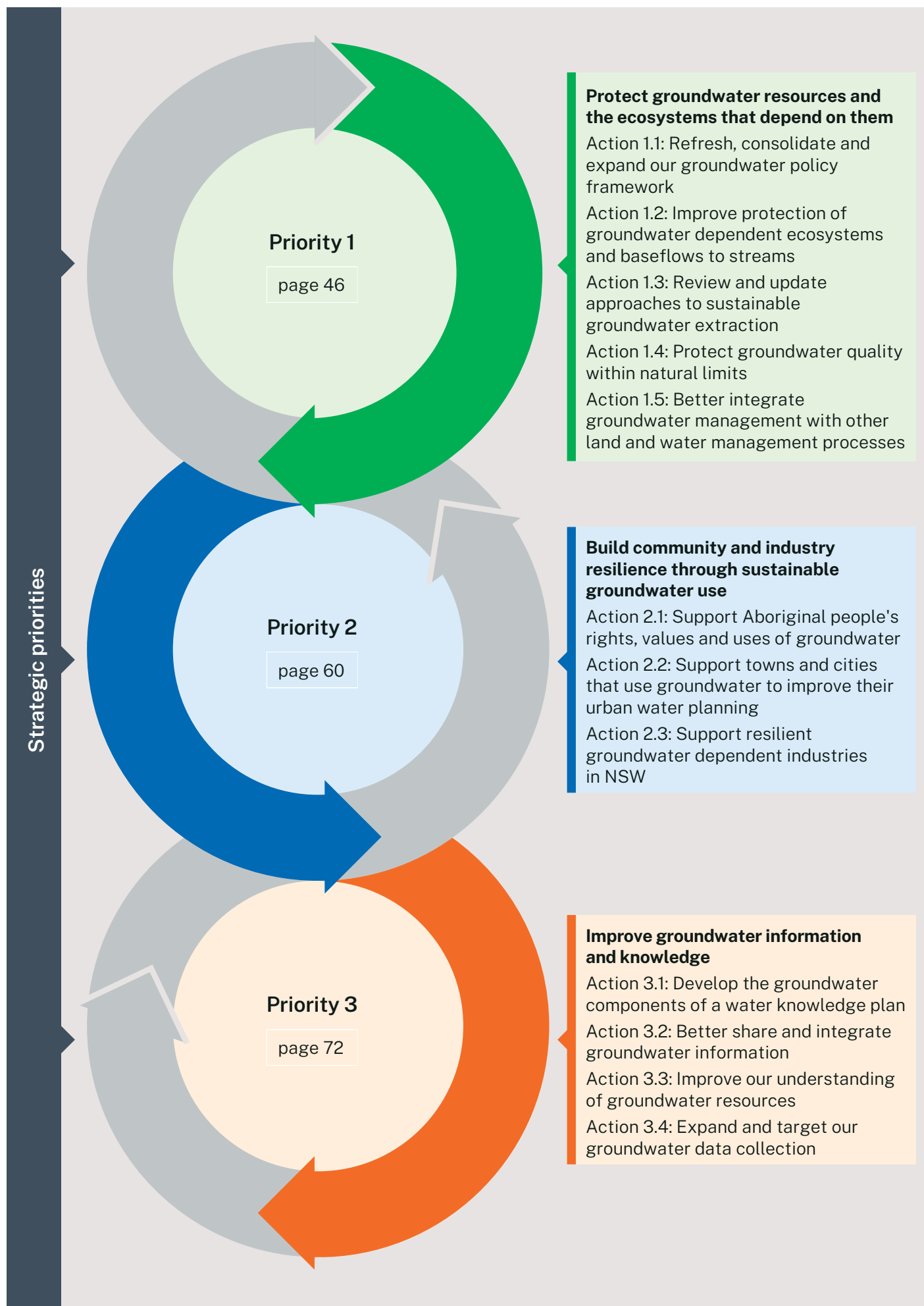
Image courtesy of Department of Primary Industries. Flood irrigation in Leeton District.

Strategic priorities

4

Image courtesy of Destination NSW. Macquarie River Trail, Dubbo.

Figure 14. Chapter summary – Strategic priorities and actions – addressing the challenges



Strategic priority 1

Protect groundwater resources and the ecosystems that depend on them



Our groundwater resources and dependent ecosystems are protected to support current and future uses.

Action 1.1. Refresh, consolidate and expand our groundwater policy framework

To ensure that groundwater management in NSW is sustainable, our groundwater policy framework needs to become more adaptive in response to challenges such as climate change, increasing development and land use change. The framework needs to be responsive to new information about our groundwater resources and dependent ecosystems and evolve as awareness of Aboriginal people's rights to, and interests in water and the importance of sustainable groundwater management for future generations increases. The current management framework has some barriers:

- Some of our groundwater policies are now more than 20 years old and many (the NSW Groundwater Quality Protection Policy 1998, for example) were in place before the *Water Management Act 2000* was enacted.
- Our policies for water sharing and quantity management have developed over time and have not been brought together in a clear and concise way.
- We have heard from industry and other water users that some policies, such as the Aquifer Interference Policy (2012), can be difficult to interpret.
- We have emerging and pressing issues that require clear policy responses and the development of adaptive management frameworks. Examples include groundwater aquifer rehabilitation, managed aquifer recharge, the critical role groundwater plays in providing water security for regional populations and the sustainable management of groundwater at mining sites.
- Our groundwater policy and implementation approaches need to be transparent, accessible, consistent and applied across all levels of government so the community and water users have clarity and are confident in the approach.

Refreshing, consolidating and expanding our groundwater policy framework will take some time. We intend to take a portfolio approach, whereby individual policies are unified by common high-level outcomes, objectives and principles that reflect, and are consistent with, the objectives and principles in the *Water Management Act 2000* and other

applicable legislation. The policies will be updated or added to the portfolio based on clear priorities.

A whole-of-government approach to policy development and implementation will give water users and the community confidence that management actions and decision-making that affect groundwater resources will be consistent and clear across all relevant government agencies. Providing our local government authorities with further guidance and more readily available information will help them manage local impacts of activities at the planning and development consent stages. Collaboration with councils on the issues of zoning, land use, mapping and assessment would support them more thoroughly in decision making.

Most importantly, the process of updating and adding policies to the portfolio will involve significant and meaningful engagement and consultation with key stakeholders and communities. This will take time and effort but is essential for building transparency and trust in the processes and outcomes. A clear understanding of the context within which decisions are made by both government and industry is crucial for all stakeholders. The policy list will be made available to the public to view on the Department of Planning and Environment's website.

The outputs from this action will provide clear guidance for both regulators and proponents on decisions made under the *Water Management Act 2000* and other relevant legislation, including, for example, the making of water (sharing) plans, licensing and approval decisions, assessment of trades and groundwater management recommendations for state significant developments.

Action 1.1 is a key integrating action. The policies will both inform, and be informed by, all other actions in this Priority 1 and in Priorities 2 and 3.

Key actions

Action 1.1. Refresh, consolidate and expand our groundwater policy framework

To continue to manage our groundwater resources sustainably into the future we will review, update, consolidate and expand our groundwater policy and planning framework.

Action 1.2. Improve protection of groundwater dependent ecosystems and baseflows to streams

Our sustainable groundwater management framework will protect dependent ecosystems and surface water baseflows as a core priority

Developing a framework for the protection of important groundwater dependent ecosystems and groundwater baseflows to streams must be a core priority to facilitate sustainable groundwater management in NSW. The existing groundwater dependent ecosystems policy was developed when there was limited information on the location and extent of these ecosystems and their level of connection and sensitivity to groundwater level variations. While our understanding remains somewhat limited given the hidden nature of groundwater, it has improved dramatically over the past 2 decades and continues to do so.

This improved understanding will be incorporated into our revised groundwater policy approaches (Action 1.1). It will also inform our approach to setting sustainable extraction limits, managing available water determinations in connected groundwater-surface water systems and making decisions about extraction of groundwater in the vicinity of sensitive groundwater dependent ecosystem sites and connected streams (Action 1.5). Given the uncertainty, adaptive management approaches will be considered so we can respond to new information and situations as they arise.

The department is currently developing a process to confirm the probability of groundwater-dependence for high priority groundwater dependent ecosystems that will be in place in 2023.

A better understanding of groundwater dependent ecosystems will help us protect them

All groundwater dependent ecosystems can be impacted by changes to water availability (from climate change and variability or extraction pressures).³⁵ Some elements of water availability critical to these ecosystems include depth to groundwater, groundwater flux and flow, soil water content, groundwater pressures and stream connectivity. Many groundwater dependent ecosystems are also sensitive to changes in groundwater quality.

If we are to protect our groundwater dependent ecosystems, a better understanding of their characteristics and groundwater requirements will be critical. Additional mapping, monitoring, information and knowledge will provide a better understanding for the different types of groundwater dependent ecosystems that exist in NSW, their ecological importance and location and the groundwater characteristics they need to persist and thrive (see Figure 15).³⁶

The NSW Government has begun an extensive program to identify groundwater dependent terrestrial vegetation and wetlands across NSW³⁷ and a spring inventory is currently available via the Bureau of Meteorology.³⁸ We are also monitoring groundwater dependent ecosystems to support the evaluation of water sharing plans and reporting under the Murray-Darling Basin.

The NSW Groundwater Strategy acknowledges the current research into the fauna that live in aquifers (stygo fauna). The diverse characteristics of these stygo fauna can reveal a lot about the type of conditions that they have been subject to over time, thus revealing crucial information about our groundwater systems.³⁹

35. water.dpie.nsw.gov.au/science-data-and-modelling/groundwater-management-and-science/groundwater-and-the-environment

36. NRC 2021, Final Report, *Review of the Water sharing plans for the Greater Metropolitan region*, February 2021, Document No. D20/2692 Sustainable limit

37. water.dpie.nsw.gov.au/science-data-and-modelling/groundwater-management-and-science/groundwater-and-the-environment

38. www.bom.gov.au/water/groundwater/gde/

39. Saccò, M, Blyth, AJ, Douglas, G, Humphreys, WF, Hose, GC, Davis, J, Guzik, MT, Martínez, A, Eberhard, SM & Halse, SA 2022, *Stygo faunal diversity and ecological sustainability of coastal groundwater ecosystems in a changing climate: the Australian paradigm*. Freshwater Biology.

Key actions

Action 1.2. Improve protection of groundwater dependent ecosystems and baseflows to streams

This action will link with and build from Action 1.1. Refresh, consolidate and expand the groundwater policy framework.

1.2.1 Review and update our methods and processes for protecting groundwater dependent ecosystems and baseflows

We will:

- better consider groundwater dependent ecosystems in the setting of sustainable extraction limits
- better identify and manage the impacts of major developments on groundwater dependent ecosystems (see Action 1.5.3)
- provide for the quality, quantity and timing of water required for groundwater dependent ecosystems through local impact management rules (see Action 1.4.3)

- implement actions in 1.5.1 to better manage surface water and groundwater connectivity and baseflows.

1.2.2. Deliver a program to improve our understanding of groundwater dependent ecosystems

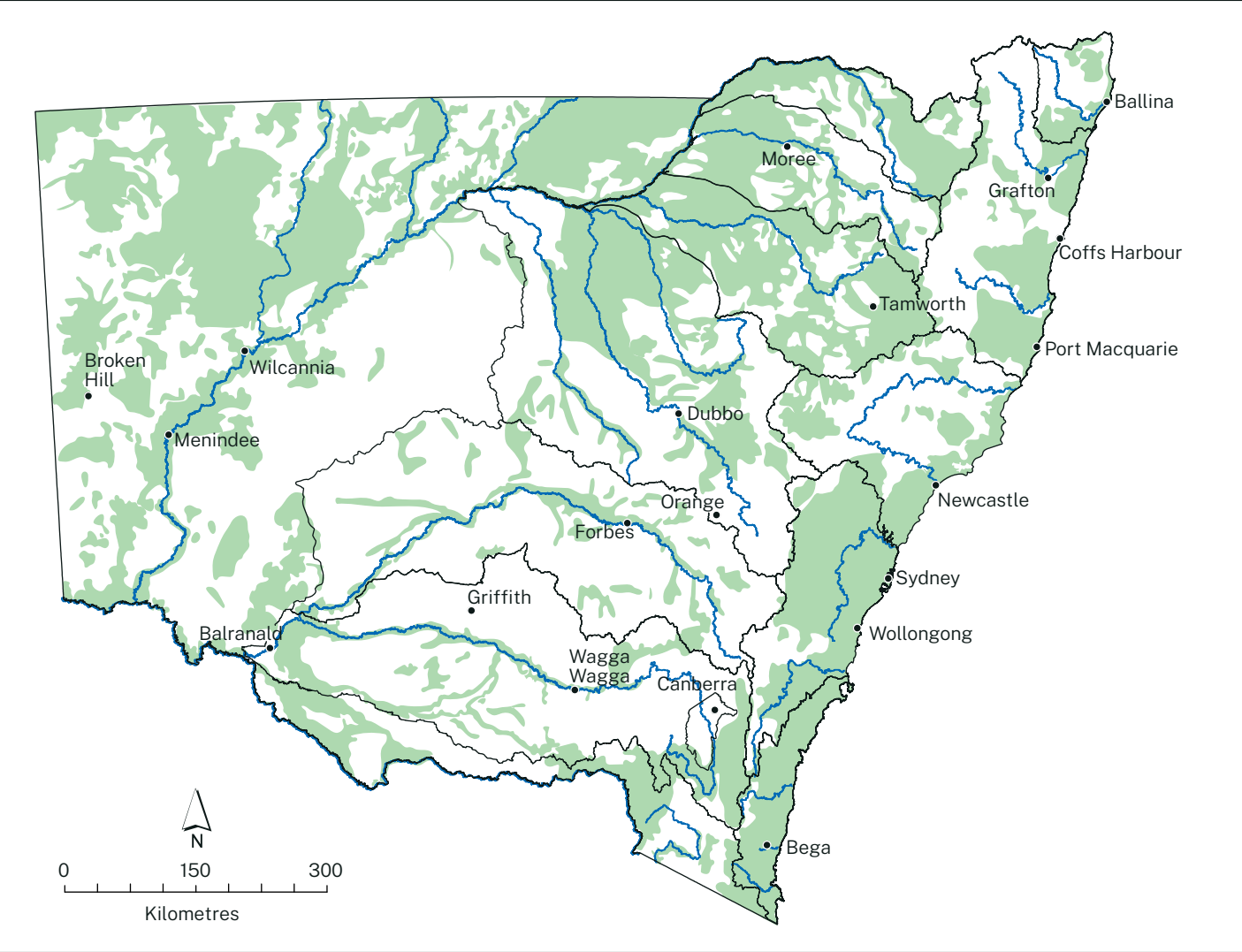
We will:

- establish and verify the location, extent, condition and risk to the health of groundwater dependent ecosystems and improve our understanding of the dependence of these ecosystems and stream flows on groundwater
- ensure our monitoring of groundwater levels, extraction, water quality and ecosystem health can better inform future decisions about groundwater dependent ecosystems and surface water baseflow protection and management.






Image courtesy of Department of Primary Industries. Irrigation bore, Darlington Point.

Figure 15. Areas in NSW where there is a high probability to find high priority groundwater dependent ecosystems



Legend:

-  Water strategy boundary
-  Rivers
-  Areas with a high probability of finding high priority GDEs

Source: Department of Planning and Environment.

Note: For more information about how Department of Planning and Environment prioritises groundwater dependent ecosystems, see: water.dpie.nsw.gov.au/science-data-and-modelling/groundwater-management-and-science/groundwater-and-the-environment

Action 1.3. Review and update approaches to sustainable groundwater extraction

New knowledge is now available to update our groundwater source extraction limits

Different methodologies have been used over the years to determine groundwater source extraction limits (see the *Guide to Groundwater Management in NSW* for further details).

As our understanding of groundwater resources and dependent ecosystems improves, we can better quantify groundwater volumes, aquifer boundaries and their connectivity with ecosystems and other water sources.⁴⁰ This knowledge can be used to refine our groundwater source extraction limits through a review of the state's water sharing plans.⁴¹

The NSW Government has already begun researching and assessing different methods to better inform the definition of groundwater source extraction limits in NSW. This work is based on a review of the historical context for defining extraction limits as well as a comparative analysis of international best-practice cases.

Any potential new methods will incorporate the most up-to-date hydrogeological, ecological, and socio-economic information and consider the most recent groundwater risk assessments as well as new climate change data.

Any changes to groundwater access will continue to be made in the context of an adaptive and consultative approach to groundwater management, especially through the review and remake of water sharing plans.

A coordinated approach is critical to managing fully committed groundwater systems

While the average annual extraction from a groundwater source must remain within the extraction limit set in the relevant water sharing plan, our current groundwater management framework allows annual extraction to vary above and below this average. This recognises that groundwater demand and use vary between years in response to climate variability, surface water availability and other factors such as commodity prices and the business strategies of individual water-using entities. We ensure that the extraction for each groundwater source remains within the legal limit in the long term, in accordance with assessment criteria set out in the plan.

If corrective action is required to keep the total groundwater source use within the extraction limit, one or both of the following actions can be taken:

- the annual water allocation credited to licence holders' accounts (available water determination) is reduced
- the amount of water that can be taken from an account in a water year (maximum water account debit) is reduced.

The likelihood of corrective action is highest in fully committed groundwater sources.⁴² There are 54 groundwater sources in NSW that are fully committed,⁴³ meaning that if each entitlement share were assigned a value of one megalitre (ML), the sum of the entitlement shares plus unlicensed rights to take groundwater meet or exceed the groundwater source extraction limit. Of these fully committed sources, there are 24 where the number of shares for issued licences is significantly higher than the groundwater source extraction limit.

Figure 16 shows the fully committed groundwater sources in NSW and the approximate entitlement 'share value' in each. This represents the ultimate volumetric value of a share (in ML per year) in these groundwater sources if all entitlements were used and action was taken to ensure total extraction remained within the extraction limit specified in the applicable water sharing plan. In most cases, average annual use remains under the extraction limit because many licence holders do not use their full entitlement. Those entitlement holders that are currently using their full entitlement can operate without restriction due to underuse of entitlements by others.

As indicated, if these underused entitlements are activated, corrective action may be required to keep total use within the groundwater source extraction limit. This may have financial implications for those that are currently using their full entitlement. Under the current arrangements, these entitlement holders would need to go to the water market to increase their entitlements to overcome any annual allocation shortfall. As the use of groundwater increases, a coordinated and planned approach is needed to manage this issue. For more details on management of extraction limits, please see the *Guide to Managing Groundwater in NSW*.

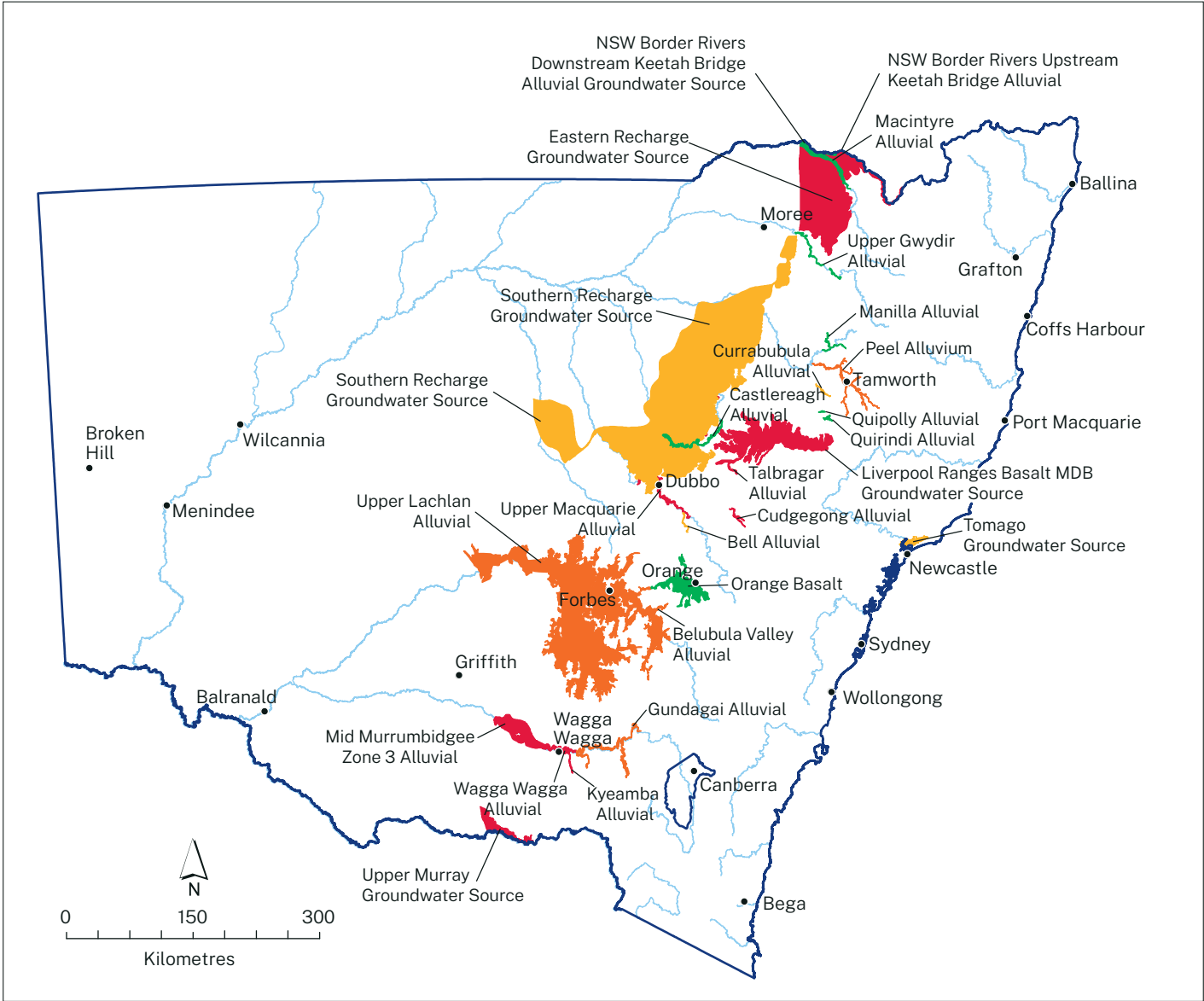
40. NRC 2021, Final Report, *Review of the Water sharing plans for the Greater Metropolitan region*, February 2021, Document No. D20/2692.

41. See *Guide to Groundwater Management in NSW*

42. See www.industry.nsw.gov.au/water/allocations-availability/tracking-groundwater

43. This does not include coastal alluvial groundwater where a single extraction limit applies to both the groundwater and the unregulated river surface water in a subcatchment water source.

Figure 16. Groundwater systems in NSW where the share value is less than 0.95 ML



Extraction as a proportion of extraction limit



Note: Based on average extraction data for 2015 to 2019 period.
Source: Department of Planning and Environment data.

Review resource condition limits to guide the implementation of local impact rules and bore assessments

While total groundwater extraction from a groundwater source may be within the established long-term extraction limits, there may be locations within the groundwater source where the intensity of pumping can cause groundwater levels or water pressure within the source to decline over the medium to long term. In circumstances where this decline is not stabilising, or the decline is approaching or exceeds the criteria for acceptable levels of drawdown, additional management actions may be required to reduce extraction. Trade of additional entitlement into these areas will also be limited or precluded. Figure 17 shows the groundwater sources within which areas of water level or pressure decline have been observed.⁴⁴

As we improve our knowledge of the requirements of groundwater dependent ecosystems, surface water–groundwater connectivity, water quality and the links between groundwater extraction and acid sulphate soils or aquifer compaction, we can refine our local impact criteria and access rules to manage groundwater levels and better protect these. Likewise, consultation is informing our understanding of what is deemed ‘acceptable’ in groundwater systems that are largely disconnected from rivers, have no dependent ecosystems or where the risks to groundwater quality or aquifer compaction are negligible. In these systems, a maximum drawdown target may largely be a function of managing impacts or interference between users, and their willingness or capacity to incur the costs associated with pumping from greater depths.

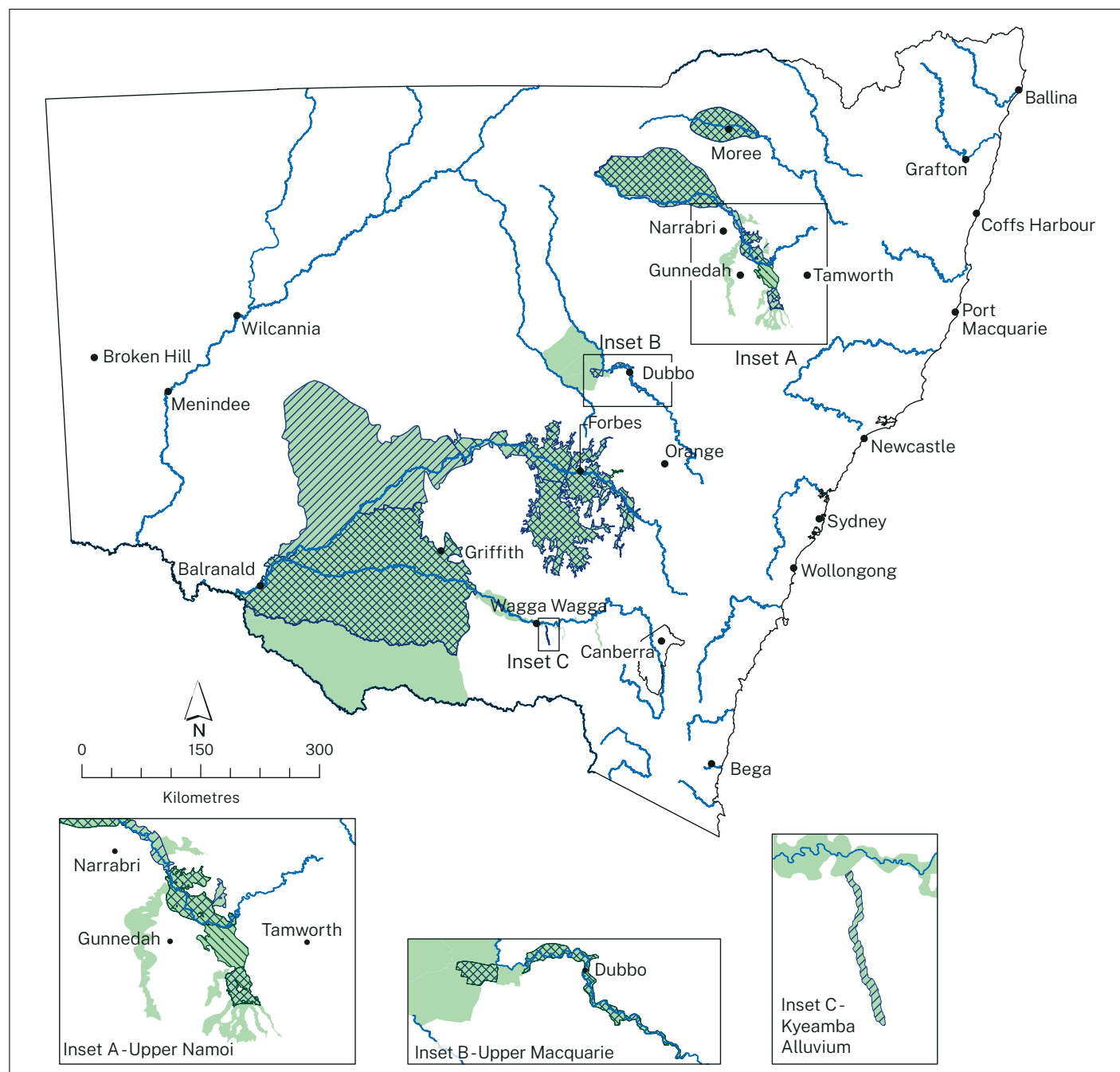
Our local impact rules are designed to manage water levels and water quality that reflect these various scenarios.



Image courtesy of Department of Primary Industries. Bore, Buronga East.

44. For more information about how Department of Planning and Environment prioritises GDEs, see water.dppe.nsw.gov.au/science-data-and-modelling/groundwater-management-and-science/groundwater-and-the-environment

Figure 17. Groundwater sources where areas of groundwater level declines have been observed



Legend:

- Rivers
- Groundwater sources assessed for local level/pressure declines
- ▨ Groundwater sources with areas of more persistent, long-term level/pressure decline
- ▨ Groundwater sources with areas of level/pressure decline over the short term

Source: Department of Planning and Environment data.

Key actions

Action 1.3. Review and update approaches to sustainable groundwater extraction

This action also builds on Action 1.1.

1.3.1 Review groundwater source extraction limits using new knowledge

We will design and implement an updated and adaptive approach to review extraction limits at the groundwater-source scale that better considers climate change and improved understanding of resource sustainability.

1.3.2 Improve clarity around management of fully committed groundwater sources where the entitlement 'share value' is low

We will develop and implement an approach that provides improved clarity to water users on the management of fully committed groundwater sources where the entitlement 'share value' is low.

1.3.3 Better manage impacts of extraction at a local level

We will:

- develop triggers to restrict groundwater extraction to manage impacts to groundwater dependent ecosystems, surface water base flows, risks to water quality, aquifer structure, recharge processes, acid mobilisation in soils and unacceptable interference between users
- improve clarity for existing, expanding and new groundwater users about local groundwater level drawdown impacts and potential extraction restrictions in areas of high extraction
- ensure that groundwater management rules for cross-border groundwater sources are harmonised where possible.

Action 1.4. Protect groundwater quality within natural limits

The quality of our state's groundwater varies naturally between and even within groundwater sources. The natural quality is a result of the type of sediments or rocks within which the groundwater is found and the length of time the water has been in the ground. Maintaining groundwater at its highest possible quality ensures that it is useable for the widest range of purposes. Remediating polluted or contaminated groundwater is difficult and costly and, if even possible, may take years or decades. In the meantime, other beneficial uses of the groundwater cannot be supported and connected rivers and dependent ecosystems may be affected.

The best approach is to prevent groundwater quality degradation in the first place. Where we know aquifers are vulnerable to pollution, high-risk activities should be carefully managed and in some cases precluded from a water source or, if already operational, phased out entirely. Where groundwater extraction can cause the movement of contaminated or saline groundwater into fresher groundwater systems, extraction restrictions should prevent this from occurring. Abandoned and deteriorating bores can also pose environmental and contamination risks over time. These bores must be assessed and decommissioned or replaced in accordance with national standards.

Where prevention is not achieved, early detection intervention and timely management of existing activities that could threaten the quality of our groundwater resources will be a priority.

Key to this action is properly defining what we consider natural limits to be. Precise quantification and definition of natural limits of each groundwater system is crucial to establishing a transparent and measurable system that appraises and reports on groundwater health.

Better groundwater quality monitoring – for both baseline quality and for potentially higher risk activities – is needed to make this action successful.

We need to increase our remediation efforts where groundwater contamination has occurred. We face legacy groundwater contamination issues from past activities and chemical use such as landfills, underground petroleum storage and the use of polluting chemicals such as PFAS. The *Contaminated Land Management Act 2007* provides the legislative framework for remediation.

Preventing further deterioration of groundwater quality, managing the existing risks and remediating sites of concern requires a systematic and collaborative effort across government agencies and with industry. This will be underpinned by new and updated policy instruments that apply our best available knowledge and science and improved monitoring, assessment and data collection – especially in high-risk groundwater sources.

Finally, we need to consider the impacts of climate change and sea-water intrusion and inundation on coastal aquifers. In general, there is a lack of information about groundwater sources and their interactions with seawater along our coasts. This information is essential to ensure future management decisions can adapt to these impacts (see Action 3.3). This issue is being progressed through the Regional Water Strategies for specific groundwater sources.⁴⁵

45. water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/final

Initiatives already under way

The NSW Legacy Mines Program⁴⁶ helps landowners rehabilitate and reduce contamination risks from historic and abandoned mines. Residual wastes, including arsenic and heavy metals, can leach from these sites into the soil and groundwater. Works delivered by the program – such as drainage structures, bunds, sediment retention dams and creek bank stability works – aim to address environmental issues at these sites and stop or slow contamination moving offsite.

The PFAS Investigation Program implemented by the NSW Environment Protection Authority aims to assess the legacy of PFAS use across NSW. With the assistance of NSW Health and the Department of Planning and Environment, the program works to identify PFAS sites across the state and provide impacted residents with tailored, precautionary dietary advice to help them reduce any exposure.⁴⁷

Key actions

Action 1.4. Protect groundwater quality within natural limits

To protect groundwater quality, this action will review and expand our approach to groundwater quality management and provide a more practical application of the water quality protection aspects of Action 1.2.

1.4.1 Review and update our approach to managing groundwater quality

We will:

- review and update our approach to managing groundwater quality to increase its effectiveness
- clarify the responsibilities, governance arrangements and processes across local and state government agencies and industry for managing groundwater contamination prevention, risk management and remediation and monitoring and reporting

- explore mechanisms and programs for reducing the risks to communities from potentially contaminating activities in vulnerable groundwater sources.

1.4.2 Deliver a program to better understand groundwater quality and risks

We will:

- establish a baseline and on-going groundwater quality monitoring program with associated analytics, including the mapping of groundwater vulnerability to contamination
- undertake assessments of activities with a high risk of contaminating high-value groundwater resources.



Image courtesy of Department of Primary Industries. Bore, Buronga East.

⁴⁶ www.resourcesregulator.nsw.gov.au/rehabilitation/legacy-mines-program

⁴⁷ www.epa.nsw.gov.au/your-environment/contaminated-land/pfas-investigation-program

Action 1.5. Better integrate groundwater management with other land and water management processes

Managing land and water resources together will protect our groundwater resources and ensure their sustainability

NSW's many landscapes are complex systems of human and natural processes where surface water, groundwater, the natural environment and land use interact.⁴⁸ Across these landscapes, human activities and land use changes can affect groundwater resources by impacting groundwater recharge, flows, and quality.⁴⁹

Natural processes such as flooding can also affect groundwater resources that can, in turn, impact human activity. In rural areas, a healthy floodplain will improve groundwater recharge. In urban areas, flood waters raise the water table and can damage infrastructure such as building foundations, basements and carparks. Land use planning and development controls need to account for these dynamics and processes.

Integrating groundwater, surface water and land use management will improve our ability to respond effectively to the challenges facing groundwater resources to ensure that these resources are not compromised and remain available for future generations.

To ensure groundwater sustainability, the multiple and varied impacts of land use on groundwater resources need to be understood and managed appropriately.⁵⁰ We will move to a framework where land use planning processes and major project approvals better consider and protect groundwater sources and their dependent ecosystem functions early in the planning phase.⁵¹

This focus reflects the NSW Government's commitments in the *NSW Water Strategy* to achieve high liveability and community benefits by linking land use planning more effectively with issues of water quality and ecosystem health (*NSW Water Strategy*, Action 4.4). This will allow better integration of infrastructure and urban development planning with sustainable water cycle management, which will help to protect built assets and increase community resilience.

A more targeted effort will reduce impacts on groundwater resources from large projects and industrial activities

Large infrastructure projects such as State Significant Developments and State Significant Infrastructure,⁵² as well as industrial activities, have the potential to impact groundwater resources and their dependent assets – including ecosystems, connected surface water sources and other water users – by:

- lowering groundwater levels or pressure – this can occur by direct pumping of groundwater for operational water or to dewater infrastructure that is below the surface and intercepts groundwater
- changing the natural groundwater flow paths – large excavations below the surface may draw the groundwater away from its natural flow path and towards the excavation. If below ground infrastructure is sealed, groundwater will be diverted around the infrastructure
- permanently reducing the groundwater storage capacity of an aquifer by removing the aquifer material (excavating, mining) or rapidly dewatering (causing compaction of the aquifer structure)
- polluting the groundwater through seepage, discharge from processing activities or by drawing or pushing poor quality groundwater into areas with higher quality groundwater.

The NSW Government assesses these interactions and potential effects through the *NSW Aquifer Interference Policy*. Pollution caused by projects is regulated by the NSW Environment Protection Authority. While the current regulatory framework is proving largely effective, policy and coordination gaps remain. More targeted action will help reduce the impacts of large infrastructure projects and industrial activities on aquifers.

48. See *Guide to Groundwater Resources in NSW* for further details about these processes. For example, on processes related to salinity and groundwater, see www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Land-and-soil/eastern-murray-catchment-150240.pdf

49. Global Water Partnership 2014, *The links between land use and groundwater*, *Global Water Partnership Perspectives Paper*, www.gwp.org/globalassets/global/toolbox/publications/perspective-papers/perspective_paper_landuse_and_groundwater_no6_english.pdf

50. National Water Commission 2014, *Integrating groundwater and surface water management in Australia*, Canberra

51. Lerner, DN and Harris, B 2009, *The relationship between land use and groundwater resource and quality*, *Land Use Policy*, 26(1), S265-S273

52. www.planning.nsw.gov.au/Assess-and-Regulate/Development-Assessment/Planning-Approval-Pathways/State-Significant-Development

Box 4. Water and mining policy

NSW is committed to the development of a water and mining policy that builds on the Aquifer Interference Policy and provides mining operations with clear guidance on groundwater licensing requirements, management of quality and quantity and ecosystem impacts, and consideration of groundwater requirements in mine closure and rehabilitation. We have recently completed the State Significant Development guidelines,⁵³ which outline the reporting and monitoring requirements within environmental impact statements from developers and proponents for a range of activities, including mining and extractive industries. These guidelines – and future policy development – also aim to account for any policy gaps regarding extractive industries and provide more transparency to the community.

Increasing cooperation is critical to sustainably manage and protect our shared groundwater sources

NSW shares several groundwater sources with neighbouring states and territories. These sources include:

- the Clarence–Moreton Basin and the Border Rivers Alluvium – shared with QLD
- the Murray Alluvium – shared with VIC (which underlies the entire 400 km length of the Murray River valley)
- groundwater sources in the upper Murrumbidgee – shared with the ACT
- the Great Artesian Basin – shared with the NT, QLD and SA (see Box 5).

To ensure the sustainability of cross-border groundwater resources, cooperation between different jurisdictions and groundwater users is critical. Challenges for these shared groundwater sources include:

- a lack of integration between different accounting and management rules
- lack of trade between states and territories due to incompatible permits and trading platforms
- potential groundwater quality issues arising due to a lack of coordination between agencies across the border, such as contamination spreading from one state to another.

To ensure the sustainability of shared groundwater resources, cooperation between different jurisdictions and groundwater users is critical. The Australian Government also plays a role by administering the federal *Water Act 2007* and *Basin Plan 2012* and coordinating and driving the National Water Initiative,⁵⁴ the National Groundwater Strategic Framework 2016–2026⁵⁵ and initiatives in the Great Artesian Basin.

53. www.planning.nsw.gov.au/-/media/Files/DPE/Guidelines/Policy-and-legislation/SSD-Guidelines/State-Significant-Development-Guidelines.pdf?la=en

54. www.dcceew.gov.au/water/policy/policy/nwi

55. www.dcceew.gov.au/water/policy/policy/nwi/national-groundwater

Box 5. Protecting the Great Artesian Basin

The Great Artesian Basin is the largest free-flowing groundwater basin in the world. It underlies about a quarter of our continent (over 1.7 million km²) and is shared between the NT, QLD, NSW and SA.

The Great Artesian Basin is a highly valued groundwater source that provides an array of benefits and services to its many users. The basin's naturally high pressure feeds springs that have supported Aboriginal people for thousands of years by maintaining cultural, social and spiritual functions. Springs also support varied and rich ecosystems that contain endangered species of plants and animals. The Great Artesian Basin provides drinking water for rural communities and towns and supports livestock, tourism and other industries.

The Great Artesian Basin Strategic Management Plan was developed by the Australian, state and territory governments. The plan gives governments, Aboriginal people, water users and other stakeholders a framework to achieve beneficial economic, environmental, cultural and social outcomes.⁵⁶ The plan was released in 2020, is reviewed every 5 years and has a 15-year lifespan.

The Cap and Pipe the Bores program, established in 1999, aims to stop groundwater wastage and rehabilitate the Great Artesian Basin by recovering naturally occurring artesian pressures. Funded through 2024, the program 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 Cap and Pipe the Bores program in NSW has saved about 80 GL of water per year and supplied approximately 4.2 million ha with permanent and reliable watering points. It has also controlled 400 free-flowing bores and installed 18,000 km of pipes. As a result, groundwater pressures across the Great Artesian Basin are increasing – resulting in improved water security, drought resilience for communities, properties and industries and better supporting springs and associated ecosystems.



Image courtesy of Department of Planning and Environment. Irrigation bore outlet, Narrabri.

⁵⁶ www.agriculture.gov.au/water/national/great-artesian-basin/strategic-management-plan

Key actions

Action 1.5. Better integrate groundwater management with other land and water management processes

The integration of groundwater management with other land and water management processes will be a key aspect of the updated and expanded groundwater policy approach introduced in Action 1.1.

1.5.1 Manage groundwater and surface water together

We will:

- improve our understanding of surface water and groundwater connectivity processes – including the role of baseflows in supporting riverine environments and stream discharges to groundwater sources, flooding and groundwater recharge
- achieve better integration of our river system models and groundwater models by improving the underlying assumptions about the physical surface water and groundwater interactions
- develop a robust approach to manage surface water–groundwater connectivity and access in water sharing plans
- ensure that surface water and groundwater management plans complement and integrate with each other where feasible.

1.5.2 Integrate groundwater considerations into land use planning decisions

We will:

- develop and implement mechanisms to embed groundwater considerations into state, regional and local planning processes
- improve governance and community collaboration to integrate groundwater management with land use planning and decision making
- assess and protect vulnerable and significant groundwater resources and recharge areas through the land use planning system and regulatory tools

- improve our understanding of the natural and human processes causing and affecting potential contamination in groundwater systems and the landscape
- develop mechanisms to protect significant groundwater recharge areas from destruction or over-development.

1.5.3 Improve management of large developments impacting groundwater

We will:

- revise the Aquifer Interference Policy, including investigating aquifer interference approvals and new approaches to managing unlicensed aquifer interference activities
- develop policy and technical approaches to understand and address the individual and cumulative impacts on groundwater of mining activities – including evaluating mining-related groundwater licensing and approval requirements, assessing currently unlicensed legacy groundwater take and the ongoing management of groundwater following mine closure.

1.5.4 Strengthen management of shared groundwater resources

We will:

- implement critical aspects of the Great Artesian Basin Strategic Management Plan and address policy gaps to ensure the continued recovery of groundwater levels in the Great Artesian Basin
- develop and implement cross-border agreements that embed shared principles, common management criteria and associated outcomes, and common processes for trade across boundaries where appropriate
- work with the Australian Government and other jurisdictions to embed groundwater considerations into future revisions of the National Water Initiative and ensure alignment with the strategic priorities of National Groundwater Strategic Framework 2016–2026.

Strategic priority 2

Build community and industry resilience through sustainable groundwater use



Through sustainable groundwater use, water dependent aspirations of Aboriginal people are supported, water resilience for urban populations is improved and development opportunities are realised.

Action 2.1. Support Aboriginal people's rights, values and uses of groundwater⁵⁷

The NSW Government recognises First Nations people's rights to water. Our aim is to secure a future where water for Aboriginal people is embedded within the water planning and management regime in NSW to help deliver cultural, spiritual, social, environmental and economic benefit to communities. Priority 2 of the *NSW Water Strategy*⁵⁸ is to 'Recognise First Nations people's rights and values and increase access to and ownership of water for cultural and economic purposes' and commits to:

- strengthening the role of Aboriginal people in water planning and management
- developing a state-wide Aboriginal Water Strategy
- providing Aboriginal people more ownership of and access to water for cultural and economic purposes
- working with Aboriginal people to improve shared water knowledge
- work with Aboriginal people to maintain and preserve water-related cultural sites and landscapes.

The government will partner with Aboriginal people to co-design a state-wide Aboriginal Water Strategy that will identify a program of measures to deliver on First Nations' water rights and interests in water management.

While the groundwater-focused actions in this strategy mirror the intent of the *NSW Water Strategy*'s actions, they will be superseded and refined as the *NSW Water Strategy* co-design processes progress and concrete actions are fleshed out and implemented.

Groundwater-dependent sites and cultural values of significance to Aboriginal people will be protected across NSW

Groundwater formations and sites are significant to Aboriginal people. Attached to these significant sites are cultural values such as scarred/carved trees, dreaming stories, teachings, economic opportunities, men's and women's business, massacre sites (which were usually close to water), totemic species,^{59, 60} ceremonial and burial sites and language.

Across NSW, limited understanding, recognition and protection of groundwater dependent ecosystems and sites and cultural values of significance persists. A program to identify and enhance the recognition for these sites and values will ensure they are respected and protected. Groundwater sharing plans under the *Water Management Act 2000* provide the framework for this recognition.

Groundwater management will be improved by integrating Aboriginal people's knowledge and increasing participation by Aboriginal people

Until now, opportunities for Aboriginal people to contribute to state-wide groundwater planning and management policies have been limited. The participation of Aboriginal people, communities and organisations in local water management decisions will be improved and mechanisms for self-determination will be enabled.

The NSW Government will provide the necessary support for Aboriginal people to realise their cultural, spiritual and economic rights and aspirations for water generally, including groundwater. In addition to enabling the participation and contributions outlined above, programs and approaches that build Aboriginal people's understanding of non-Aboriginal groundwater management mechanisms and processes will be developed.

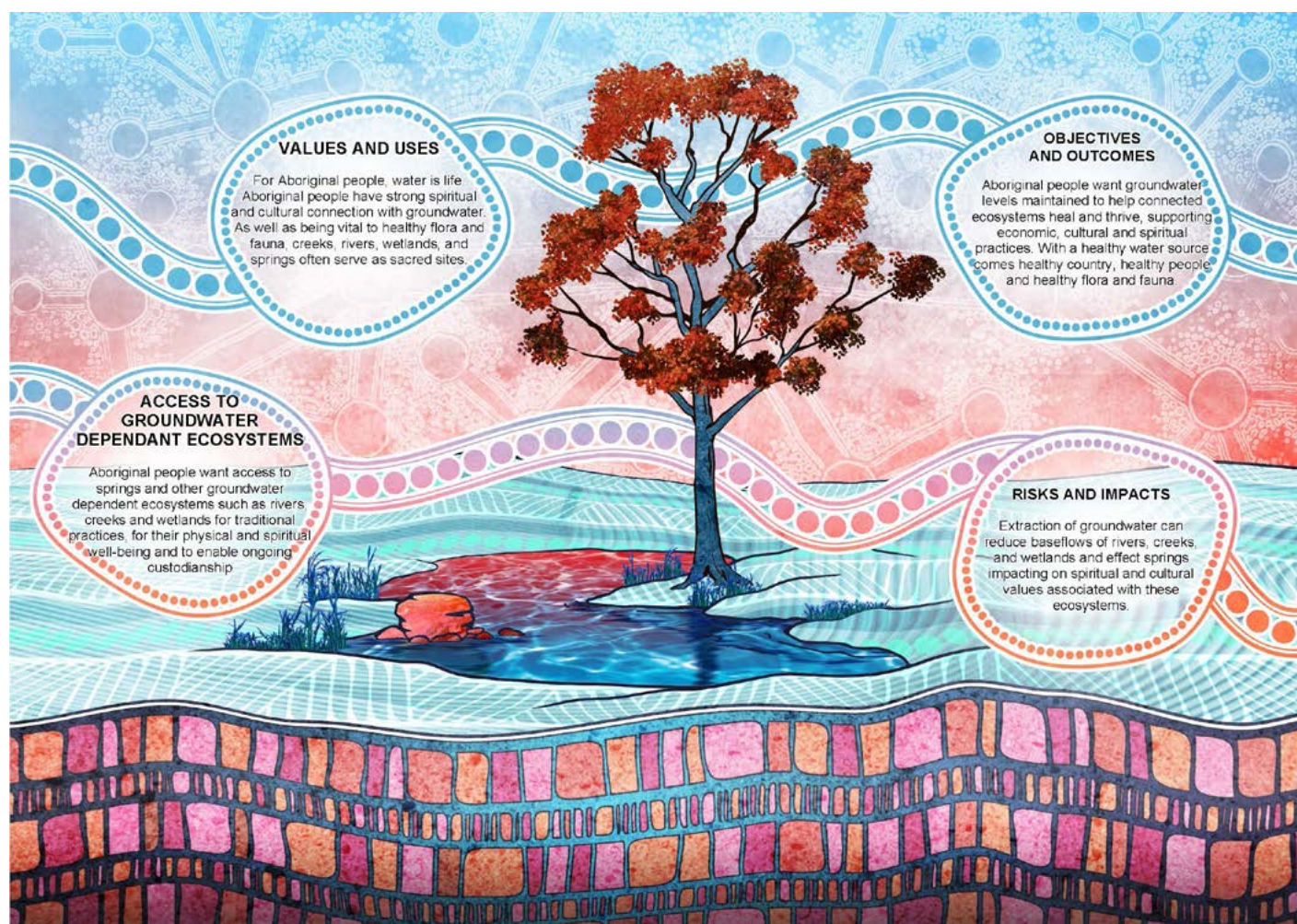
57. Many thanks to Brad Moggridge for his assistance in developing this Action. Brad is a proud Kamilaroi man (North-West NSW) living in Canberra on Ngunnawal land. He is an environmental hydrogeologist and currently an Associate Professor in indigenous water science at the University of Canberra's Centre for Applied Water Science.

58. water.dpie.nsw.gov.au/plans-and-programs/nsw-water-strategy/toward-2050/priority-2

59. Moggridge B.J., L. Betteridge & R. M. Thompson 2019, *Integrating Aboriginal cultural values into water planning: a case study from NSW*, Australia, *Australasian Journal of Environmental Management*.

60. Moggridge B.J. & R. M. Thompson 2021, *Cultural value of water and western water management an Australian indigenous perspective*. *Australasian Journal of Water Resources* doi.org/10.1080/13241583.2021.1897926

Figure 18. Aboriginal peoples' values, uses, risks, objectives and outcomes as considered in groundwater resource management



Note: This is a depiction of a spring water hole (Wiradjuri – giimbir). The bottom half of the design depicts the underground connection to the giimbir through the layers of rock beneath. The pattern in the sky represents the connections of waterways both visible and unseen.

Source: Artist Nathan Peckham, 2021⁶¹

We will work with Aboriginal people to increase their rights and access to groundwater

The government has committed to enhance rights and access to water for Aboriginal people for cultural and economic purposes through the *NSW Water Strategy*. This action will work closely with the actions within the water strategy – specifically Action 2.3 of the *NSW Water Strategy*: ‘Provide Aboriginal people ownership of and access to water for cultural and economic purposes’. In particular, the action aims to:

- recognise and protect Native Title rights to water in water sharing plans
- work with First Nations people to better understand cultural values and flow requirements to inform water planning and sharing decisions
- increase the water available for cultural and spiritual purposes
- increase water entitlements in Aboriginal people’s ownership
- where there are synergies, use water allocated for environmental and consumptive purposes to deliver outcomes and benefits for Aboriginal communities
- improve and enable access to Country to maintain healthy water sources and engage in cultural practices.

61. Artist’s acknowledgement: As a proud Tubba-gah man from Dubbo in the Wiradjuri Nation, I respectfully acknowledge all nations which the Department of Planning and Environment operates on. I acknowledge this artwork will be viewed off my home country of the Tubba-gah people and therefore ask you accept this artwork as an offering on behalf of my family as a gesture of continuing the legacy of the knowledge of our ancestors. I would also like to pay respect to all traditional custodians of the country whose ancestral lands we all walk upon. I thank the Elders for their wisdom, courage, and sacrifice and pledge my commitment to preserving their legacy for future generations – Nathan Peckham.

Initiatives already under way

The Aboriginal Communities Water and Sewerage Program is a \$200 million joint initiative between the NSW Government and the NSW Aboriginal Land Council to improve water supply and sewerage services to Aboriginal communities. Projects include the installation and refurbishment of bores. Since the program began in 2008, it has led to verified improvements in drinking water quality and infrastructure in Aboriginal communities throughout NSW.

Key actions

Action 2.1. Support Aboriginal people's rights, values and uses of groundwater

This set of actions will align with, and build on, the *NSW Water Strategy* and *Aboriginal Water Strategy*. As these initiatives are co-developed, the actions below will be adjusted or superseded.

2.1.1 Protect groundwater-dependent places of significance to Aboriginal communities

We will develop a program to identify and enhance protection of groundwater-dependent cultural sites and values in a culturally appropriate way.

2.1.2 Better integrate Aboriginal knowledge into groundwater management

We will:

- co-design, socialise on Country and implement a program to empower Aboriginal people to fully participate in groundwater management, including (without limitation):
 - exploring and implementing methodologies for considering cultural values of water 'in a way that is culturally appropriate, and which generates a culturally safe space for Indigenous researchers and communities'⁶²
 - programs for improving the Aboriginal people's understanding of non-Aboriginal water management frameworks and methods.

- provide training and job opportunities for Aboriginal people in the management of groundwater resources
- review the legal framework for groundwater management to better integrate Aboriginal people's knowledge and science into decisions
- implement an awareness program for government agencies to encourage wider understanding of Aboriginal people's values, uses and rights to rights to groundwater.

2.1.3 Increase access to groundwater for Aboriginal people

We will:

- implement any Closing the Gap⁶³ targets relating to groundwater entitlements and use, in line with the *Aboriginal Water Strategy* and NSW government commitments
- review the existing cultural access provisions in water sharing plans to overcome barriers to Aboriginal people acquiring these access licences
- consider reserving unassigned groundwater for Aboriginal people where of benefit.

62. Bradley J. Moggridge, Ross M. Thompson, Peter Radoll, 2022, *Indigenous research methodologies in water management: learning from Australia and New Zealand for application on Kamilaroi country*, *Journal of Wetlands Ecology and Management*, Aug 2022.

63. www.closingthegap.gov.au/national-agreement/targets

Action 2.2. Support towns and cities that use groundwater to improve their urban water planning

All water extraction and use must be managed within a larger framework of sustainability. This involves demand management and water efficiency options. Not being specific to groundwater, these are addressed via the *NSW Water Strategy*. Here and in the next action, the focus is how groundwater, within sustainable limits, can support towns and industries in NSW.

To maintain water supply security in the face of increasing demand and a changing climate, towns and cities need to protect their existing groundwater access, diversify their sources of water and plan for their future water needs – particularly during drought.

Many initiatives are already in place or underway. The state government is working in partnership with councils, government agencies and the broader water sector to provide regional communities across NSW with safe, secure and sustainable water supply and sewerage services through several initiatives, including:

- The *Australian Drinking Water Guidelines*⁶⁴ provide guidance to water regulators and suppliers on monitoring and managing drinking water quality, including drinking water supplied from groundwater.
- The Town Water Risk Reduction Program is improving support and advice and providing new regulatory settings that will enable local water utilities to identify, manage and reduce risks in town water systems more strategically and effectively.⁶⁵
- The Water Security for Regions and Safe and Secure Water program⁶⁶ provides funding and other support for safe, secure and sustainable water and wastewater services to regional NSW towns. The program funds and supports planning studies, new and upgraded water supply and sewerage infrastructure and the development of strategic planning systems for urban water service (such as integrated water cycle management strategies).

- The Water Efficiency Framework⁶⁷ delivered through the *NSW Water Strategy* provides clear steps to design, deliver and review water efficiency programs. A best practice guide has been developed with input from the water industry and consideration of lessons learnt in the last drought. This guide is designed for governments, water utilities, councils and large businesses to use when implementing water efficiency initiatives.
- As part of the *NSW Water Strategy*'s Action 1.6, the NSW Government has committed to reviewing the regulation of domestic and stock basic landholder rights.⁶⁸ This includes the use of groundwater for stock and domestic purposes. Recent droughts have raised further concerns about water extraction and use under domestic and stock basic landholder rights during extreme dry periods.

Through these initiatives this strategy seeks to:

- facilitate better management of current and future urban groundwater supplies
- ensure our regional towns consider and plan for the sustainable development of groundwater supplies to contribute to meeting the requirements of future urban growth demands and to respond to future droughts.

A key part of this will be the identification of strategic groundwater reserves in local land use planning and the protection of critical catchments and capture zones to guard against pollution of groundwater that is, or could be, used for human consumption. See also Action 1.5.4.

64. www.nhmrc.gov.au/about-us/publications/australian-drinking-water-guidelines

65. www.dpie.nsw.gov.au/water/plans-and-programs/town-water-risk-reduction-program

66. www.industry.nsw.gov.au/water/plans-programs/infrastructure-programs/water-security-for-regions

67. www.dpie.nsw.gov.au/water/plans-and-programs/water-efficiency

68. water.dpie.nsw.gov.au/licensing-and-trade/basic-landholder-rights/domestic-and-stock-rights

Key actions

Action 2.2. Support towns and cities that use groundwater to improve their urban water planning

2.2.1 Support improved management of urban groundwater supplies

We will:

- provide support for local water utilities to understand the level of risk to availability and quality of groundwater supplies
- develop guidelines for urban borefield construction, maintenance, decommissioning and monitoring as well as wellhead and capture zone protection
- review the regulation of groundwater stock and domestic basic landholder rights in and around urban centres to assess whether new rules are required to better manage this type of water take – particularly during drought.

2.2.2 Enable efficient and timely integration of groundwater supply options to help growing regional towns and cities, particularly during drought

We will:

- resolve groundwater regulatory and licensing issues for towns, and explore innovative licensing options for groundwater-based drought resilience
- work with local governments to identify and protect high value groundwater resources that can be used in drought and to support future growth
- review and better integrate surface water and groundwater management responses to severe water shortages and other extreme events.



Image courtesy of Destination NSW. Township, Inverell.

Action 2.3. Support resilient groundwater dependent industries in NSW

Better planning will secure sustainable access to groundwater for industry, and support regional development and economic growth within sustainable limits

In 2021, the NSW Government launched its *20-Year Economic vision for Regional NSW*,⁶⁹ Together with *Regional Economic Development Strategies*,⁷⁰ *Special Activation Precincts*,⁷¹ and other strategic initiatives such as the NSW Hydrogen Strategy, the *Economic vision for Regional NSW* aims to foster economic development and increase populations, jobs, liveability and prosperity in regional areas.

Where sustainable, groundwater can support new business ventures and economic growth in the decades to come (see Box 6). Regional development and its impact on water resources represents a subset of the wider interactions between land and water (see Action 1.5).

To ensure that regional development is viable, resilient and sustainable – especially under a changing climate – current and future regional planning initiatives will need to understand the groundwater-related opportunities and constraints early in the planning and development process, including:

- its availability, current level of commitment and capacity to support economic growth
- the operation of the groundwater entitlement and allocation markets
- the risks posed by certain development activities to groundwater quality, local water levels and dependent ecosystems.

A whole-of-government approach can ensure that clear information about groundwater and its licensing and management framework is available to prospective industries so that both the resource and any new industries are sustainable in the long term.



Image courtesy of Destination NSW. Yarren Wines, Yenda.

69. www.nsw.gov.au/a-20-year-economic-vision-for-regional-nsw-refresh

70. www.nsw.gov.au/regional-nsw/regional-economic-development-strategies

71. www.planning.nsw.gov.au/Plans-for-your-area/Special-Activation-Precincts

Box 6. The importance of groundwater for the economy of NSW

Groundwater is an important asset for NSW's economy. Over the past 15 years, groundwater extraction has accounted for approximately 20 per cent of metered water extraction in NSW on average, with the direct economic value estimated to be over \$800 million per year.⁷²

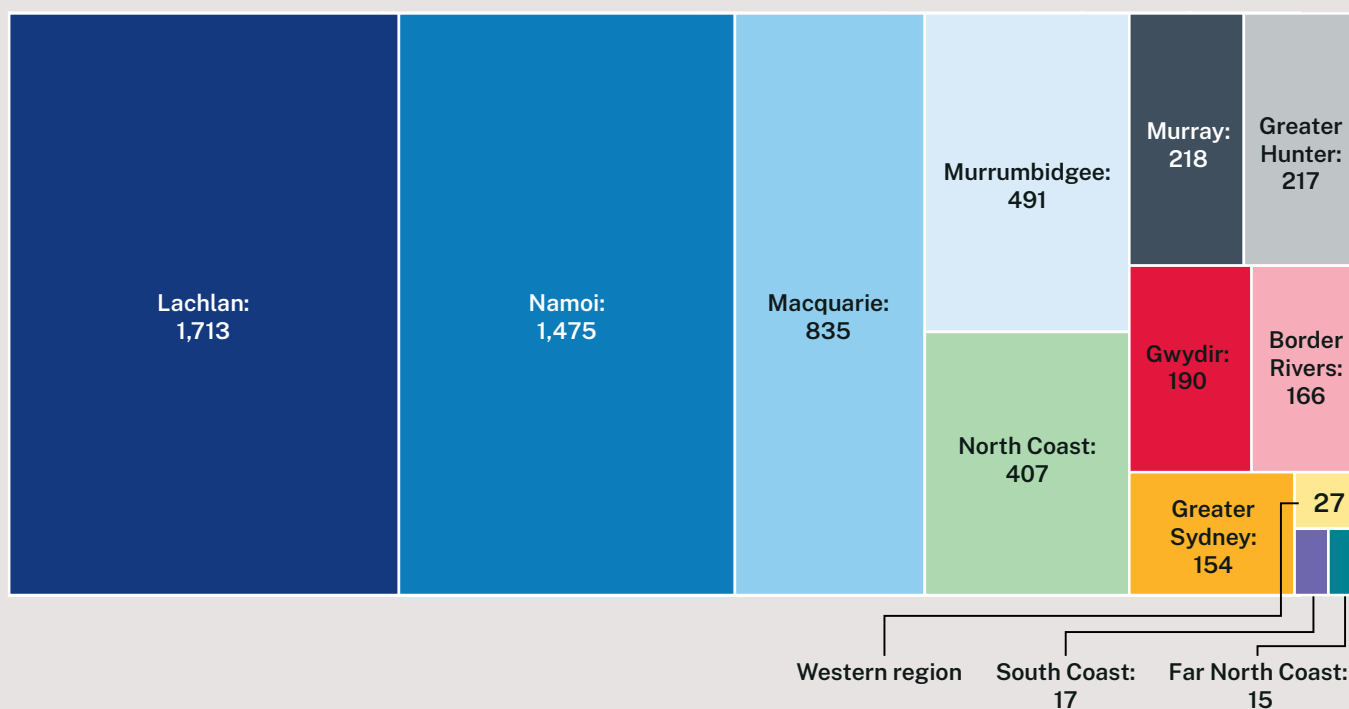
Taking into account the relative uncertainty of such calculations due to the limitations of metering and usage information availability, the Centre for International Economics has estimated that In NSW, agriculture is the largest user of groundwater. The sector uses around 65% of the total volume extracted each year⁷³ but its economic value represents less than 27% of total annual economic value. The economic value of groundwater for town water supply is estimated to be \$160 million per year and towns use approximately 5.5% of total groundwater extracted annually.⁷⁴

The largest economic value derived from groundwater use is found in industrial activities such as livestock watering, water bottling, manufacturing and food processing (estimated at around \$400 million per year). The value of groundwater as water supply for the mining sector is estimated to be \$40 million and the sector's groundwater use accounts for 2.8% of all extractions each year.

Groundwater can have significant impacts on the broader economy when considering the indirect income generated by businesses and other economic activities supported by groundwater as well as other income generated by servicing industries and sectors (the so-called multiplier effect).

With this approach, the value of economic activities depending on groundwater could be as high as \$6 billion⁷⁵ and support around 17,000 jobs (Figure 19). During drought when the reliance on groundwater increases, this value could be as high as \$10 billion – with 28,000 jobs linked to groundwater use. Geographically, the highest economic value is found in the Lachlan and Namoi regions.

Figure 19. The broader value of groundwater by catchment in NSW (in \$Mil/year)



Source: Department of Planning and Environment data.

Note: This figure shows preliminary economic analysis results, subject to further review.

72. Centre for International Economics (CIE), *Understanding NSW's economic dependency on groundwater*, July 2021.

73. Centre for International Economics (CIE), *Understanding NSW's economic dependency on groundwater*, July 2021.

74. Centre for International Economics (CIE), *Understanding NSW's economic dependency on groundwater*, July 2021.

75. Calculations based on average groundwater extraction volumes. See Appendix 1, *Guide to Groundwater Resources in NSW*.

Box 7. Considering groundwater resource availability through land use planning will support regional growth

Special Activation Precincts are a planning tool to foster growth and community development in regional NSW. They are dedicated areas identified for their potential to become thriving business hubs.

The precincts aim to support local industry, create jobs and drive investment through the provision of new infrastructure and fast-tracked planning procedures. Technical and environmental studies are used to inform the development of master plans for each precinct to make sure land uses and development occur in the right locations for the right purposes.

Six precincts are currently in planning and delivery phases: Narrabri, Parkes, Wagga Wagga, Moree, Williamstown and Snowy Mountains.

Groundwater may assist economic development and business growth in these precincts by contributing to the water needs of new economic activities while remaining within existing sustainable limits. We will need to carefully plan these precincts using a fully integrated approach that coordinates activities between different agencies and councils, ensures a clear understanding of the condition and potential availability of local groundwater sources (through the market or otherwise) and the potential risks that industry may pose to these resources.

New measures will allow access to groundwater in targeted areas to support economic activities

There are areas in NSW where groundwater could potentially accommodate additional uses. New entitlements could be granted for groundwater sources where current entitlements are well below the extraction limits. A precautionary approach will be taken to granting new entitlements that considers the risks to the groundwater resources and dependent ecosystems in the context of a changing climate. Opportunities also exist for activation of currently unused entitlements by new or expanding industries through the water market. To confidently invest, new or expanding businesses need clarity about the groundwater supply opportunities and limitations.

Technology and innovation can support communities and industries that use groundwater to become more resilient

Technological advances can improve groundwater access. Solutions such as desalination⁷⁶ can allow us to use saline or brackish groundwater to improve water supply reliability or provide new sources of water.⁷⁷ Desalination could be attractive to businesses producing high-value commodities and for providing additional value for industries. Portable self-contained desalination systems could be used in remote locations and communities in NSW to bolster water supply reliability.

While concerns about desalination exist and need to be addressed – such as what to do with the hypersaline by-product, the costliness of the process and the amount of energy it consumes – further investigation is warranted. Complementary technology such as solar power may also address some of these concerns.

The use of green infrastructure and specific solutions such as managed aquifer recharge can also help protect groundwater and improve water storage and quality (Box 8 and Box 9).

While managed aquifer recharge comes with significant policy, technical and regulatory challenges, it may deliver longer-term community and environmental benefits. Further studies are required to explore the feasibility of artificial recharge in targeted groundwater sources – including resolving technical, regulatory, accounting and licencing issues – and a policy framework is required to support the uptake of managed aquifer recharge.

76. Desalination uses membranes or heat to remove salt from water, making it suitable for drinking or other purposes such as industrial and commercial uses in the mining industry for example.

77. news.mit.edu/2018/study-finds-potential-brackish-groundwater-desalination-0705publications.csiro.au/publications/publication/Plcsiro:EP211403

The NSW Water Strategy Action 6.8 aims to enable the use of managed aquifer recharge by developing a new policy and regulatory framework in NSW and identify where it is technically and economically viable. Before managed aquifer recharge is adopted widely in NSW we will undertake further analysis, testing and community consultation.⁷⁸

Other initiatives in the agricultural sector continue to improve water-use efficiency. Farms of the Future is one of 3 priority areas in the NSW Government's

\$400 million Regional Digital Connectivity program. Investments made through this program will enable farmers and agribusinesses to use agricultural technologies to boost productivity and efficiency. The groundwater efficiency savings can be used to expand existing businesses or sold to new or expanding enterprises elsewhere in the water source. Opportunities may also exist to 'retire' these savings and take the pressure off stressed groundwater resources.

Box 8. Using nature's solutions to better protect groundwater

Green infrastructure⁷⁹ (as opposed to grey or concrete-based infrastructure) aims to protect, restore and mimic the natural water cycle and use the properties of water and nature to deliver effective and economical water management solutions. The use of green infrastructure to address water storage issues can provide significant benefits to groundwater and covers a range of environmental management techniques, including:

- using conservation tillage
- managing dryland salinity with plants
- restoring or creating wetlands to improve groundwater quality
- managing flood and storm water to support groundwater recharge.

Some of these solutions are already used successfully in NSW. In Sydney, urban wetlands are used to increased groundwater recharge in Penrith. Using recycled water to recover groundwater levels has been proposed for the Botany Sands Aquifer.



Image courtesy of Department of Planning and Environment. Boomi River, Budelah Nature Reserve.

78. Considerations for Water Resources Planning and Management of an international overview of governance of MAR systems, *International Association of Hydrogeologists*, July 2022 (Dillon et al 2022).

79. www.unep.org/resources/publication/green-infrastructure-guide-water-management

Box 9. Managed aquifer recharge – a natural storage solution

Building our water resilience as climate variability increases will require diversifying our water storage options. Managed aquifer recharge – also known as ‘water banking’ – stores surface, storm or recycled water in aquifers during wetter periods to use later. Managed aquifer recharge uses the natural properties and processes of aquifers as an alternative to above-ground reservoirs. Water can be artificially injected into the aquifer with pumps or infiltrate through ponds or purpose-designed wetlands. Evaporative losses are minimised while this water is underground.⁸⁰ Water banking can be used in conjunction with other water storage options, creating an integrated water storage infrastructure system that would increase the resilience of NSW’s long term water supply.

The technical, economic and environmental limitations of managed aquifer recharge need to be considered:

- the suitability of aquifers in terms of storage capacity and flow dynamics
- the quality of the injected water
- availability of local surface water sources, particularly in ‘capped’ systems
- cost and energy consumption
- the regulatory and policy framework – including the nature of the associated rights and accounting for water stored and subsequently taken.

Managed aquifer recharge test schemes are being piloted in NSW. The government is also delivering a project with CSIRO and the National Water Grid Authority to explore the technical feasibility of developing water banking for agriculture. Specific sites are being considered under the place-based regional water strategies as well as the metropolitan water strategy.



Image courtesy of Department of Planning and Environment. Narrabri Lake, NSW.

80. For managed aquifer recharge examples, see United Nations Educational, Scientific and Cultural Organisation 2018, *Nature-Based Solutions for Water*, at www.unwater.org/publications/world-water-development-report-2018/

Key actions

Action 2.3. Support resilient groundwater dependent industries in NSW

2.3.1 Provide better information to communities and industries on groundwater development constraints and opportunities

We will:

- provide clear guidance to mining and other State Significant Developments about groundwater opportunities, constraints and protection responsibilities that impact their operations through all phases of development, including the management of legacy quality and quantity impacts after closure
- develop groundwater constraints and opportunities guidelines and information products for regional development initiatives
- ensure strategic alignment and information sharing concerning the availability and sustainable use of groundwater in regional planning and development initiatives through a timely whole-of-government engagement approach.

2.3.2 Enable the increase of sustainable groundwater use in targeted areas

We will:

- investigate market or other barriers to sustainable groundwater development in groundwater sources where extraction is low
- continue to provide opportunities for the controlled allocation of new groundwater entitlements in groundwater sources where entitlements are well within sustainable limits and the risks to the groundwater source and dependent ecosystems is low

- provide clarity for existing and potential groundwater users on:
 - opportunities and constraints of the groundwater trading market
 - extraction limits, typical bore yields and quality of groundwater in each groundwater source
 - timing, criteria and mechanisms for offering new groundwater entitlements through tender processes (controlled allocation orders)
 - processes for determining the allocations made available each year to entitlement holders (available water determinations)
 - the entitlement ‘share value’ in each groundwater source (see Action 1.3.3).

2.3.3 Foster innovative groundwater solutions, including managed aquifer recharge, to support communities and industries

We will:

- provide access to, and use of, saline groundwater resources where feasible and sustainable, including ensuring stringent conditions for appropriate disposal of desalination by-products
- investigate the feasibility and use of green infrastructure groundwater solutions such as managed aquifer recharge, including a policy framework with necessary legislative changes and accounting, assessment and approval processes needed to implement managed aquifer recharge.



Image courtesy of Department of Planning and Environment. Train coal wagons, Namoi River.

Strategic priority 3

Improve groundwater information and knowledge



Better groundwater management and investment decisions are made based on improved information and knowledge.

Action 3.1. Develop the groundwater components of a water knowledge plan

Robust decision-making by government and non-government stakeholders needs to be supported by quality information. With better information and knowledge, the risks to our groundwater and the value it provides decreases. Information and knowledge products such as models must be underpinned by good and accessible data, with systems and management systems that enable its efficient use. Figure 20 shows how data, information and knowledge build on top of one another to support decision making concerning sustainable groundwater management.⁸¹

Groundwater systems are complex and diverse. Due to their very nature – largely out of sight and, in many instances, at great depth – there will always be gaps in our data and understanding of them. ‘Uncertainty is common and unavoidable in all the complex processes found in natural landscapes... [and] even with improved models and more data, uncertainty will remain’.⁸²

By understanding the uncertainty intrinsic to groundwater management, we can be strategic in our data collection and knowledge generation activities. We can target our efforts to support decision making in the most efficient and cost-effective ways. We can

tailor our groundwater management framework and decisions to account for uncertainty and manage the associated risks.

The government will also need to work closely with the community to understand what they need to know about groundwater their groundwater and the best approach to building our collective understanding.

Key actions

Action 3.1. Develop the groundwater components of a water knowledge plan

This plan will target and prioritise information and knowledge to inform Strategic Priorities 1 and 2, including:

- data, systems, tools and information products required
- the specific policies for sharing data and models, as well as information sharing opportunities and pathways
- the mechanisms for review, and periodic update of the knowledge plan, with inclusion of innovative technical solutions as these emerge.

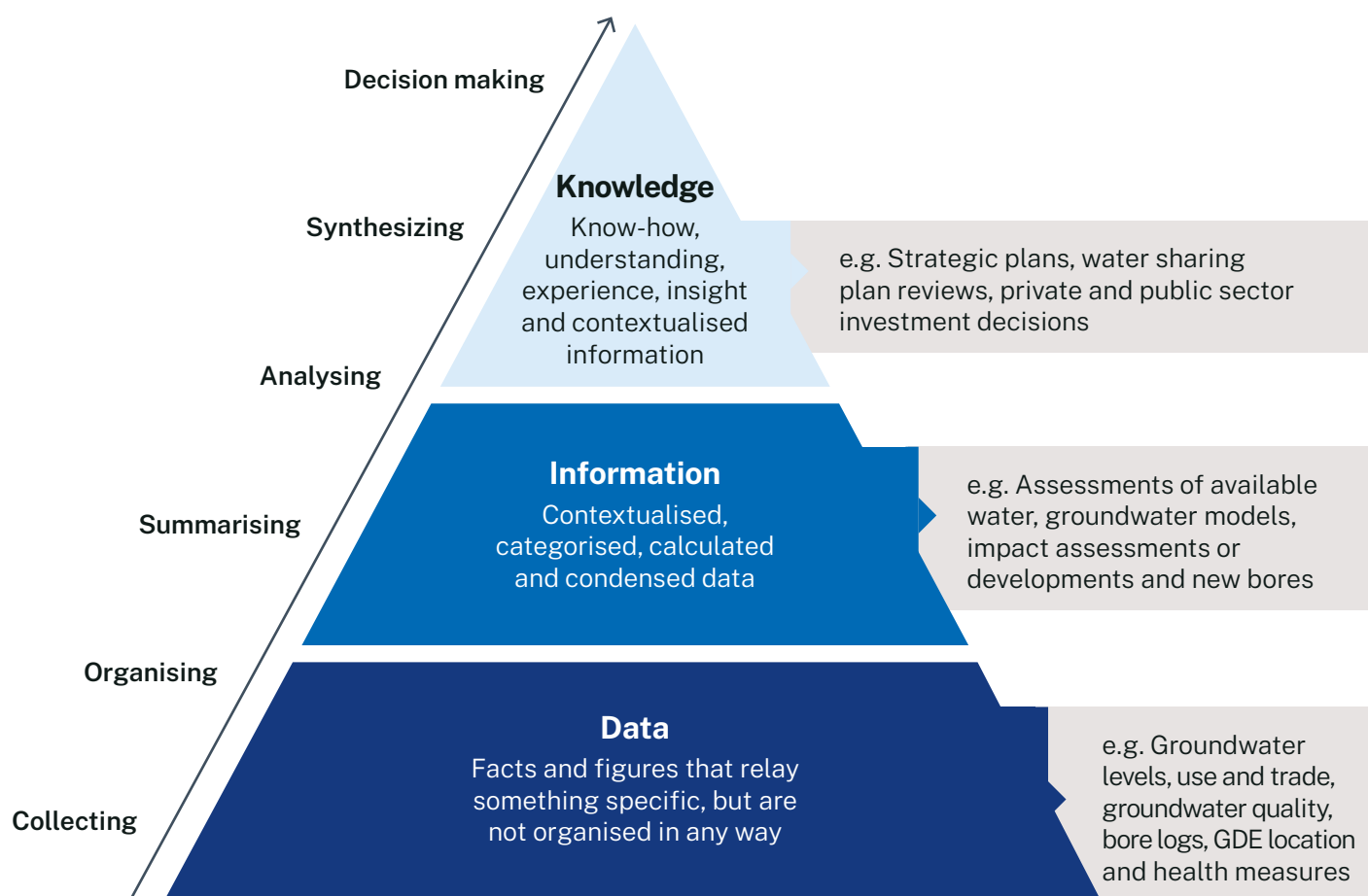


Image courtesy of Jess Thompson. Mascot Spring.

81. See more about how the NSW Government collects and uses water data at www.chiefscientist.nsw.gov.au/independent-reports/water-data-review

82. DARE Centre Draft NSW Groundwater Strategy Response, 2022.

Figure 20. Data, information and knowledge are necessary to manage groundwater



Source: Adapted from www.knowledge-management-tools.net/knowledge-information-data.html

Action 3.2. Better share and integrate groundwater information

While we have made considerable advances in sharing water data, more can be done to integrate groundwater information into existing platforms, improve how we communicate groundwater information and distribute information products as widely and openly as possible.⁸³ This will facilitate efficient government and private sector decision making and help create a shared understanding and sense of ownership, responsibility and trust across a wide range of interests, organisations and stakeholders.

The NSW Government is committed to the principles of transparency consistent with whole-of-government principles. The *NSW Water Strategy* supports aligns with these principles by taking an ‘open by default’ approach to information and data access.

To meet this strategic outcome of the *NSW Water Strategy*, the NSW Open Data Framework for water has been established.⁸⁴ The framework aligns with the NSW Government’s *Open Data Policy and Government Information (Public Access) Act 2009* (NSW).⁸⁵ It aims to establish a proactive and open approach to ensuring transparent government information for the community. Through this approach, we aim to improve our communication by collating and hosting previously unreleased datasets such as stratigraphic records, water chemistry results, hydraulic property data and various spatial data in a groundwater specific data repository.

83. Gorelick, SM and Zheng, C 2015, *Global change and the groundwater management challenge*, *Water Resources Research*, 51(5), 3031-3051, doi.org/10.1002/2014WR016825

84. water.dpie.nsw.gov.au/science-data-and-modelling/data/open-data-framework

85. www.digital.nsw.gov.au/sites/default/files/NSW_Government_Open_Data_Policy_2016.pdf

There are many different types of groundwater data, including but not limited to:

- data on groundwater levels and quality
- geology, bore locations and logs
- groundwater yields (pumping test results)
- groundwater use and licensing
- groundwater dependent ecosystem locations and health
- groundwater source definitions and extents
- geospatial data
- current and historical management plans and strategies
- research papers.

Once groundwater data is collected, integrating and sharing it between government agencies and with the public can be challenging because different agencies use separate systems and databases to record and store data. There are also multiple state and national online platforms to visualise and present groundwater information.

Integration of industry-collected data into government databases will be a new priority. While State Significant Developments and major infrastructure projects are now required to submit groundwater data, further processing and consolidation is needed before this data can be released for public access or used for making decisions and managing resources. This could be far more efficient if the data received was quality assured, tagged and readily available to be integrated into government databases. A common framework, developed in consultation with industry, will improve the integration, presentation and accessibility of this data. This action is closely linked to Priority 1 of the *NSW Water Strategy*: 'to build community confidence and capacity through engagement, transparency and accountability'.

Box 10. Better data access can boost market confidence and inform trading decisions

Water markets are an important component of Australia's approach to managing water resources.

The 2021 Australian Competition and Consumer Commission report on water markets in the Murray–Darling Basin identified several areas that should be targeted for improvement.⁸⁶ The review found that quality and timely water information was key to improving market confidence and supporting better informed trading decisions for water market participants across the basin.

As surface water availability becomes scarcer and water prices continue to rise, conducting additional modelling and making groundwater data available to groundwater users will support water markets and enable a more efficient allocation of resources through trade.

Big data analytics, telemetry and blockchain are examples of further reforms and innovations that could provide more up-to-date information about water trading to improve trade efficiency and maintain resilient water markets.

86. www.accc.gov.au/focus-areas/inquiries-finalised/murray-darling-basin-water-markets-inquiry-0

Initiatives already under way

WaterNSW hosts the WaterInsights portal, a powerful interactive tool that provides meaningful and easily understood information on how water is shared, allocated and managed. The portal helps water users and the public understand what water is present in the system (in storages or in rivers or groundwater) and the rules about how it is used, shared and managed. WaterInsights has been developed with direct feedback from WaterNSW's customers, stakeholders and local communities. It covers more than 760 water sources across NSW.⁸⁷

The NSW SEED portal⁸⁸ is the state's central resource for sharing and enabling environmental data. Other existing data viewing platforms such as Commonground⁸⁹ and Minview⁹⁰ also help citizens find information about current exploration and mining activities in their local areas and explore and download maps and title and licence documents. Expanding these portals to include more detailed groundwater information would improve information access and resource management.

The NSW Water Register⁹¹ is the public water licensing information system. The register amalgamates information from several public registers and provides public access to information about water licences, approvals, water trading, and other matters related to water entitlements in NSW. Consultation was undertaken in 2018 as a part of the NSW Water Reform action plan to determine what information stakeholders want to see in the public water register. Results of consultation can be found in the Transparency Measures consultation paper.⁹²

The NSW groundwater extraction limit dashboard is a powerful online tool that tracks groundwater extraction.⁹³ The dashboard aims to use the best available information available to calculate estimates of current extraction against the annual compliance trigger. It includes the annual volume that, if extracted, will trigger compliance action in the following year, volume remaining to be extracted in the year before reaching the compliance trigger and the likelihood that compliance action will need to be taken in the following water year.

The NSW Government has also launched a Drillers Portal to make it easier for bore drillers to complete the reports required when a bore is drilled.⁹⁴ Drillers can access the portal from mobile devices and tablets.

Key actions

Action 3.2. Better share and integrate groundwater information

To improve access to relevant and accurate groundwater information and data, and consistent with the groundwater knowledge plan, we will:

- expand the range of knowledge and insights products including information systems, platforms and interfaces for storing, managing, accessing and interrogating groundwater data
- improve and diversify how we communicate information on groundwater resources and their management
- support strategic planning and decision making by councils and groundwater users with improved access to information on groundwater and its management
- develop a unified framework to consolidate and analyse groundwater data across all relevant agencies, groundwater users and impacting activities
- support data and database integration across agencies to address data gaps and improve customer service delivery.

87. www.waternsw.com.au/waterinsights

88. www.seed.nsw.gov.au/

89. commonground.nsw.gov.au

90. minview.geoscience.nsw.gov.au

91. waterregister.waternsw.com.au/water-register-frame

92. www.industry.nsw.gov.au/_data/assets/pdf_file/0019/145423/transparency-measures-consultation-paper.pdf

93. www.industry.nsw.gov.au/water/allocations-availability/tracking-groundwater

94. www.waternsw.com.au/waterinsights

Action 3.3. Improve our understanding of groundwater resources

By using the best available science and a multidisciplinary approach, we can generate more knowledge about our groundwater resources.

Effective management of groundwater requires evidence from both natural and socio-economic sciences. This is because groundwater management sits at the interface between consumptive and environmental water uses and requires policies that account for complex and coupled socio-ecological interactions.⁹⁵

We need to make sure our management approach fully accounts for these interactions. Broadening our approach will give a better understanding of these interdependent relationships and provide a much greater range of information we can use to make predictions and decisions about groundwater management over the long term.⁹⁶

Multidisciplinary approaches to understanding these interactions are beginning to evolve in Australia. For example, researchers at the University of Technology in Sydney are using stakeholder behaviour and decision-making models (known as agent-based models) to represent socio-economic drivers of groundwater extraction and their effect on groundwater resources.⁹⁷ Further developing this type of modelling will support a more informed and effective systems approach to groundwater management.

Aboriginal people have intricate knowledge of the water cycle and related environmental systems that has been passed down by custodians of the land for generations. Where appropriate, understanding and integrating this knowledge into our management approach is crucial.

Updated and expanded models will improve our groundwater management

Groundwater models can range from simplified conceptual models to analytical models to the most complex and data hungry numerical models. While groundwater models are a simplification of a more complex reality, they have proven to be useful tools over several decades for addressing a range of groundwater problems by supporting decision-making processes.⁹⁸ There is scope to expand our more complex modelling to additional groundwater resources in NSW and refine our existing models with new data and understanding of local groundwater dynamics and surface water-groundwater interactions.

We now have new datasets that better capture the range of possible climate scenarios and provide insights into how groundwater availability could change under a 'dry climate change' scenario. These new datasets are likely to be incorporated into future modelling to support water sharing plan reviews and management decisions.

The Independent Expert Scientific Committee on Coal Seam Gas groundwater modelling uncertainty guidelines provides a foundation for uncertainty analysis of groundwater models in a risk assessment framework.⁹⁹ This work in quantifying the uncertainty of model predictions can contribute to effective groundwater management decision making and improve confidence in model results.

The roll out of the non-urban water metering policy¹⁰⁰ across NSW will significantly improve the measurement and collection of groundwater data that can be used in models to support better decision making. However, to get the most value from this new data we need to be using it in the best available models.¹⁰¹

New capabilities will make NSW a leader in groundwater science

Significantly expanded research into groundwater resources is not only a priority for NSW but increasingly essential throughout Australia and around the world as communities grapple with the need to manage our limited water resources. With a strong foundation of public and private sector water research, there are positive prospects for NSW to become a global leader in groundwater science.

To secure this leadership, the science-policy nexus between government and researchers needs to be strengthened and formalised so that groundwater science supports public policy and has practical applications for groundwater planners, managers and users.¹⁰² Actions taken under this strategy will prioritise new science-based partnerships with a focus on using the next generation of technology-driven solutions to acquire more groundwater knowledge and improve groundwater services.

Expanding the capacity and capability of public sector scientists is essential to address niche knowledge gaps. By collaborating with universities and other research centres, the NSW Government can support future generations of groundwater professionals through initiatives such as internships, graduate programs, scholarships and other targeted actions.

95. Elshall, AS et al 2020, *Groundwater sustainability: a review of the interactions between science and policy*, Environmental Research Letters, 15, 093004, doi.org/10.1088/1748-9326/ab8e8c

96. NSW Chief Scientist and Engineer 2020, *Review of water-related data collections, data infrastructure and capabilities*, www.chiefscientist.nsw.gov.au/_data/assets/pdf_file/0003/337503/Water-Data-Review.pdf

97. J.C. Castilla-Rho, G. Mariethoz, R. Rojas, M.S. Andersen, B.F.J. Kelly, *An agent-based platform for simulating complex human-aquifer interactions in managed groundwater systems*, Environmental Modelling & Software, Volume 73, 2015, doi.org/10.1016/j.envsoft.2015.08.018.

98. Barnett et al, 2012, *Australian groundwater modelling guidelines, Waterlines report*, National Water Commission, Canberra, p.1.

99. www.iesc.gov.au/publications/information-guidelines-explanatory-note-uncertainty-analysis

100. www.dpie.nsw.gov.au/water/nsw-non-urban-water-metering

101. NRC 2021, Final Report, *Review of the Water sharing plans for the Greater Metropolitan region*, February 2021, Document No. D20/2692

102. Milman, A and MacDonald, A 2020, *Focus on interactions between science-policy in groundwater systems*, Environmental Research Letters, 15(9), 090201.

Key actions

Action 3.3. Improve our understanding of groundwater resources

We will deliver new projects to help us to better understand and manage groundwater resources and their dependent ecosystems across NSW.

3.3.1 Expand our multi-disciplinary understanding of groundwater

We will:

- undertake new research to understand groundwater processes, including:
 - recharge and infiltration processes
 - the impacts of climate change on groundwater systems including the effects of sea-level rise
 - connectivity between surface water and groundwater
 - groundwater needs for ecosystems
 - dynamics of groundwater levels
 - changing patterns in groundwater quality and contaminant pathways.
- better understand socio-economic constraints and opportunities for groundwater demand
- embed information about water user behaviour and cultural values into our conceptual models for groundwater management.¹⁰³

3.3.2 Improve our groundwater models where required

We will develop:

- integrated, fit-for-purpose and peer-reviewed numerical surface-groundwater models where needed
- explore the opportunities to develop and apply multi-disciplinary models that incorporate socio-economic and physiochemical data.

3.3.3 Increase our capacity and capability to apply leading groundwater science

We will:

- formalise strategic research partnerships between the Department of Planning and Environment and other research and industry-led organisations and agencies
- maintain a live government groundwater research prospectus that identifies key research gaps in groundwater science and outlines specific research proposals
- bring together the groundwater community of practice to improve the dialogue about innovative groundwater solutions between researchers, government and industry
- encourage a pipeline of groundwater professionals in NSW.



Image courtesy of Department of Primary Industries. Furrow irrigation of cotton, Warren.

103. Heinrichs, Danielle H. and Rojas, Rodrigo 2022, *Cultural values in water management and governance: where do we stand?*, Water 14(5)803.

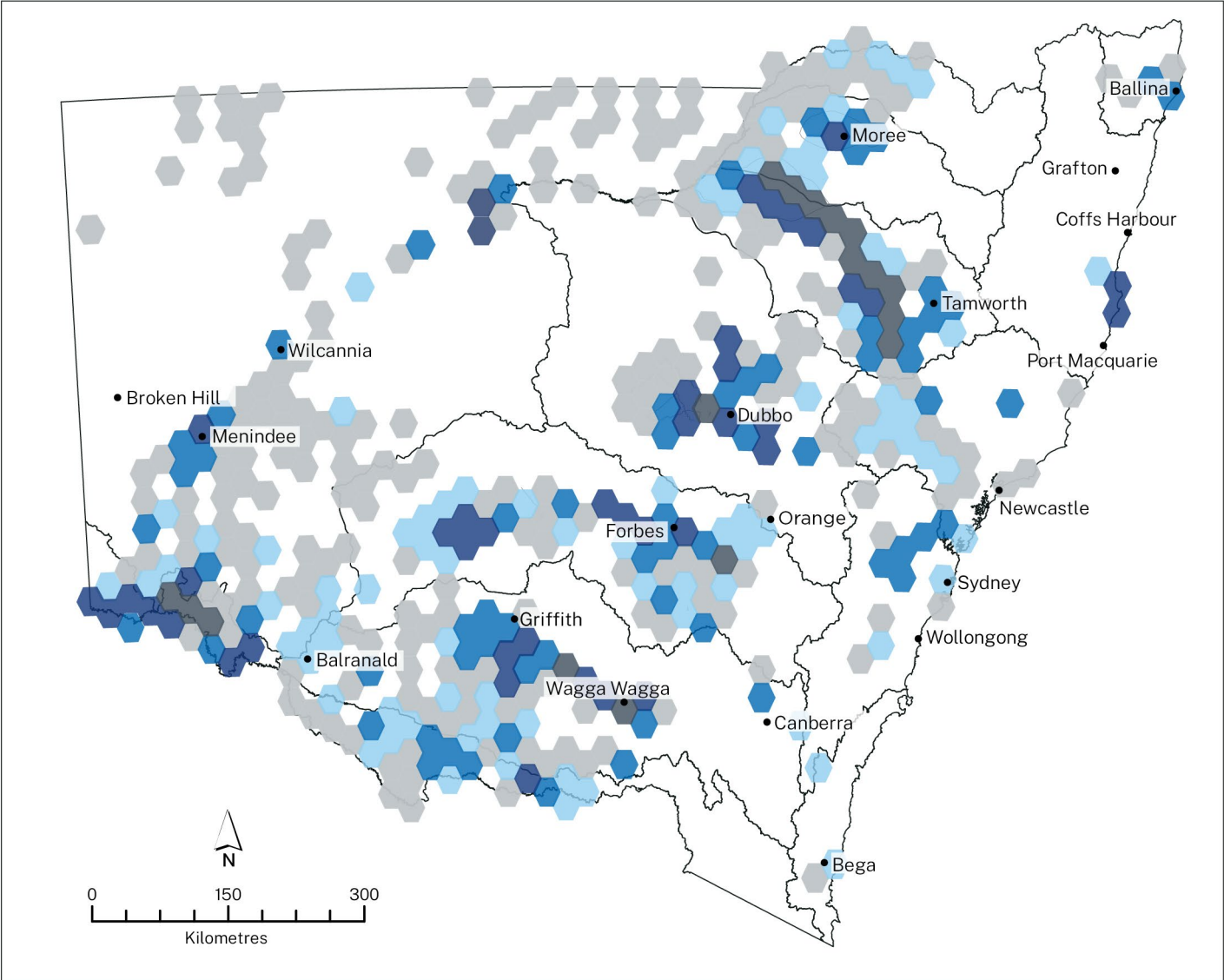
Action 3.4. Expand and target our groundwater data collection

If you can't measure it, you can't manage it

Our state-wide network for groundwater monitoring requires regular re-evaluation and maintenance to ensure we are measuring the right things in the right places and making decisions about groundwater resources based on accurate information.

The existing monitoring network of bores needs to be expanded to cover additional parts of the state, including in coastal areas where increasing population and demand is adding pressure on groundwater resources. Currently, of the nearly 4,700 government monitoring bores, more than half (54%) are located within the large inland alluvial groundwater systems (Figure 21). Groundwater exploration of the highly productive inland alluvial groundwater systems occurred during the 1960s and 1970s to support agricultural expansion and, until relatively recently, there has been less demand for our small coastal groundwater resources.

Figure 21. Bore density in NSW's groundwater monitoring network



Legend:

□ Regional water strategy boundary

Monitoring bores/500 km²

1-4 5-9 10-19 20-49 50-200

Source: Based on data from the Department of Planning and Environment.

Our existing network of monitoring bores is ageing. More than 50% of bores are 30 years or older. Asset maintenance and refurbishment or proper abandonment is necessary if we are to maintain the continuity of data that supports decision making. It's also crucial to ensure deteriorating monitoring bores do not cause groundwater quality issues and aquifer cross contamination.

While the Non-Urban Water Metering Policy and the Water Monitoring Strategy for Coal Basins (see Box 11) are expanding our groundwater monitoring capabilities, we must continue to extend the reach of the network, equip more bores with remote data transmission (telemetry) systems¹⁰⁴ and improve the monitoring capabilities of local water utilities.

Maintaining and upgrading groundwater monitoring networks to better capture the information needed to support effective decision making is expensive and time consuming. Network design objectives need to target critical areas and management risks and, where available, groundwater models should be used to optimise the locations of monitoring infrastructure.

Monitoring initiatives will benefit from commitments in the *NSW Water Strategy* to forge closer collaborations with researchers and industry to find technological solutions that better measure, monitor and report information and data for the water sector.

Greater groundwater data access and sharing will support more informed, collaborative and complex decision making

Once groundwater data is collected, integrating and sharing it between government agencies and with the public can be challenging because different agencies use separate systems and databases to record and store data and have different confidentiality agreements with their users.

Industry-collected data also needs to be integrated with existing databases. While State Significant Developments and major infrastructure projects are now required to submit groundwater data, further processing and consolidation is needed before this data can be released to the public or used for making decisions and managing resources. A common framework to account for all groundwater use accompanied by new methods to determine passive water take by industry will give us a better understanding of the resource and allow us to plan for sustainable growth.

Actions taken through the *NSW Groundwater Strategy* will develop consistent approaches and better integrate the information available across these platforms. Consolidating cross-government groundwater data sources and sharing all available data online through dashboards or other user-friendly tools will result in better information to support complex decision making. Data that can be consolidating includes groundwater accounting data, geological cross-sections and geochemistry plots, boundary maps for groundwater trading zones and more.

Complementary Data

Groundwater data is not limited to groundwater levels and characteristics. Different types of data can be used to inform our knowledge, including remote sensing and geophysics. The groundwater strategy aims to bring focus to these other data sources – with special attention to spatial datasets and how we can integrate them with our current datasets and decision-making processes.

Box 11. New monitoring bores in NSW's coal basins

In 2021, the NSW Government completed a \$22.8 million expansion of the state's groundwater monitoring network. The project aimed to improve understanding of groundwater behaviour and provide baseline water level, pressure and quality data to better measure the effects industry abstraction has on groundwater resources in coal basins.

This investment is part of the Water Monitoring Strategy for Coal Basins in NSW, established in 2015 in response to the NSW Chief Scientist and Engineer's Independent Review of Coal and Coal Seam Gas Activities in NSW.

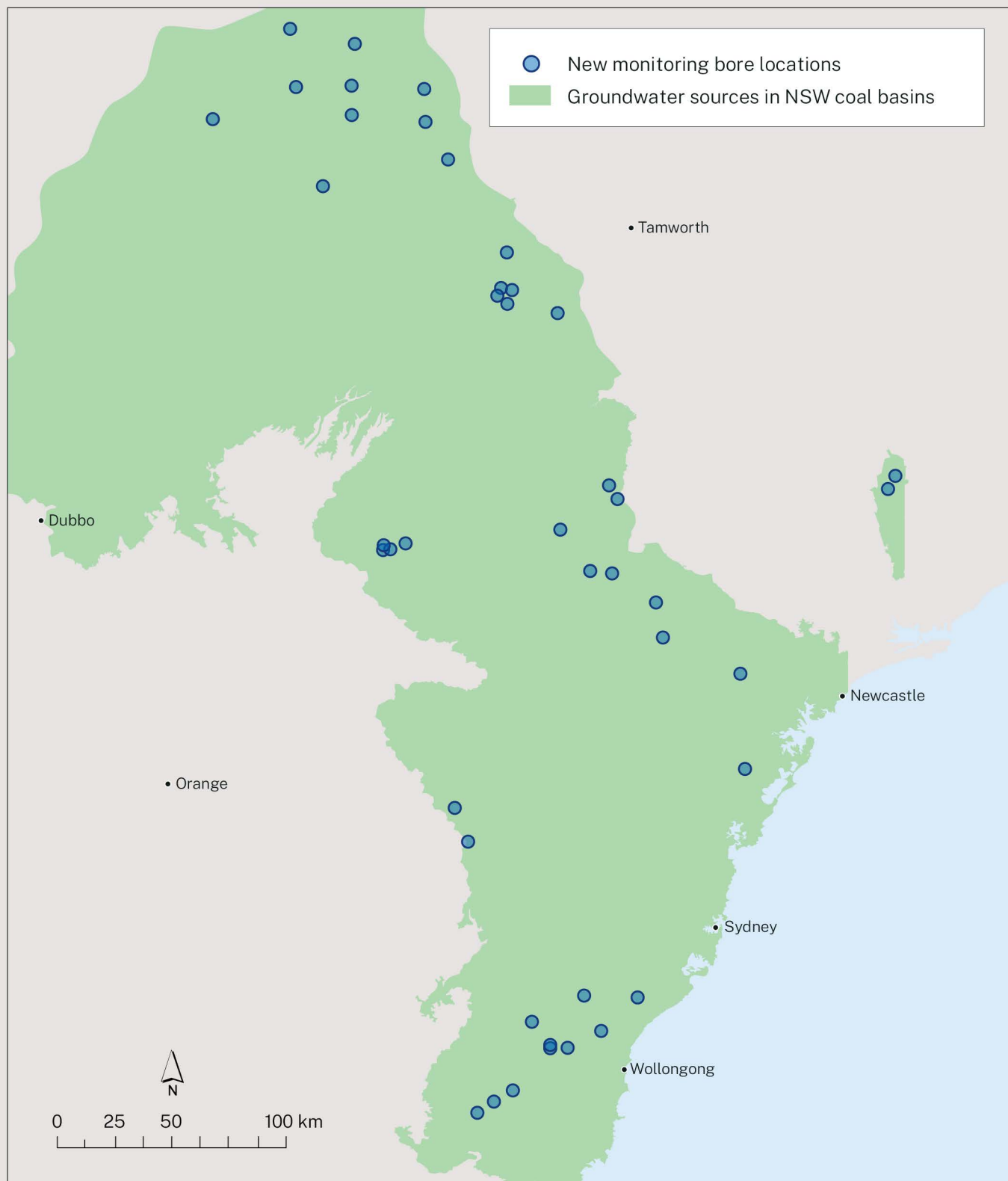
The project targeted 7 coal basins and delivered 67 new bores across 39 sites and 13.6 km of drilling. The bores will monitor groundwater level and pressure. Groundwater samples will be collected for water quality testing. The bores have internet-connected monitoring equipment that delivers water level data in 'real time' through the WaterInsights portal.¹⁰⁵

104. NSW Chief Scientist and Engineer 2020, *Review of water-related data collections*, data infrastructure and capabilities, www.chiefscientist.nsw.gov.au/_data/assets/pdf_file/0003/337503/Water-Data-Review.pdf

105. See WaterInsights portal from WaterNSW, www.waternsw.com.au/waterinsights/real-time-data

Box 11. New monitoring bores in NSW's coal basins (continued)

Figure 22. New monitoring bores will help understand groundwater behaviour in coal basin



Source: Department of Planning and Environment data.

Key actions

Action 3.4. Expand and target our groundwater data collection

This action will be consistent with the groundwater knowledge plan in Action 3.1.

3.4.1. Improve our groundwater monitoring infrastructure

We will:

- optimise our existing monitoring network and align it with current and future management needs
- invest in asset maintenance to refurbish existing monitoring infrastructure
- explore and use new technology to enable more efficient collection of groundwater levels and quality parameters.

3.4.2. Improve our groundwater monitoring programs

We will:

- review monitoring programs to ensure continuity of data series
- continuously assess the structural integrity and long-term risk of sediment compaction in priority aquifers
- implement a groundwater quality monitoring program across the state with an emphasis on identifying areas of focus for long-term monitoring
- increase water quality monitoring requirements for impacting industries
- ensure we have a suite of mechanisms in place to measure, monitor or account for all groundwater take in NSW (including legacy take, road and rail projects and major infrastructure dewatering)
- aim to integrate complementary data sources with historical data collection methods
- publish bore location, bore logs, levels/pressures and quality data.



Image courtesy of Department of Planning and Environment. Telemetered monitoring bore.

Implementing the strategy

5

Image courtesy of Department of Primary Industries.
Recycled irrigation runoff water, Breeza.

Getting our timing right

A risk-based implementation approach – in collaboration with a range of partners – combined with transparent monitoring, evaluation and reporting will make the NSW Groundwater Strategy effective over the long term and deliver measurable ‘on-the-ground’ results.

A critical feature of developing the NSW Groundwater Strategy has been deciding which actions and investments are needed now and which ones will be needed further into the future. The strategy has a 20-year timeframe. The timing of various actions is aimed at meeting existing challenges, identifying and preparing for foreseeable challenges and laying the groundwork for adapting to future uncertainties and changed circumstances.

The approach to implementation of actions is guided by an understanding potential risks and threats, identification of vulnerable areas and taking the necessary steps to avoid or reduce risks. Such an approach will enable us to prioritise and direct resources efficiently. Implementation funding will follow this staged approach.

Not all actions will commence immediately and funding will be a key consideration in planning when and how the actions will be implemented. The NSW Groundwater Strategy will be a key tool in seeking funding as future opportunities arise.



Image courtesy of Peter Simpson, Department of Primary Industries. Water bore for irrigation.

Working with partners

The strategy and its actions will require significant investments of resources – financial and human – over the next 20 years. Many actions will need to be implemented in collaboration with a range of partners including councils, other government agencies, the community and other non-government stakeholders. Further consultation will be required to refine the details of many of the actions.

Government agencies have legislated roles and responsibilities relating to groundwater, but there are many other groups and individuals that have a role to play in delivering the NSW Groundwater Strategy.

To effectively implement the actions of the strategy, the NSW Government will work with a diverse group of partners including councils, the community and other non-government stakeholders. Further consultation will be required to refine the details of many of the actions.

This partnership focus is about engaging meaningfully, building trust and transparency, reaching agreement on objectives, and listening and learning together. This approach will form the basis of the enduring governance arrangements that will support implementation of the strategy.



Image courtesy of Department of Primary Industries. Cadia Ore Stockpile, Bathurst.

Ongoing monitoring, adaptation and reporting

The NSW Groundwater Strategy is designed to respond to changing circumstances. We will undertake a formal review of the strategy at least every five years or in response to significant changing circumstances. The formal review will determine whether the key underlying assumptions remain relevant and adjust if necessary.

Amendments may also be made in response to key changes in water demand, social preferences, science and technology, economic conditions or other events – including how climate change assumptions and responses evolve. These amendments may result in a shift in priorities and the implementation plan will be updated to reflect this.

We will report every year against actions in the implementation plan so that the community can track our progress and we can demonstrate which actions have commenced, been delivered or progressed in the previous year (Figure 24).

Figure 24. Implementing the NSW Groundwater Strategy

