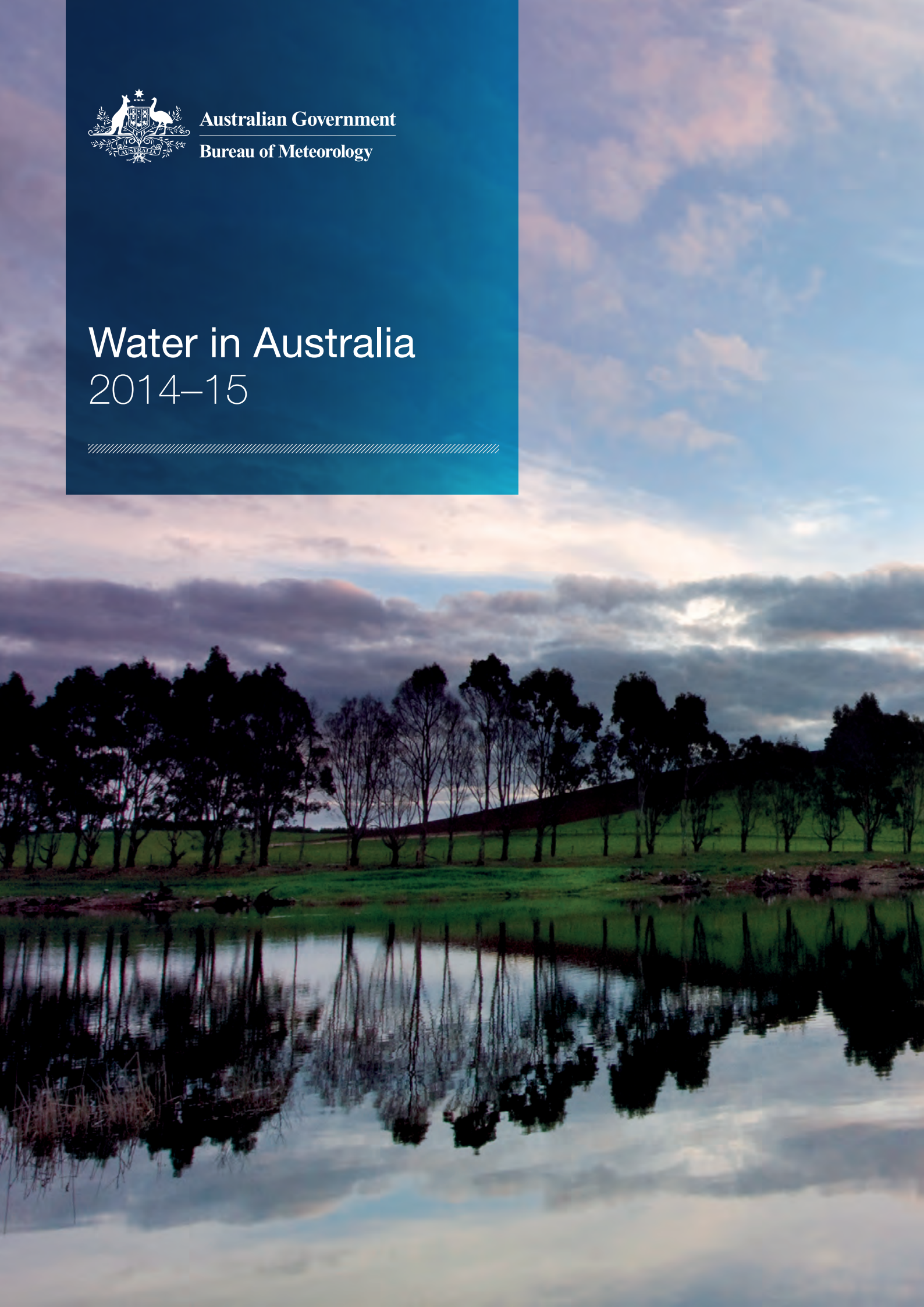




Australian Government
Bureau of Meteorology

Water in Australia 2014–15



Water in Australia

2014–15

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FOREWORD



Our communities, environment, industry and economy depend on reliable supplies of suitable quality water. Climatic variability and change across Australia mean that meeting these needs is an ongoing challenge that requires good-quality information.

Hundreds of organisations across Australia collect data to facilitate water management, and send a copy to the Bureau of Meteorology to integrate it and make it available across the nation. This has resulted in a range of water information products being made available from the Bureau's website (www.bom.gov.au/water).

Water resources assessments use this information to help us to understand and learn from the past. We can see how water sources respond to climate drivers (e.g. El Niño), and how our water consumption patterns change in response to changes in water availability and management strategies. So next time we face similar conditions, we have a better idea of how they might affect our water resources and the environment—and the industries and communities that rely on them—and can plan accordingly.

This national report pulls together information from many of the Bureau's products to provide an overview of Australian water availability and use in the context of longer-term trends and climate influences. This puts us in a better place than ever to understand the past, evaluate how we are tracking and apply this knowledge to plan for the future.

We do not do this alone. In addition to the hundreds of organisations collecting and passing on data, this report has been reviewed by specialists in climatology, hydrology and geohydrology. I would like to thank everyone involved for their valuable contributions.

The report provides overview information on the state of water in Australia, together with a library of figures to download and use in your own reports and presentations. We propose to continue refining the report format, with a goal of releasing at least some of the report sooner for the next publication.

Graham Hawke
Deputy Director, Environment and Research
Bureau of Meteorology

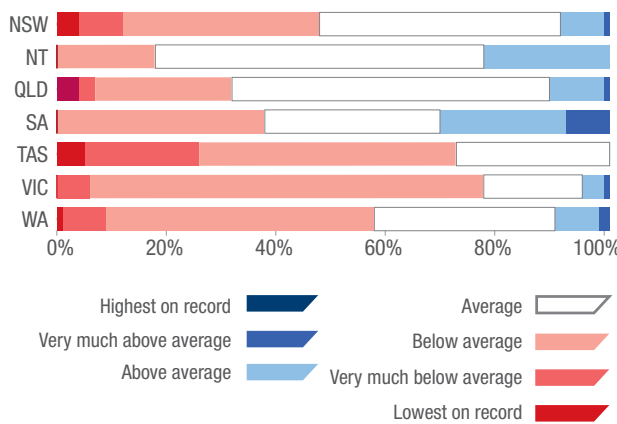


SUMMARY

DRY CONDITIONS WITH DECLINING RESERVES

With near-El Niño conditions in place in the Pacific Ocean in the spring of 2014, daily maximum temperatures reached new record highs in many parts of the country. During March 2015, there was a notable heatwave across northern and central Australia, and these high temperatures increased the potential for higher-than-normal evaporation and rapid depletion of soil moisture.

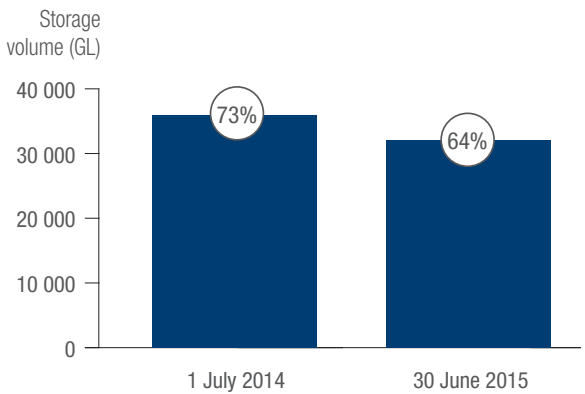
The usual spatial and temporal variability in rainfall and streamflow existed throughout 2014–15. In the east and south, dry conditions prevailed across vast areas, and, overall, the annual average rainfall was 10 per cent below the long-term national average. However, despite the national average, some areas had ample rainfall—large areas in the central north and along the New South Wales coast received 100–400 mm above the annual average rainfall.



State summary for all streamflow stations with valid data

The low rainfall and high temperatures had a substantial impact on streamflow. At the Bureau of Meteorology's Hydrologic Reference Stations that are not affected by urban or agricultural developments, most had average or below-average streamflow.

Overall, the accessible surface water storage volume for agriculture and urban use at the beginning of the assessment period was 73 per cent of the total storage capacity. By the end of the assessment period, the accessible storage volume had declined to 64 per cent.



Australia's agricultural and urban storage status at the beginning and end of the assessment period

Upper aquifers had more bores with declining trends in water levels than in the 2013–14 assessment, although this varied spatially. Along the east coast, fewer bores showed rising trends, especially in alluvial aquifers in the Murray–Darling Basin. Patterns in the Perth Basin and the Northern Territory were largely unchanged.

Similarly, the middle aquifers in eastern Australia had more bores with declining trends in water levels than in the 2013–14 analysis. However, the Perth Basin to the west showed increased levels, indicating a decrease in extractions from the middle aquifer. Trends in the lower aquifer were largely unchanged since the 2013–14 assessment.

Water in Australia 2014–15 describes the characteristics of the country's water resources, availability and use from 1 July 2014 to 30 June 2015 in the context of climatic conditions, and past water availability and use.

CONTINUING TRADE AND DECLINING WATER USE

Australia's water market continued to facilitate high levels of buying and selling water entitlements and allocations. This allowed water to move between various urban, agricultural and environmental uses. Entitlement trade volumes dropped nationally during 2014–15, but remained higher than the wet years from 2010–11 to 2012–13. Allocation trading volumes in the southern Murray–Darling Basin were maintained at similar high levels to 2013–14.

The estimated total bulk extractions for non-environmental use from rivers, dams, high-yielding aquifers, and recycling and desalination plants across Australia were 16 700 GL in 2014–15. This volume is 4 per cent lower than in 2013–14.

The total extraction of water for agricultural use in Australia in 2014–15 was estimated at 12 600 GL—about 6 per cent less than the previous year. Australian water users continued to use surface water as their primary source of water because of its high accessibility and therefore lower extraction cost. However, groundwater extractions did increase in some areas to supplement supplies.

VARYING RESPONSES TO WATER AVAILABILITY

Regulated water supply systems across Australia use the largest volumes of water. In the north and along the Queensland coast, there is relatively high physical water availability throughout the year, and allocations and use vary little between years, with generally full allocations announced against the entitlements.

The northern Murray–Darling Basin catchments all showed increasing physical water availability coming out of the 1996–2010 Millennium Drought, with allocations and use following the same trend, often with a

one-year time lag. In 2014–15, physical availability and, consequently, annual water-use permissions were the lowest for the past five years, resulting in use approaching total water-use permissions.

The southern Murray–Darling Basin catchments have a lower level of variability in their physical water availability volumes, because of the larger storage capacity in the southern regulated systems and less variable rainfall conditions between years. As a result, the variability in the combined volume of allocation and carryover is lower between years, and use levels during the past three years have remained fairly stable.

Use in major urban centres is mostly provided from surface water storages. In 2014–15, storage volumes and inflows were high enough to meet demand. The exceptions were Perth and Adelaide, where storage capacities and volumes remained low. Surface water use in these cities was supplemented by other sources, particularly groundwater, desalinated water and transfers from outside the storage catchments.

REDUCED STORAGE AT THE START OF 2015–16

In the Murray–Darling Basin, storage volumes had dropped substantially in most catchments by July 2015. Opening allocations in 2015–16 were mostly zero for the general- and medium-security entitlements. Even some high-security entitlements were given less than 100 per cent opening allocations for 2015–16. Additionally, carryover volumes were also substantially lower at the start of 2015–16 than in 2014–15.

Outside the Murray–Darling Basin, the change in storage volume between the start of 2014–15 and 2015–16 was much more variable.

1 INTRODUCTION

AT A GLANCE

The Bureau of Meteorology is responsible for producing regular reports on water resources, availability and use in Australia. This report draws on a range of Bureau information sources to analyse and describe the characteristics of the country's water resources and their use over time. This enables us to track changes and identify any emerging issues.

This report and supporting documentation are available from the Bureau's website.

The Bureau of Meteorology is responsible for producing regular reports on water resources, availability and use in Australia to help water managers and policymakers make informed decisions. Under Part 7 of the *Water Act 2007*, the Bureau is required to collect, hold, manage, interpret and disseminate Australia's water information. As part of this role, the Bureau is responsible for conducting regular national water resources assessments.

Water in Australia 2014–15 is the second in a series describing our water resources, availability and use in the context of longer-term trends and climate influences. The reports build on earlier assessments integrating and summarising data and investigations from across the Bureau, to provide a national overview for the reporting year. The information focuses on the period from 1 July 2014 to 30 June 2015, which represents the latest planning year for which national-level water-use data were available at the time of writing.

The report starts with an assessment of water resources across Australia; it examines the seasonal events affecting water resources and how these relate to average conditions. It also examines the salinity of the available water, which constrains its use. The report then moves on to look at a variety of water uses and how these have changed over the past five years. It compares availability with use for major supply systems.

The Bureau's Australian Water Resources Assessment modelling system¹ was used to generate estimates of runoff across the country. Data from the Bureau's Hydrologic Reference Stations² were used to provide information on the hydrologic response to climate, because they represent catchments that are unaffected by diversions or storages, and show minimal effects from water resource development and land-use change.

Water in Australia and related products are available on the Bureau's website. Data used in the report are available for download through two complementary products:

- Regional Water Information³ provides spatial information down to the river-region level on the status of water resources and use during the assessment year.
- Monthly Water Update⁴ provides a regular snapshot of rainfall and streamflow for the previous month relative to average conditions.

Other products apply to specific types of water information, or regions. They include:

- Water Data Online—stream gauge information at approximately 3400 stations, some of which are updated daily
- Water Storage—daily update of storage levels for more than 300 major water storages
- Groundwater Information Suite—bore water levels and trends, and associated data on hydrogeology and groundwater management
- Climate Resilient Water Sources—inventory of desalination and water recycling plants across Australia
- National Water Account—detailed annual accounting of water assets and liabilities for ten key water-use regions
- Urban National Performance Report—annual benchmarking of the performance of 78 major urban water utilities and councils.

The technical terms used in this report may be found in the glossary at the end of this report or in the Australian Water Information Dictionary⁵.

1 www.bom.gov.au/water/landscape/

2 www.bom.gov.au/water/hrs/

3 www.bom.gov.au/water/rwi/

4 www.bom.gov.au/water/monthly-water-update/

5 www.bom.gov.au/water/awid/index.shtml

2 WATER RESOURCE SITUATION IN 2014–15



AT A GLANCE

In 2014–15, Australia generally experienced below-average rainfall (10 per cent less than the national average since 1910–11) with large seasonal and regional variation, including below-average rainfall throughout the east, and above-average rainfall in the central north, northwest and southeast. Mainly in the eastern parts of Australia, these patterns were influenced by near-El Niño conditions in spring 2014, evolving into El Niño by May 2015.

Streamflow and inflows into water storages reflected these conditions, with more than half of Australia's stream gauges showing below-average flows. At the end of 2014–15, the water volume stored for water supply purposes was about 51 000 GL—64 per cent of Australia's total accessible storage capacity, down from 73 per cent at the start of the year.

Groundwater levels in upper and middle aquifers are generally declining, except in the west where extraction has decreased in response to higher use of desalinated sea water. The water level of lower aquifers is stable.

Stream salinity varies from fresh to saline across the country. Streams in northern Australia and along the east coast are typically less salty than in southwestern Australia, southern South Australia and southwestern Victoria. In 2014–15, the majority of streams across Australia had salinity levels that were suitable for drinking water, irrigation and stock watering. Australia's groundwater is naturally saline in many places, and less than 30 per cent of Australia's groundwater is of drinking quality.

Many factors influence the status and condition of water resources, and the way water is used. Rainfall is the main influence on how much water is available across Australia. Soils and their wetness are critical to the distribution of water in the landscape. High rainfall does not always translate into high streamflow, because part of the rainfall can be retained in soils, evaporate back to the atmosphere, be taken up by plants or contribute to groundwater recharge.

This chapter provides an overview of water availability, along with stream and groundwater salinity in Australia. National, regional and seasonal patterns of rainfall, soil moisture and streamflow are explored in section 2.1, and the effect of these patterns on water storage is covered in section 2.2. Section 2.3 looks at water quality—particularly salinity—and section 2.4 covers Australia's groundwater resources.

2.1 CLIMATE, RAINFALL, SOIL MOISTURE AND STREAMFLOW

2.1.1 National overview

Rainfall quantities and anomalies for 2014–15 are shown in Figure 1. Figure 3 shows the major influences on rainfall during this assessment period, and the streamflow response.

Overall, the 2014–15 average rainfall was 412 mm for Australia, which is 10 per cent below the national average of 458 mm from 1910–11 to 2014–15. There was great spatial and temporal variability in rainfall, soil moisture and streamflow across Australia in 2014–15. Large areas in the central north, northwest and southeast had 100–400 mm of rainfall above the average (Figure 1). A substantial proportion of annual rainfall occurred in January 2015, when the northern monsoon and a mid-level trough pulled tropical moisture southward across the central regions. The above-average rainfall near the southeast coast was caused by many east coast lows during the year.

Drier-than-average conditions occurred across large areas of the north, including northern New South Wales, western to central Queensland, Cape York Peninsula and

the Gulf of Carpentaria, reaching into the Top End and Kimberley (Figures 1 and 3). Annual rainfall was 100–400 mm less than the average across large areas. A few pockets in northeastern Queensland had rainfall that was up to 1800 mm below average. Southern Australia and southwest Western Australia also had about 100–200 mm less than the average rainfall.

Streamflow corresponded strongly to rainfall conditions across the country (Figure 3). Almost half of the Bureau of Meteorology's Hydrologic Reference Stations, which are placed where flows are unaffected by developments (Zhang et al. 2014), had below-average flows, and about 2 per cent of these stations recorded their lowest flow since 1975.

The dry conditions, particularly in spring 2014, were influenced by near-El Niño conditions. For the general influence of El Niño, see Box 1. In late 2014, Pacific Ocean temperatures neared El Niño thresholds, but the atmospheric pattern and the ocean remained El Niño Southern Oscillation neutral (i.e. neither El Niño nor La Niña), albeit on the warm side of average, through the summer of 2014–15. After this 'false start' in late 2014, El Niño conditions developed rapidly in the tropical Pacific Ocean by May 2015.

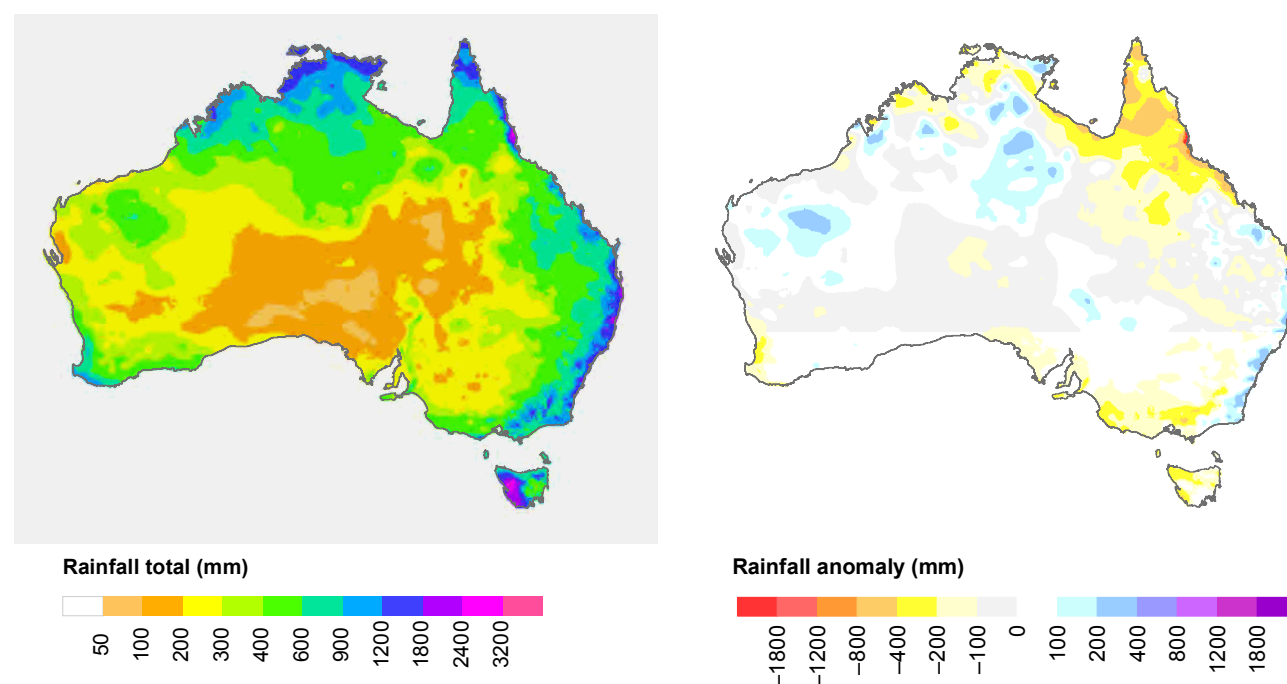


Figure 1. Annual rainfall total and anomaly, 2014–15

BOX 1 WHAT IS EL NIÑO AND ITS INFLUENCES?

El Niño and its opposite phase, La Niña, are part of the El Niño Southern Oscillation—a periodic variation in winds and sea surface temperatures over the tropical Pacific Ocean. El Niño is defined by above-average sea surface temperatures in the eastern and central equatorial Pacific Ocean. The changes in ocean temperatures are associated with changes in atmospheric pressure and tropical wind patterns, which feed back to reinforce the sea surface temperature pattern. This has consequences for global and Australian rainfall and temperatures.

El Niño events tend to begin in autumn, mature during winter and spring, and begin to decay in summer, generally ending in the autumn of the following year. The phenomenon recurs every three to eight years.

For Australia, this shifts in cloudiness and rainfall away from the continent. El Niño impacts are usually most pronounced across inland eastern Australia, with the chance of reduced rainfall being greatest in winter–spring (i.e. June to November; Figure 2). Warmer temperatures across southern Australia are also often observed (Figure 2), typically strengthening drought conditions.

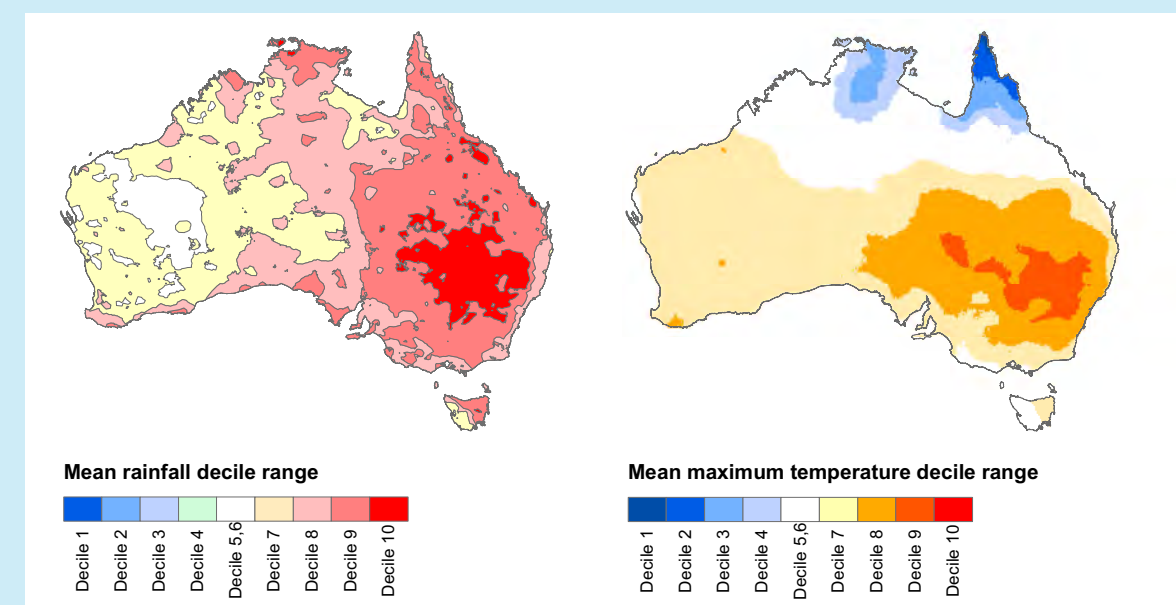


Figure 2. Average winter–spring mean rainfall and mean maximum temperature deciles across Australia for 12 moderate–strong classical El Niño events

Other potential effects include shifts in temperature extremes, increased frost risk due to less cloud cover, reduced tropical cyclones, later onset of the northern Australian monsoon, increased fire danger across southeastern Australia, and decreased alpine snow depth.

El Niño effects can sometimes be erratic and are not always predictable. Although some drying occurs in at least some areas of Australia, not every El Niño brings widespread drought. Of the 26 El Niños since 1900, 17 were associated with widespread drought in Australia.

For more information on ENSO, visit the Bureau of Meteorology's climate web pages (www.bom.gov.au/climate/about/?bookmark=enso).

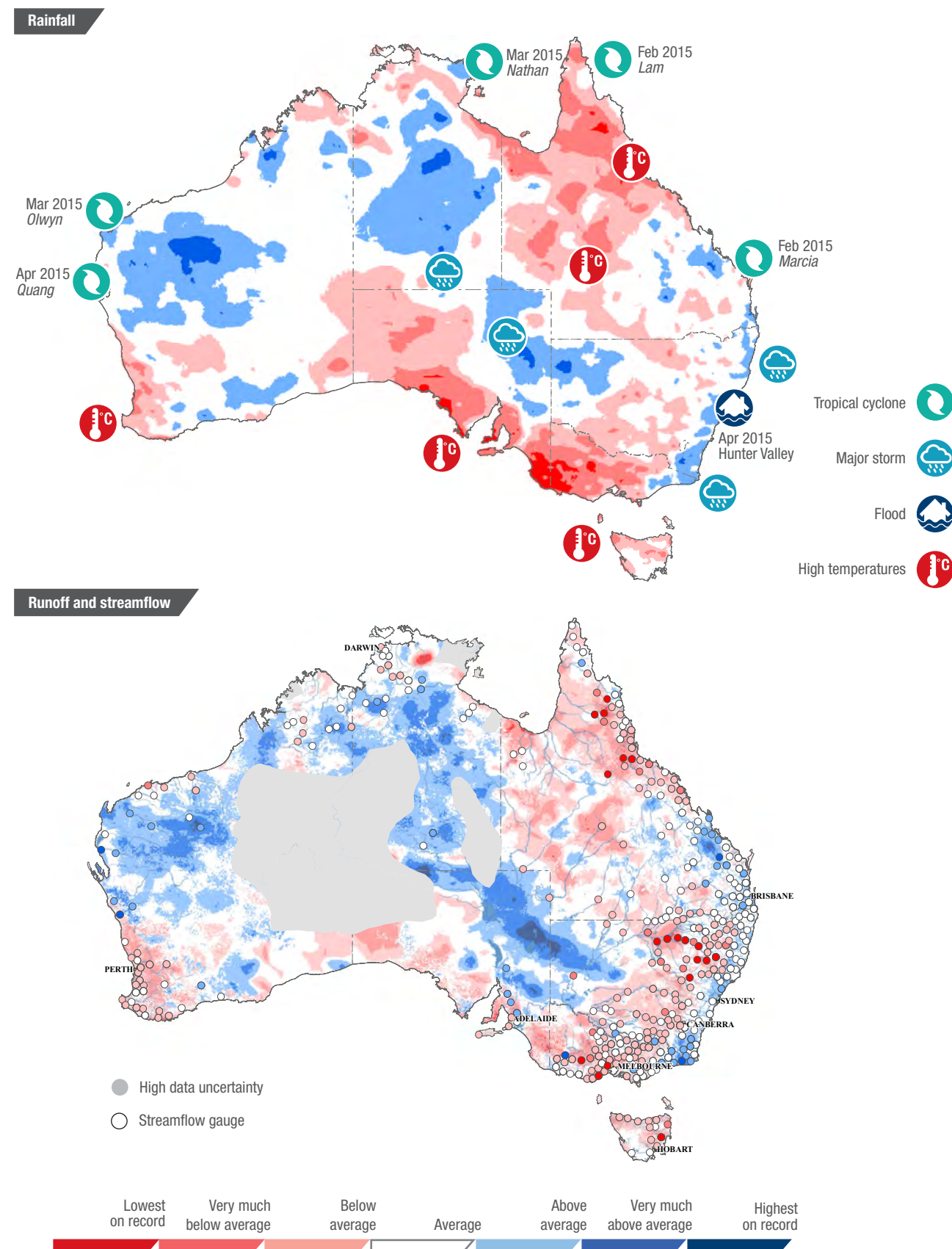


Figure 3. Rainfall, runoff and streamflow deciles, including notes highlighting major influences on the water situation for 2014–15.

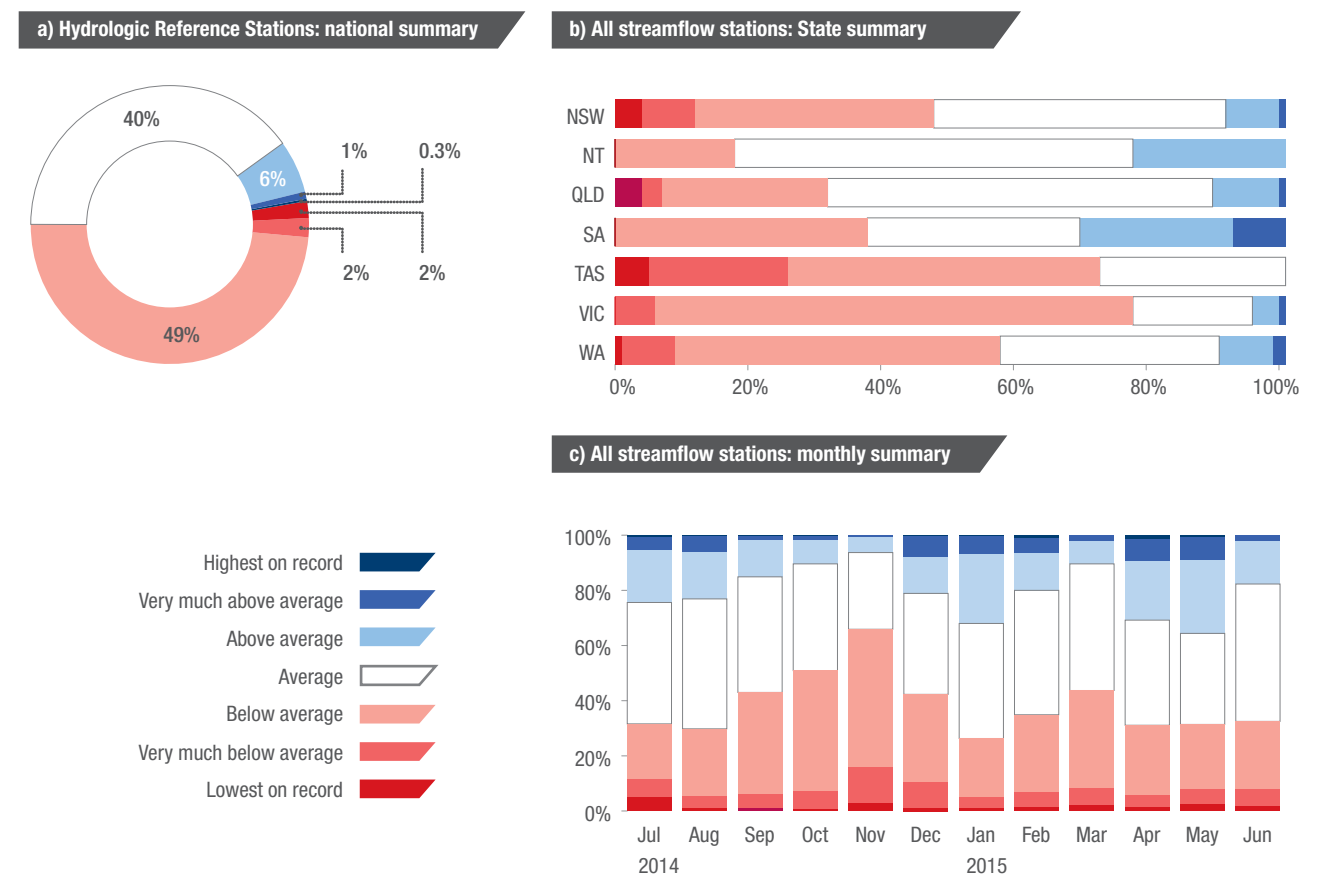


Figure 3 (continued). Streamflow deciles summarised as the percentage of stations falling into the respective categories for a) Hydrologic Reference Stations, b) States for all streamflow stations with valid data and c) monthly summaries

With near-El Niño conditions in place in the Pacific Ocean in spring 2014, southern and eastern Australia experienced El Niño-like impacts. Daily maximum temperatures reached new record-setting highs. Australia as a whole, New South Wales, Victoria and South Australia all measured their hottest spring on record. These high temperatures generally increased the potential for elevated evaporation, rapid depletion of soil moisture and a reduction in plant transpiration.

Spring rainfall was below average to very much below average for most States and Territories, a pattern that was also very El Niño-like for spring, although Western Australia experienced generally above-average rainfall. Low spring rainfall across eastern Australia contributed

to low streamflow in these areas. By November, below-average streamflow was measured at more locations than at any other time of the year (Figure 3c).

A notable heatwave across northern and central Australia occurred during March 2015, again resulting in a high number of locations with below-average streamflow (Figure 3c). This was exceptional, because mean maximum temperatures in this region are typically below average during El Niño (Figure 2).

Particular regional and seasonal differences in climatic drivers and their implications on water resource conditions, summarised in Figure 3, are explained in more detail in section 2.1.2.

2.1.2 Regional and seasonal overview

Tropical north

Consistent with El Niño patterns, the tropical north experienced a dry build-up to the 2014–15 wet season, a late onset of the monsoon and a serious rainfall deficit in Cape York because of sparse monsoon activity.

The tropical north depends on rainfall during the wet season, which is usually from October to April, although it can be shorter in more southern locations.

Consistent with observations during El Niño events (Box 1), there was a drier than normal build-up period for the tropical north in October and November 2014, with below-average rainfall, particularly in northeastern Queensland.

The situation changed by the end of December 2014, when mid-latitude storms moved northward, bringing above-average rainfall across the inland deserts and tropical savannahs, although stopping short of the Top End or northern coastal regions.

January 2015 was particularly wet because of a burst in monsoon activity, which lasted for the first two weeks of the month (see January 2015 in Figure 4). At many central Australian locations, the influx of tropical moisture southward brought 200–300 per cent of the January monthly mean rainfall. This heavy rainfall, which in some areas fell in a single day, quickly saturated soils. It allowed many dry, intermittent rivers to run and also allowed Lake Eyre to have the biggest inflow since 2011.

The 2014–15 wet season then saw monsoon activity remain offshore from February to April, leaving very hot and dry conditions across the tropical north for this period. Wet-season totals were more than 200 mm below average in northern Queensland.

Tropical cyclones typically contribute to the Top End’s wet-season rainfall. Australia’s tropical cyclone season runs from November to the end of April. On average, 11 tropical cyclones form within the Australian region, with four of them crossing the coast each season. This season, nine cyclones developed (Bureau of Meteorology 2016a); four cyclones crossed the coast, and another crossed the coast as a tropical low. All brought heavy rainfall between February and April 2015 (Figure 5).

Severe tropical cyclone *Lam* in February 2015 was the first tropical cyclone in the northern region in the 2014–15 season, and the first severe tropical cyclone (sustaining winds of greater than 165 km/h) to cross the Northern Territory coast for almost five years. *Lam* caused severe damage to the Arnhem Land communities of Galiwin’ku, Ramingining and Milingimbi, but no serious injuries were reported. Hours after *Lam* made landfall on 19 February, tropical cyclone *Marcia* also made landfall at its peak strength just south of Rockhampton. It was the first time on record that two severe tropical cyclones hit Australia on the same day. The heavy rainfall associated with tropical cyclone *Marcia* caused major flooding in the Fitzroy, Burnett and Mary river catchments in Queensland, and caused an estimated \$750 million in damage.

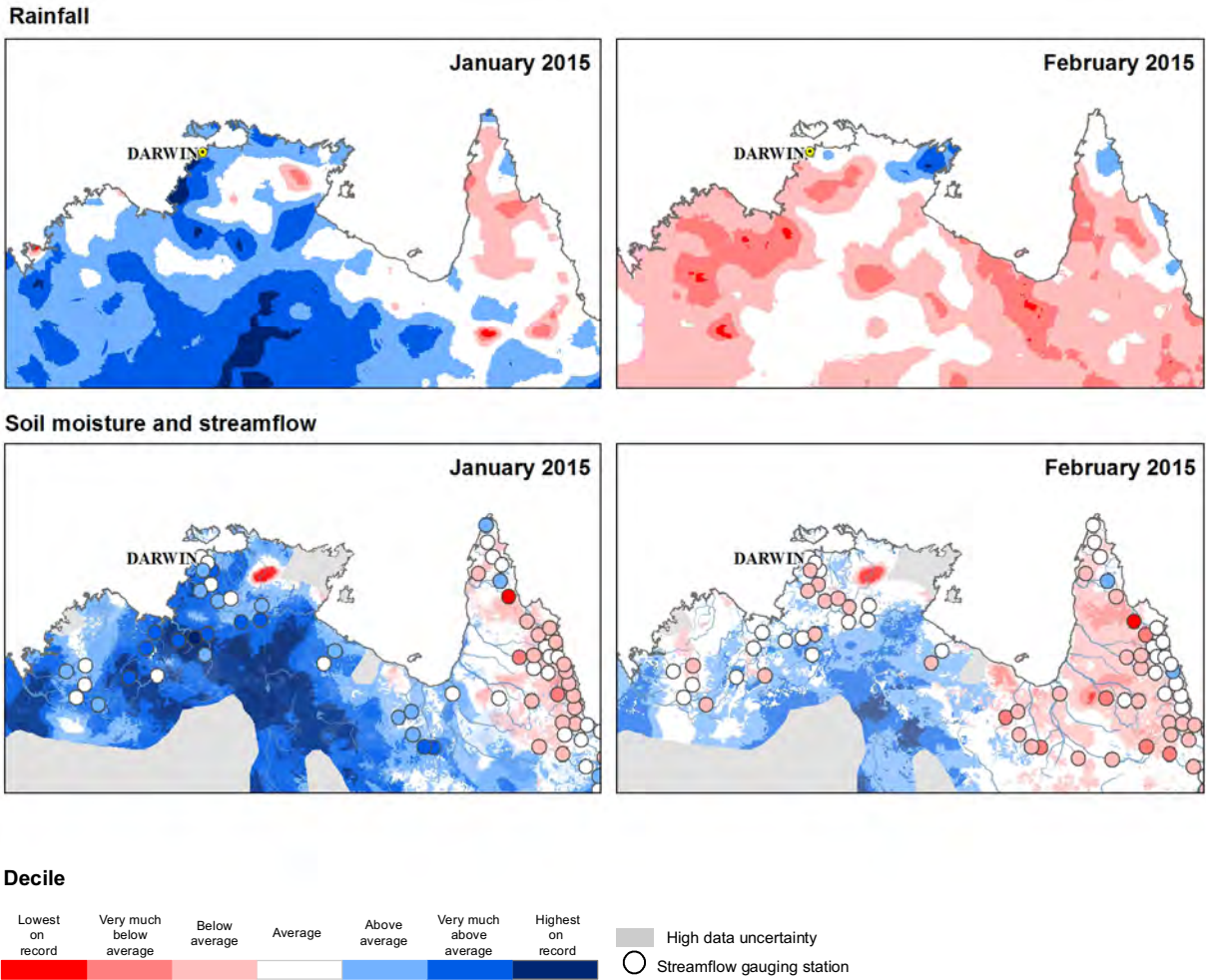


Figure 4. Rainfall, soil moisture aggregated for 1 m depth, and streamflow deciles in the tropical north, January and February 2015

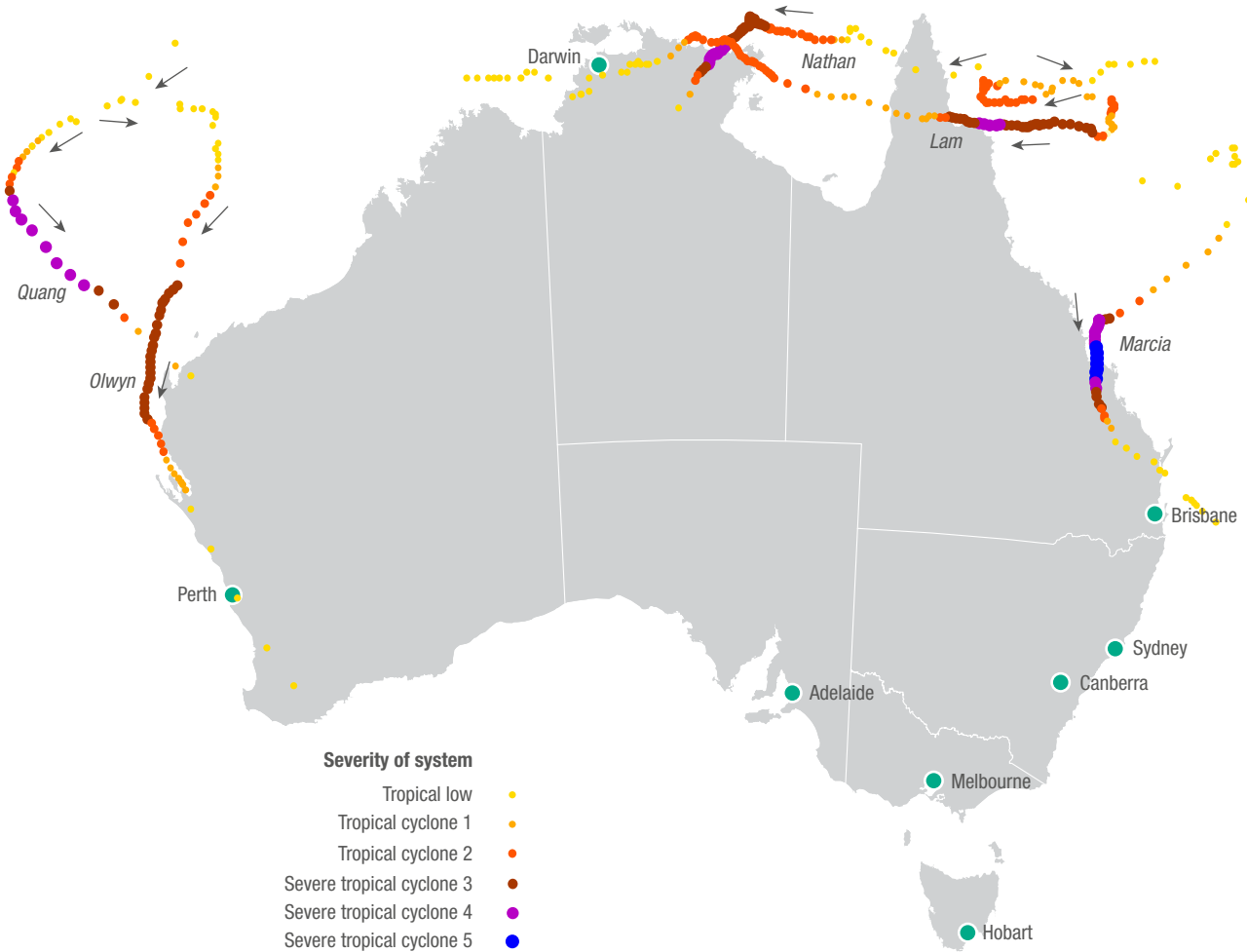


Figure 5. Cyclone tracks across Australia, 2014–15

In March 2015, tropical cyclone *Olwyn* caused flooding in the Gascoyne and Central West regions of Western Australia. A second tropical cyclone in March, tropical cyclone *Nathan*, and its remnant tropical depression brought heavy rainfall and flooding to Arnhem Land and other parts of the Northern Territory.

Severe tropical cyclone *Quang* formed in late April off the northwest coast and made landfall as a tropical storm along the Western Australia coastline on 1 May 2015. *Quang* contributed to widespread rainfall in the Pilbara and adjacent areas of Western Australia during late April as an off-shore system and early May after the system made landfall and dissipated.

Most locations in the tropical north that were not affected by monsoon activity and tropical lows received average to below-average rainfall for February–April 2015. Soil moisture rapidly declined through this period, exacerbated by an exceptionally hot spell in March 2015, which extended from the Northern Territory and Queensland to the outback of South Australia and northern New South Wales.

With the exception of tropical cyclone *Lam* in February 2015, the Gulf of Carpentaria and Cape York did not receive any rainfall from passing tropical lows and missed out on the early monsoon burst, so northern Queensland ended the tropical wet season with a rainfall total very much below average. In fact, northern Queensland was one of two areas during the assessment year where some rivers had their lowest flows on record (e.g. the Burdekin, Mitchell–Coleman, Normanby and Flinders–Norman rivers). Among the affected centres was Townsville, which had one of its driest years on record.

The northern dry season typically begins in May. The Top End, Cape York and the Gulf of Carpentaria region experienced unseasonable rainfall in late May and early June 2015, with total monthly rainfall exceeding 50 mm across Arnhem Land and 100 mm along Cape York's east coast. These rainfalls contributed to soil moisture replenishment and some above-average streamflow conditions, although streamflow is typically low during this period.

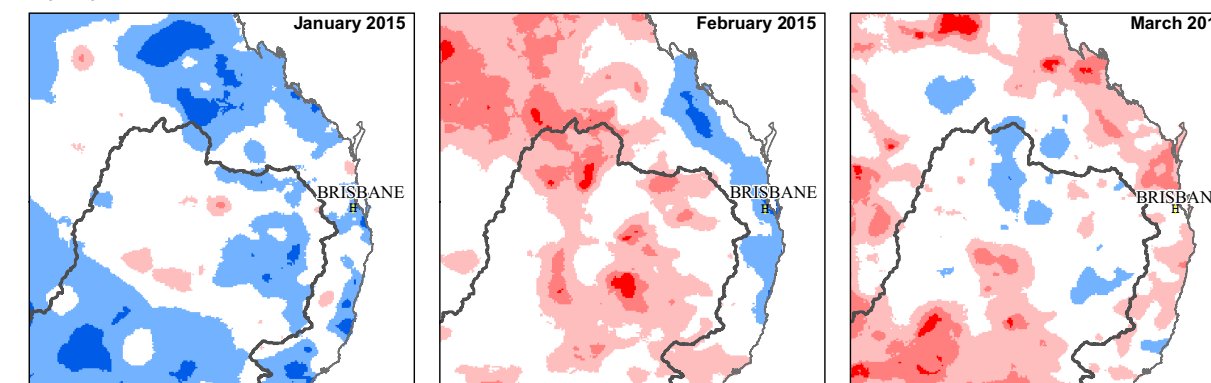
Queensland and northern New South Wales

Influenced by El Niño, dry conditions continued in western and central Queensland through winter and spring 2014. Rainfall brought some relief in the northern Murray–Darling headwater drought areas during the wet season of 2014–15, except for the Namoi catchment.

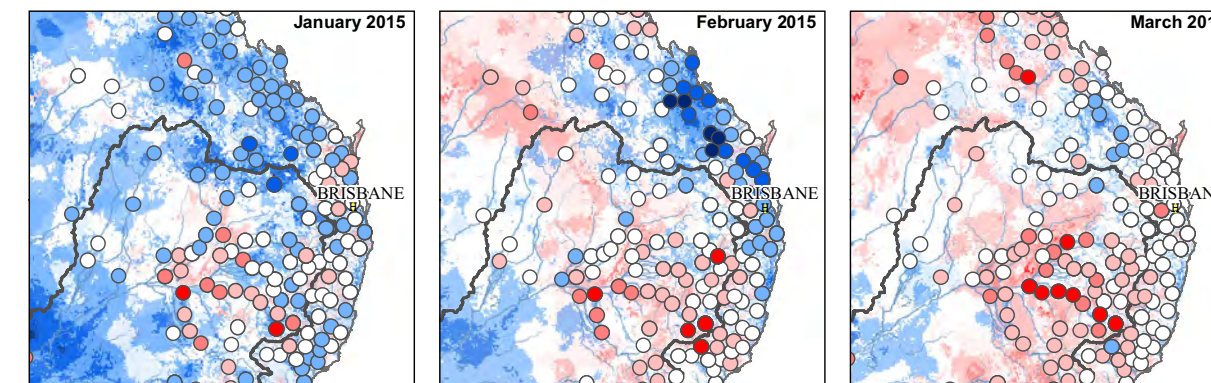
In 2014–15, large parts of western and central Queensland, and northern New South Wales continued to be affected by long-term rainfall deficiencies and temperatures that were 1.0–2.5 °C above the mean. Rainfall mainly falls during summer in this area, changing to a more uniform pattern across the year in areas south of the Namoi catchment. In 2014–15, rainfall was generally 200–400 mm lower than the annual average, with some areas having even less. The assessment year started with particularly low winter rainfall, and many coastal river systems between Brisbane and Sydney had their lowest July flow since 1975 (see July in Figure 3c). Streamflow conditions did not recover in spring, despite close-to-average rainfall. High evapotranspiration rates because of high temperatures rapidly depleted soil moisture stores. The substantial depletion of soil moisture and a lack of summer rainfall affected the summer growing season, reducing crop viability and causing crop failures. This was the third year of particularly poor summer rainfall affecting dryland cropping areas.

In the northern headwater areas of the Murray–Darling Basin—the Border Rivers, Gwydir River and Namoi River (which were some of the hardest-hit drought areas in the previous assessment year)—above-average rainfall in December 2014 and January 2015 brought some short-term relief from the drought (see January 2015 in Figure 6). Soil moisture stores were replenished, but the rainfall did not contribute much to streamflow, and many rivers in these catchments remained at below-average flows. In February and March 2015, the low streamflow conditions continued (see February 2015 and March 2015 in Figure 6), affecting urban and irrigation water supplies, and environmental releases in this area. The March 2015 heatwave reached this area and exacerbated the impact of dry conditions through increased evapotranspiration, limiting soil moisture and further reducing crop growth.

Rainfall



Soil moisture and streamflow



Decile

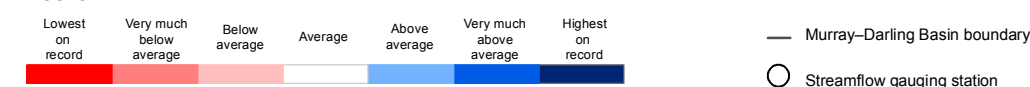


Figure 6. Rainfall, soil moisture aggregated for 1 m depth, and streamflow deciles in the northern Murray–Darling headwater and surrounding areas for the high-flow months of January–March 2015

The autumn months of April and May 2015, which is a critical time for sowing and establishing winter crops, had some patchy but average to above-average rainfall in this area. This meant that soil moisture and streamflow conditions improved towards early winter in June 2015. However, rainfall and streamflow are typically much lower during this period than in the summer months.

An exception was the Namoi catchment in the south of this area, which received little autumn rainfall. Because of this, the catchment remained particularly dry, with many streamflow stations recording the lowest flows since 1975.

Central east coast

Many active east coast lows brought above-average rainfall along the temperate east coast and alleviated the drying influence of above-average temperatures (see Box 2).

In contrast to the dryness further north and south, New South Wales had near-average rainfall in 2014–15, with areas along the southeast coast and reaching into northeastern Victoria having rainfall that was very much above average. Similar to much of Australia, temperatures were above average, particularly during spring. Extended dry conditions did not, however, develop during the period.

Rainfall occurred throughout the year, and the coast had several major downpours associated with east coast lows. The winter of 2014 ended with relatively wet conditions because of two east coast lows. Heavy rain (250–300 mm in two days) in mid-August 2014 caused many streamflow stations to have high flows for this time of year (see August 2014 in Figure 7).

Rainfall during late winter helped to sustain reasonable soil moisture conditions throughout early to mid-spring. Rainfall and soil moisture deficiencies started to occur in November 2014, which were assisted by record-breaking maximum temperatures—these were up to 3.2 °C above average and supported high evapotranspiration (see November 2014 in Figure 7). The soil moisture

was rapidly replenished when record-breaking rainfalls occurred in the south in December 2014.

Rainfall was also above average in January 2015. Streamflows responded with average to above-average conditions during this period. Autumn 2015 continued with a series of several east coast lows producing heavy rains. During this period, rainfall was often of high intensity but short-lived, causing flash flooding and resulting in several fatalities. Of these events, the most destructive occurred in the Hunter, Central Coast and Sydney regions in April 2015 (Figure 7), with widespread flooding and four fatalities. The late autumn and early winter period became drier, with below-average rainfall, except for the northern rivers in May 2015.

BOX 2 WHAT IS AN EAST COAST LOW?

East coast lows are intense low-pressure systems that occur, on average, ten times each year near the eastern coast of Australia. East coast lows can generate heavy widespread rainfall, leading to flash and/or major river flooding, gale or storm-force winds along the coast and adjacent waters, and very rough seas, causing coastal erosion.

Beginning in 1973, a detailed database of these lows has been maintained by the Bureau of Meteorology. Recent research indicates that future east coast lows are expected to become fewer, but more intense, during the cool months of May–October when the majority of the lows typically occur (Pepler, et al. 2015). There is no clear trend for future frequencies of east coast lows during the warm season; however, some models predict more frequent occurrence, mostly for areas close to the coast that have high population densities (Pepler, et al. 2015).

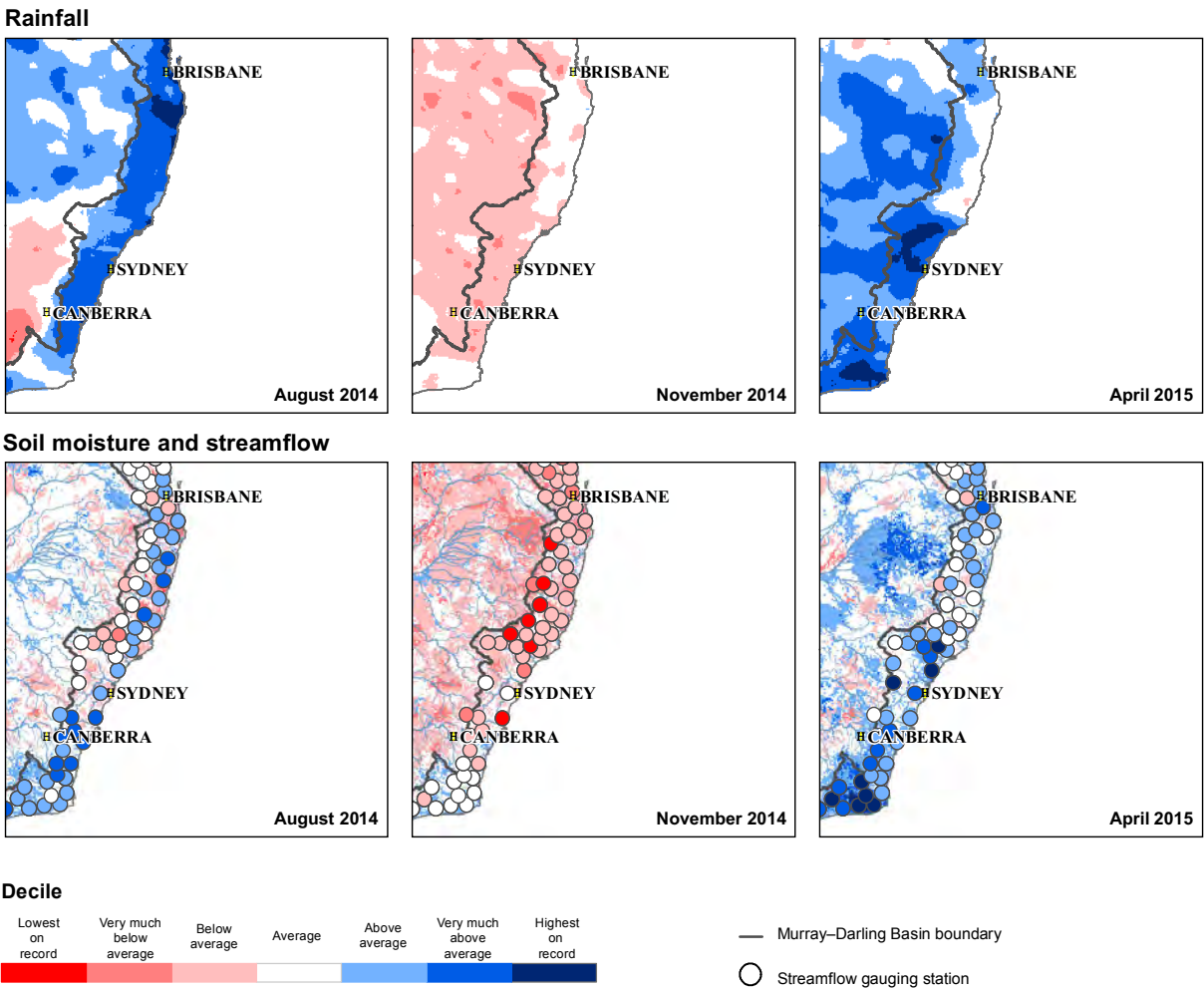


Figure 7. Rainfall, soil moisture aggregated for 1 m depth, and streamflow deciles along the east coast, August and November 2014, and April 2015

Southeastern Australia

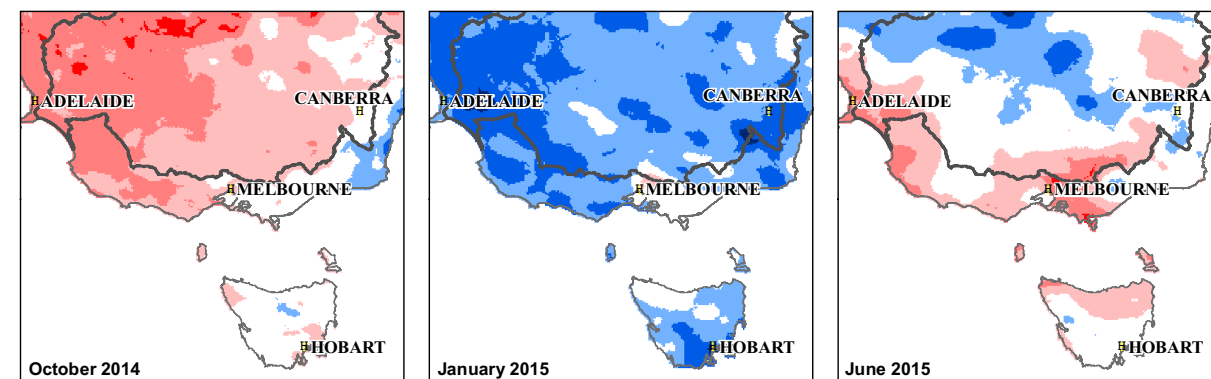
Southeastern Australia had an exceptionally dry spring, and mostly below-average rainfall was coupled with above-average temperatures for most of the year. This was influenced by El Niño conditions, in addition to the continuation of long-term declines in winter rainfall in parts of southeastern Australia.

In southeastern Australia, rainfall is typically winter dominant. In 2014–15, there was low winter rainfall across central and western Victoria. Regions affected included the wet alpine and southern headwater areas of the Murray–Darling Basin, the southern catchments and some lower-lying areas, such as the Murray irrigation areas. The southeast of South Australia, including the Adelaide region, Kangaroo Island to the Eyre Peninsula and the southwestern plateau, also had low rainfall. Similarly, parts of Tasmania were particularly dry, including the west, the north and the northern midlands, which encompass irrigation areas in the Tamar Valley (Figure 8). In these regions, rainfall was 20–40 per cent less than the long-term average. Southern South Australia and Victoria along the coastal fringe had their tenth-lowest average annual rainfall on record.

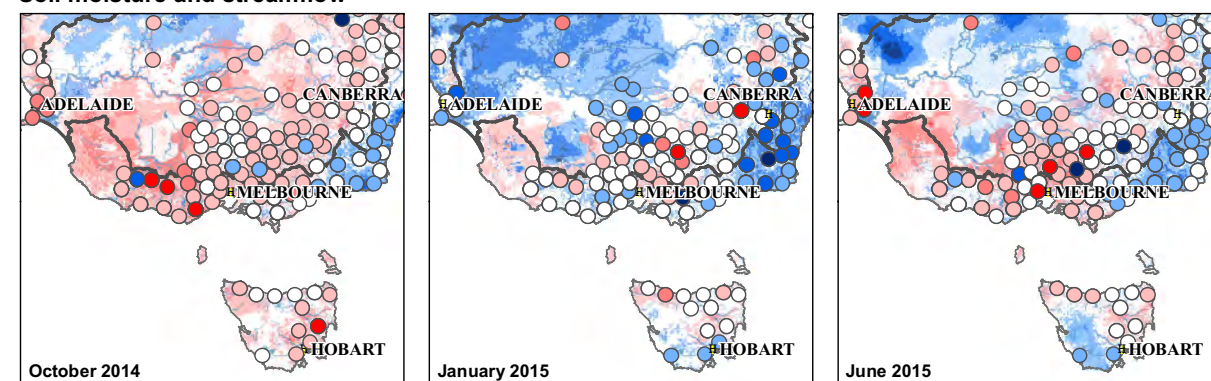
The transition from winter to spring in 2014 saw a change from relatively wet conditions in July to below-average rainfall for much of spring and summer in southeastern Australia (see October 2014 in Figure 8). Record-breaking high temperatures, on average 2.5 °C above the mean, contributed to the rapid depletion of soil moisture stores, which affected pasture and crop growth until the end of the growing season. Soil moisture stores improved for a short period when showers moved across the region in January 2015, but streamflow remained below average for that time of the year (see January 2015 in Figure 8). Streamflow in Victoria diminished back to the levels of the 1996–2010 Millennium Drought. Water supplies to several important agricultural areas and urban centres were affected (see Figure 10), with below-average flows at more than 70 per cent of all streamflow stations in Victoria and Tasmania (Figure 3). Hydropower generation in Tasmania’s west declined by 30 per cent, partly because of the reduced flows (Office of the Tasmanian Economic Regulator 2016).

Autumn 2015 rainfall was mixed across southeastern Australia. Higher rainfall resulted in higher soil moisture and streamflow in South Australia, whereas southwest Victoria experienced below-average streamflow. Streamflow in Tasmania was near average.

Rainfall



Soil moisture and streamflow



Decile

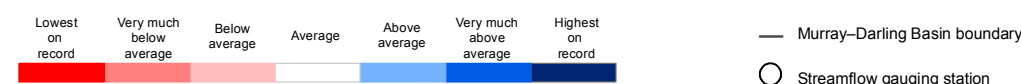


Figure 8. Rainfall, soil moisture aggregated for 1 m depth, and streamflow deciles in southeastern Australia, October 2014, and January and June 2015

Southwest Western Australia

Southwest Western Australia experienced an overall continuation of the long-term drying trend, but with high intrayear variability.

In southwest Western Australia, where rainfall is typically less affected by El Niño, the dry conditions observed this year were mainly a continuation of the long-term rainfall deficits that started some decades ago. This decline in rainfall has been attributed to a combination of natural variability and a southward-shifting 'storm track', with high pressure systems displacing cold fronts and lows across southern Australia (Timbal et al. 2006). As a consequence, streamflow supplying major urban water storage systems for Perth showed some of the earliest and greatest declines since 1970 compared with other parts of the

country. This trend has since continued and appears to have intensified.

During the assessment period, below-average rainfall coincided with above-average temperatures. Similar to southeastern Australia, the region saw its third-warmest spring on record and third-hottest summer, with maximum temperatures 1.5 °C above average.

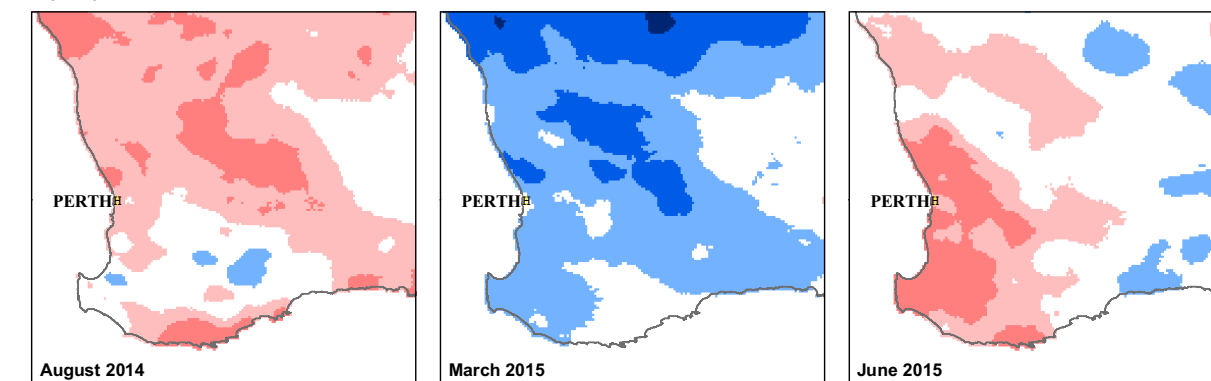
Rainfall in July 2014 was near average, but was followed by below-average rainfall in August 2014 (see August 2014 in Figure 9). As winter transitioned to spring, September 2014 rainfall returned to near average for the region. During this period, sufficient soil moisture, combined with record-breaking high temperatures, favoured good winter crop growth. Streamflow was near average for the region.

Spring rainfall was generally near average in southwest Western Australia, but with temperatures that were very much above average. Soil moisture stores that were replenished during the 2014 cool season depleted rapidly in spring, and, consequently, streamflow was mostly below average. Very dry conditions developed, with below-average rainfall and exceptionally warm temperatures.

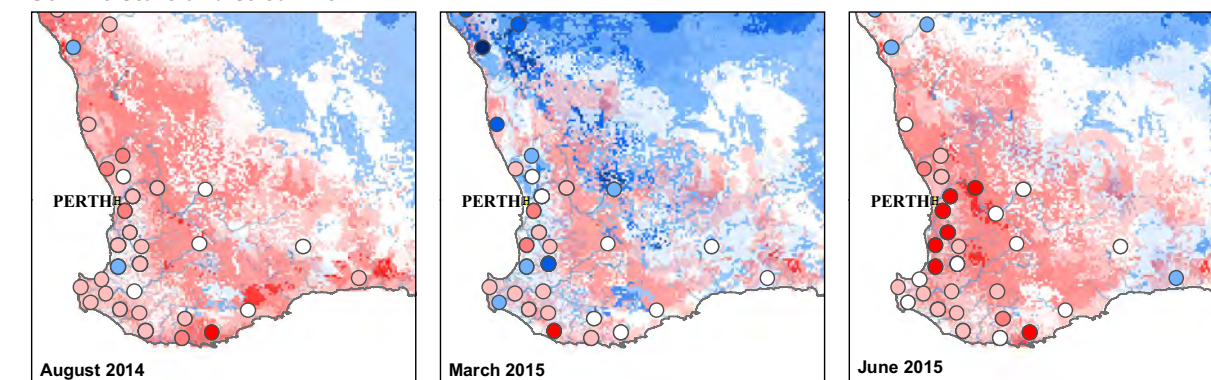
The dry conditions were interrupted by rainfall only during March and April 2015, which mark the beginning of the cool season. Most areas across the region

received above-average rainfall for this period. The rains replenished soil moisture stores but did not generate much streamflow (see March 2015 in Figure 9). Further into the cool season, May and June 2015 had particularly low rainfall. The area received 25–200 mm less rainfall than the long-term average. This generated very low runoff during a period when the majority of streamflow typically occurs, with some streams having the lowest flows on record for June (see June 2015 in Figure 9). Storage systems in and around Perth generally missed out on the filling season in 2014 and 2015 (see also Figure 10 for inflows into storages).

Rainfall



Soil moisture and streamflow



Decile



Figure 9. Rainfall, soil moisture aggregated for 1 m depth, and streamflow deciles in southwest Western Australia, August 2014, and March and June 2015

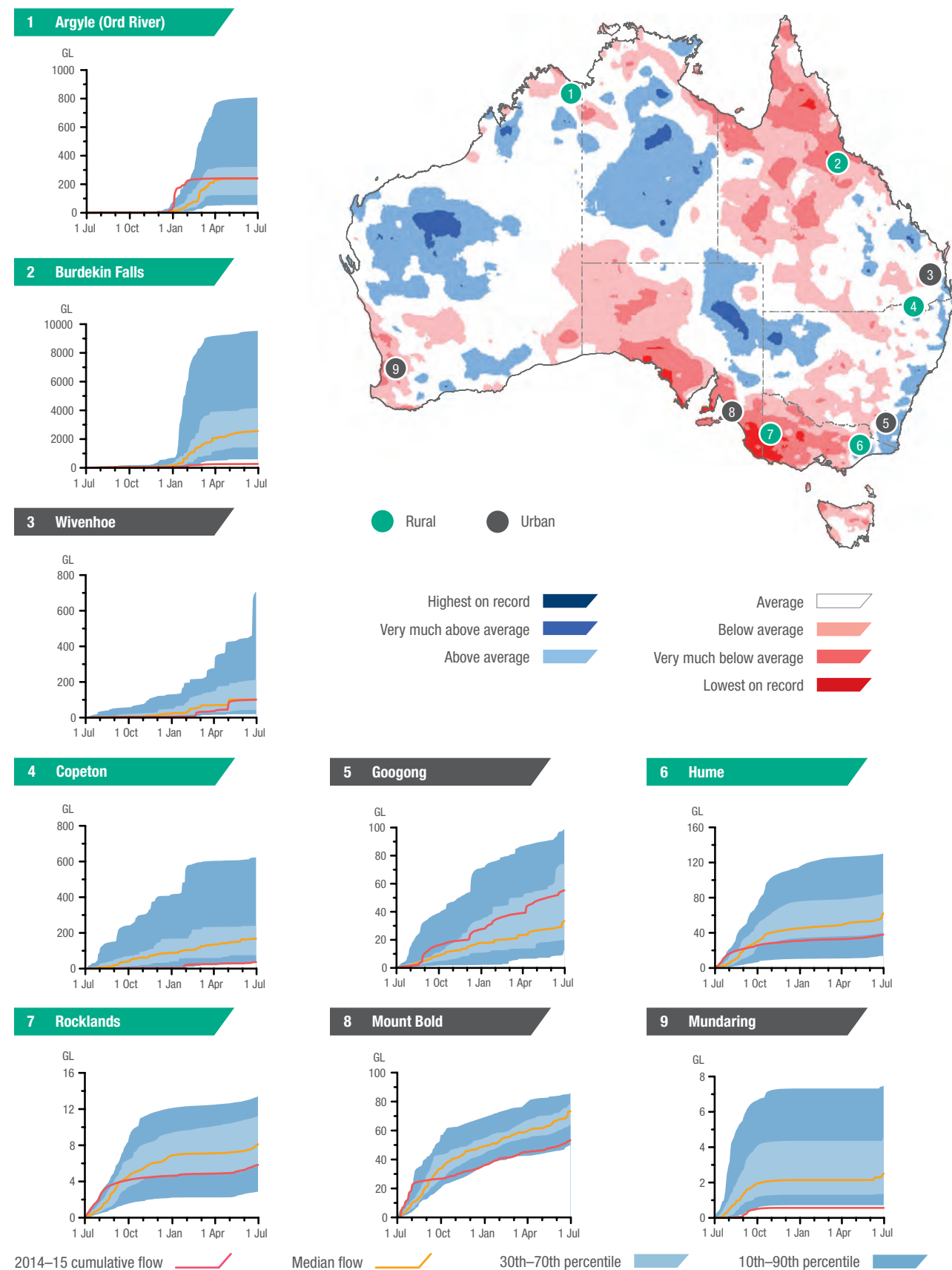


Figure 10. Rainfall decile map and cumulative inflows to selected rural and urban storage systems during 2014–15, compared with the range of historical cumulative flows

2.2 WATER STORAGE

2.2.1 Inflows into storages

The replenishment of water storages depends on streamflow, which in turn depends on conditions such as rainfall and soil moisture. Inflows, and the amounts of water that are withdrawn, govern the status of storage systems (see section 2.2.2).

Figure 10 shows cumulative inflows into selected storage systems in response to rainfall in 2014–15. In the areas affected by dry conditions, limited streamflow increased the stress on the water supply. The lack of rainfall in the wet seasons meant that stream inflows remained below average, as seen with the inflows into the Copeton, Burdekin Falls and Mundaring reservoirs. In fact, these three storages had inflows among their lowest on record. Inflows into storages in the dry regions of southeastern Australia (e.g. Mount Bold and Rocklands) benefited from wet conditions in winter 2014, but remained below average because of dry conditions in autumn and winter 2015 (Figure 10).

Major events contributed to episodic but high inflows into storages, as shown by the short bursts of increases in cumulative streamflow into Lake Argyle for January 2015, and into Lake Wivenhoe for May 2015. Similarly, various high rainfall events associated with east coast lows brought large increases along the east coast and some inland areas (e.g. Googong reservoir) (Figure 10).

2.2.2 Status of storage systems

Australia's total accessible storage volume is close to 80 000 GL of water, which could fill Sydney Harbour approximately 157 times (Figure 11). The available water is stored in around 500 storages greater than 1 GL spread across the country (representing 97 per cent of Australia's publicly owned water storage capacity).

Around 29 000 GL of storage capacity is part of the large hydro-electric power generation schemes in Tasmania (Hydro Tasmania), and in New South Wales and Victoria (Snowy Mountains Hydro-Electric Scheme). About 51 000 GL or 64 per cent of the total 80 000 GL accessible storage capacity is mostly used for direct water supply purposes (Figure 11). This includes agricultural and urban water supply, water for environmental releases, and water for industrial and commercial use, but also allows for flood mitigation and smaller-scale hydro-electric power generation.

Overall, the accessible storage volume for agricultural and urban use (excluding hydropower storages) at the beginning of the assessment period was 73 per cent of total capacity. During the 12 months of the assessment period, the accessible storage volume declined to 64 per cent (Figure 11).

Australia's accessible storage volume varies considerably across the country. Typically, storage systems have higher accessible volumes in the north than in the south. Most storage systems in Australia are along the east coast, reflecting the suitability of climate and topography of these regions, and are used for multiple purposes.

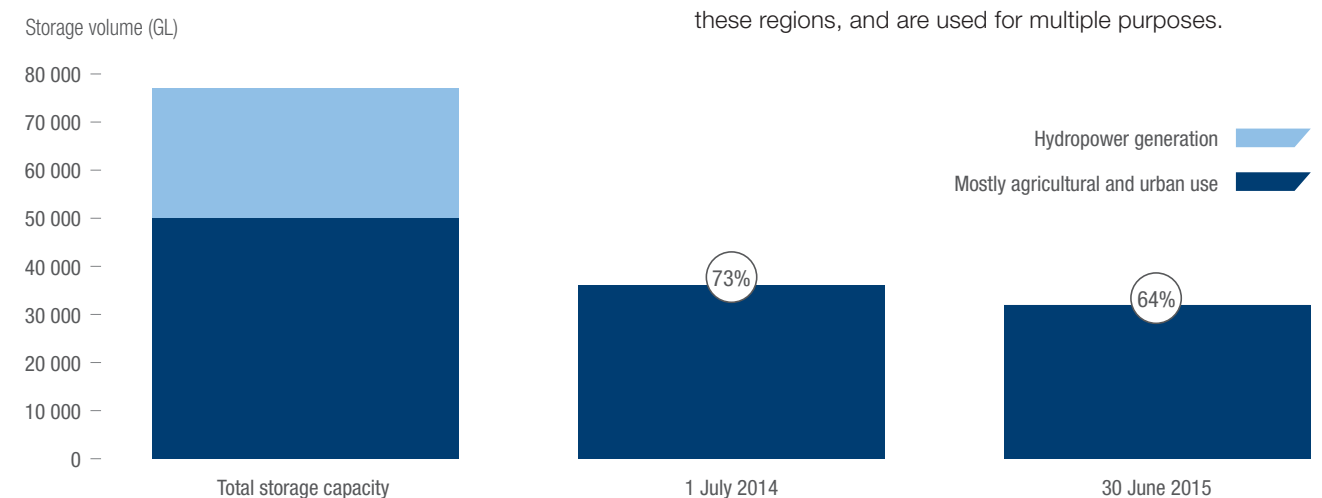


Figure 11. Australia's total accessible storage capacity and storage status at the beginning and end of the assessment period

1 Perth



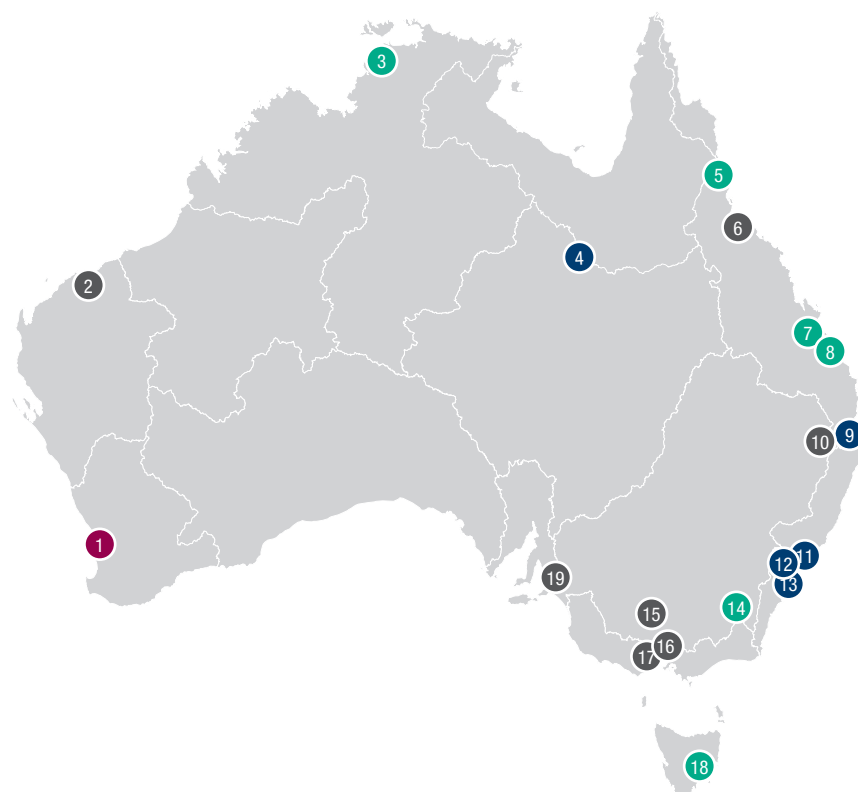
2 Pilbara



3 Darwin



4 Mount Isa



Lake Argyle on the Ord River in Western Australia is the country's largest reservoir that was built mainly for irrigation, storing about 20 per cent of Australia's total accessible storage volume. Central and western Australia rely mainly on groundwater.

Changes in accessible storage volumes followed hydrological conditions during the assessment period. Areas along the east coast—including urban storage systems in the Hunter, Sydney and Canberra regions—and in Mount Isa, and rural systems in the Bundaberg region saw increased storage volumes. In other areas, accessible storage declined, mostly because of lower-than-average inflows and high demand. Storages in the Border Rivers, Gwydir and Namoi catchments—headwater areas of the Murray–Darling Basin—were particularly low as a result of persistent dry conditions during the past three years. Accessible storage levels are, however, also influenced by carryovers (see section 3.4.2), which varied considerably across the storage systems.

At the beginning of July 2014, urban system storage levels were higher than at June 2015. The storage system in Townsville showed one of the largest declines during

the assessment period, from almost full to about 50 per cent accessible capacity; this was because of the lack of storage inflows and high use. Urban storage systems in Perth had the lowest accessible storage volumes in the country (23 per cent full), reflecting the long-term trend in streamflow decline in that city. Supply systems in other major urban cities were mostly close to full capacity (Brisbane, Sydney and Darwin) or had sufficient storage (Melbourne, Adelaide and Canberra) at the end of June 2015.

To support water use for agriculture—in particular, high-security water use—rural systems typically experience much faster drawdown than urban storage systems (Figure 12). For example, the major rural systems in the Murrumbidgee and lower Murray river areas that support irrigation activities declined in accessible storage by 20 per cent during the assessment period—the urban systems in this same area declined by 5–10 per cent.

Figure 12 shows the distribution and status of the main urban and rural storages, by supply system, at 30 June 2015 compared with 30 June 2014.

5 Cairns



8 Gladstone



11 Newcastle



14 Canberra



17 Barwon–Geelong



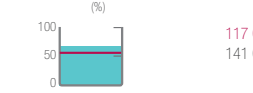
6 Townsville



9 Brisbane



12 Central Coast NSW



15 Coliban



18 Hobart



7 Rockhampton



10 Toowoomba



13 Sydney



16 Melbourne



19 Adelaide

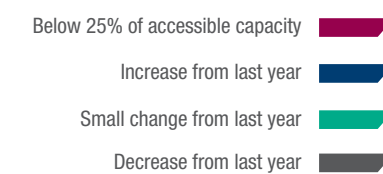


Figure 12a. Status of urban storages by supply system at 30 June 2015

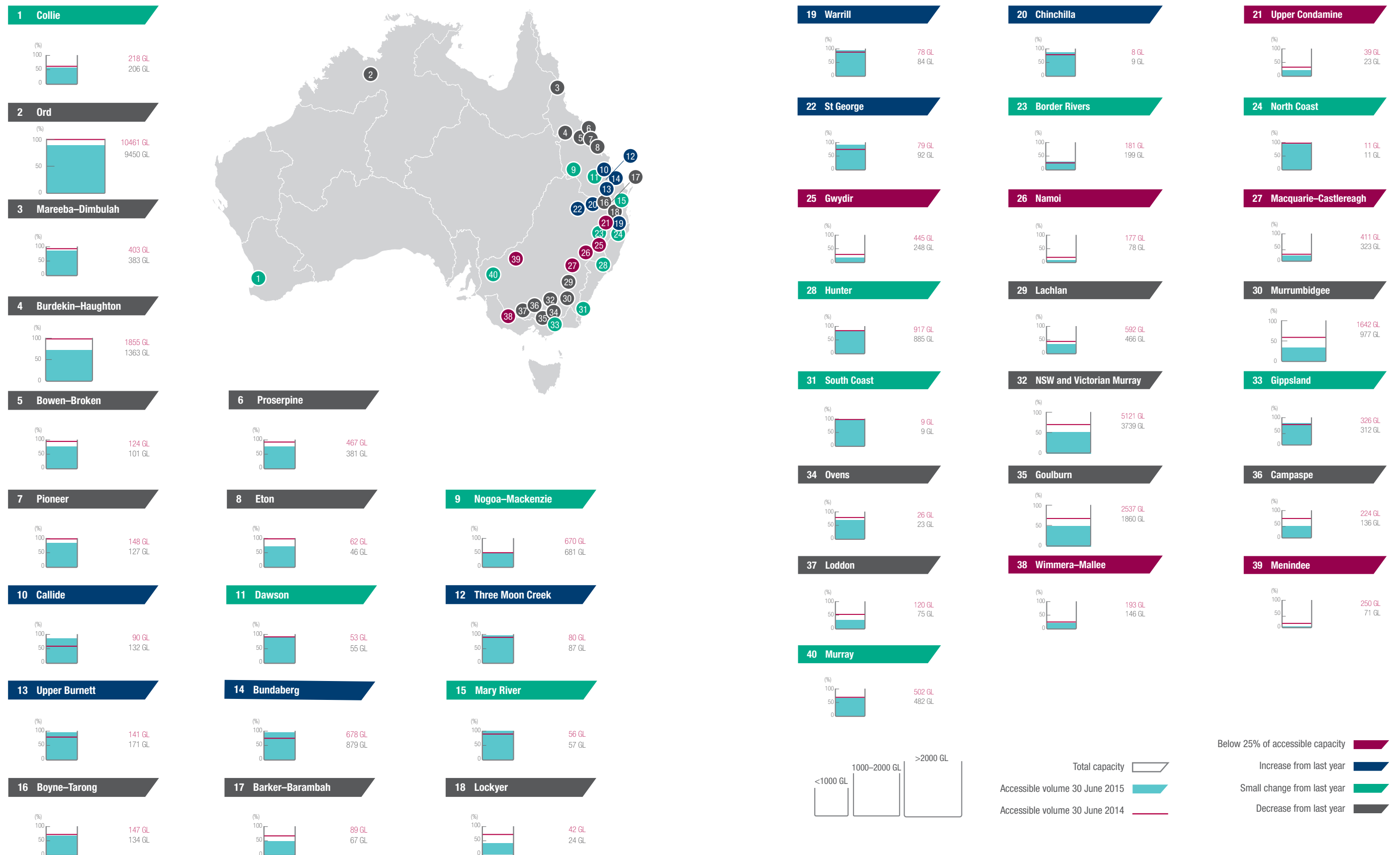


Figure 12b. Status of rural storages by supply system at 30 June 2015



2.3 STREAM SALINITY

Both the quantity and quality of surface water are important for human and environmental health and development.

In many parts of Australia, salts occur naturally in soils, surface water and groundwater. Salts are highly soluble, and streams can be naturally saline (primary salinity), particularly where soils have high salt content and where saline groundwater discharge dominates.

In Australia, many ecosystems, plants and animals have adapted to a wide range of natural water-quality conditions, including salinity. However, changes beyond natural ranges can pose a risk to the environment. In many parts of Australia, human activities have increased stream salinity (secondary salinity). The clearance of native perennial, deep-rooted vegetation and its replacement by shallow-rooted crops or grazing activities (dryland salinity), or excessive irrigation and leakage from irrigation channels (irrigation salinity) can cause groundwater to move closer to the land surface, bringing salts that then accumulate in the soil profile or surface. The extent of saline build-up depends on the characteristics of catchments, rainfall and evapotranspiration, and human modification to the landscape—in particular, the extent and location of land clearing.

Jurisdictional salinity management plans are implemented across Australia to provide fit-for-purpose water quality. Mitigation strategies include flushing out salt with

adequate water flows, intercepting salts, and modifying land management practices to minimise the movement of salt. These measures are typically targeted at benefiting aquatic ecosystems, drinking water supplies, and irrigation and other industries.

Excessive streamflow salinity can have serious implications for water use. Depending on the salinity concentration, water use can be limited for human needs (drinking water), agriculture (irrigation water, stock and domestic) or industrial use. High salinities can also damage infrastructure and ecology, and thus can increase the costs associated with improving water quality. For example, stream salinity has gradually affected potable water supplies from the River Murray to Adelaide, with costs for mitigation measures increasing steadily over time for each unit of electrical conductivity reduction (MDBMC 2007).

Stream salinity concentrations determine the suitability of the water for various uses. Median stream salinity concentrations have been categorised according to use (Table 1). Salinity is expressed as electrical conductivity, or as total dissolved solids (TDS) or salt concentration (in milligrams per litre—mg/L), and represents the sum of all ion particles smaller than 2 microns.

Additional factors (e.g. pH, alkalinity, nutrient levels, particular element concentrations and their ratios, the presence of particular algae) can further affect the suitability of the water for particular purposes.

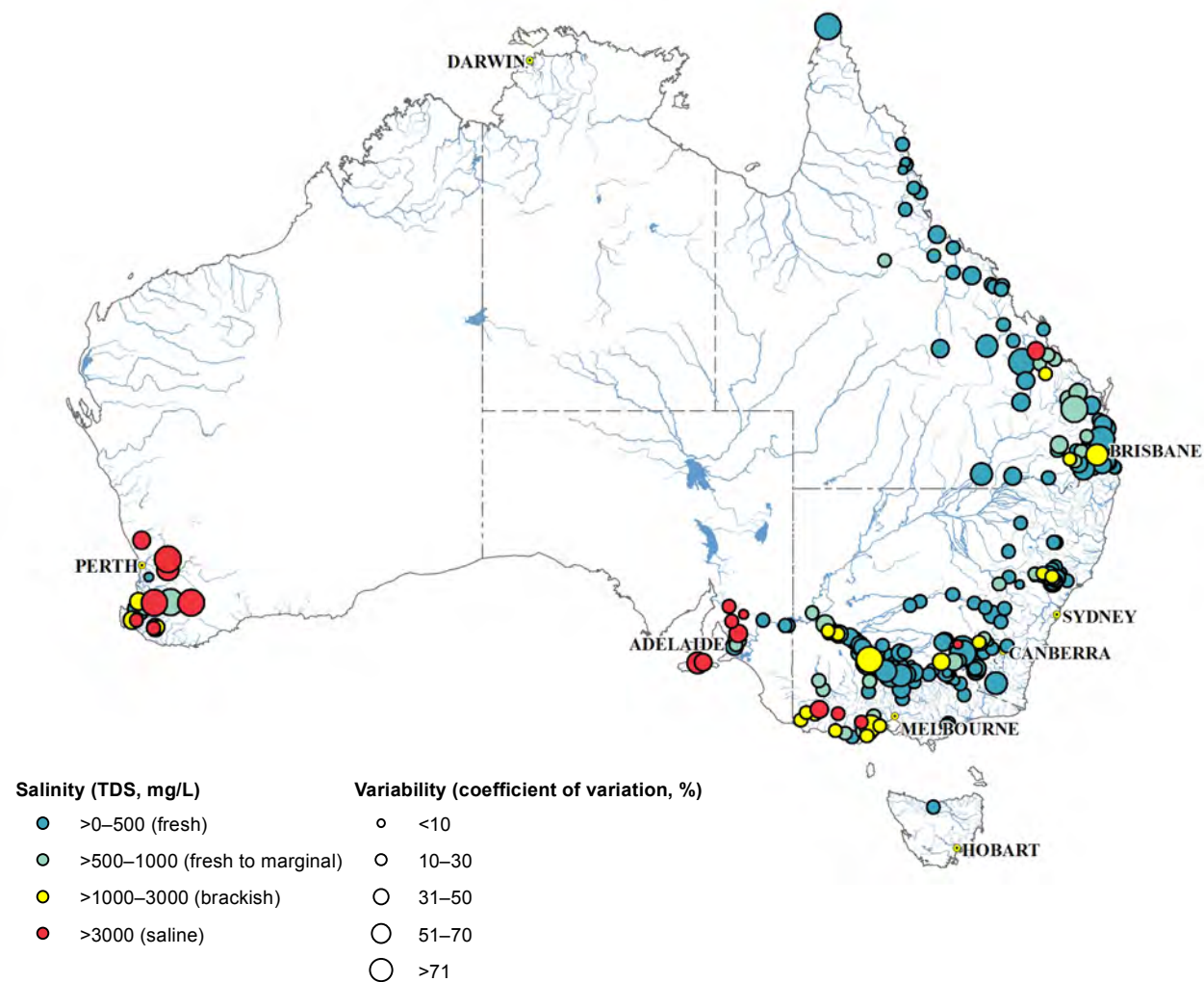
Table 1. Surface water salinity and use^a

Beneficial use	Fresh (0–500 mg/L TDS): good-quality drinking water	Fresh to marginal (500–1000 mg/L TDS): fair- to poor-quality drinking water	Brackish (1000–3000 mg/L TDS): unacceptable-quality drinking water	Saline (>3000 mg/L TDS): unacceptable-quality drinking water
Potable				
Irrigation				
Industry				

mg/L = milligrams per litre; TDS = total dissolved solids or salts

^a Colours in the table match those used in Figure 13.

Source: Based on Western Australian Department of Water (2014)



µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; TDS = total dissolved solids

Note: Electrical conductivity (EC) values of surface waters have been converted into TDS using the following relationship:
 $TDS (mg/L) = EC (\mu S/cm \text{ at } 25^\circ C) \times 0.65$ (Snoeyink and Jenkins 1980).

Figure 13. Median streamflow salinity and variability, 2014–15

2.3.1 Regional variation

Figure 13 provides an overview of the median stream salinity across Australia for 2014–15. Data used for this analysis are based on continuous monitoring of electrical conductivity from 250 gauging stations across Australia and where reliable data for 2014–15 exist. The data are collected under the Water Regulations 2008.

In 2014–15, stream salinity varied from fresh to saline across the country. Given the higher amounts of rainfall

available to dilute salts, streams in northern Australia and along the eastern divide are typically less salty (Figure 13)⁶. Stream salinity is thus an issue in much of temperate southern Australia, and affects surface waters along the southwest coast, in southern South Australia, along the southeast coast and in the southern Murray–Darling Basin.

⁶ A detailed account of regional variation for the northeast can be found in State of Queensland (2013).

In the Murray–Darling Basin, salinity tends to be higher towards the lower reaches of the River Murray unless there is sufficient flow to flush the salt out through the Murray Mouth. Salt is a natural part of the Murray–Darling Basin because groundwater delivers large amounts of salt to the rivers. All landscapes in the basin contribute to the salinity issue, although some key landscapes contribute more: the Mallee regions of South Australia, Victoria and New South Wales; and parts of the Riverine Plains of New South Wales and Victoria (MDBA 2014a). In addition to natural salinity levels in the rivers, sources of salt include salt mobilised by past actions and recent developments (MDBA 2014a).

In Queensland, higher salinities in the Dee River might be a result of leachates from the decommissioned Mount Morgan mine. In southwest Western Australia, the higher stream salinities are because of a generally higher catchment salt storage and lower rainfall (Ruprecht & Schofield 1991), and also because a higher proportion of the catchments have been cleared for a longer time (Schofield & Ruprecht 1989).

In 2014–15, the majority of streams across Australia had median salinity that, on average, is suitable for drinking water (up to 500 mg/L TDS), and irrigation and stock watering (up to 3000 mg/L TDS) (Figure 13). A much smaller number of streamflow stations (20 per cent) were brackish or saline on average, and were only suitable for some applications (irrigation and industry). These include the Warren, Collie–Preston and Blackwood rivers in Western Australia; the Wakefield, Broughton and Gawler rivers in South Australia, and the northern rivers on Kangaroo Island; and the Glenelg and Portland Coast rivers in Victoria. Many of these rivers are influenced by salty groundwater seepage.

2.3.2 Temporal variation

Stream salinity at a single location can also be highly variable, and the suitability of the water for particular purposes can be reduced at times (Figure 14). Rainfall drives the movement of salts through the landscape, and stream salinity varies with phases of salt accumulation and leaching. During rainfall and high-flow periods, when many hydrologic processes are active, salts from the landscape are mobilised and enter river systems by different pathways (i.e. varying amounts of surface runoff, subsurface lateral flows, recharge and groundwater discharge).

Salinity can be relatively diluted or concentrated depending on the local landscape characteristics, quantity of flow, dominant flow process, connectivity with other water bodies and source location of salts. Although discharge–salinity concentration relationships in different streams are complex and vary regionally, they can also show similarities (Figure 14). Often, high flows and floods initiate flushing of accumulated salts into streams after drier periods, leading to high, but short-term, pulses of elevated salt concentrations, followed by a dilution of salts by increasing contributions of stormwater. The magnitude and frequency of each phase shown in Figure 14 will vary over time and according to local conditions.

During periods with no or low rainfall, groundwater often dominates river inflows in connected systems and can have relatively higher levels of salinity (see section 2.4.2). Salinity levels tend to gradually increase during dry periods, because higher evaporative losses concentrate the salt levels in the rivers. These low-flow periods are often considered to be critical for aquatic communities and systems that can be adversely affected by high salinity. Studies suggest that freshwater species are generally restricted to salt levels of less than 3000 mg/L TDS, and a reduction in species richness is observed when salinity exceeds 1000 mg/L TDS (Nielsen et al. 2003). However, other factors—such as the frequency of flushing events, the specific life cycle of biota (e.g. mature fish are less sensitive to salt than juvenile fish) and the ratio of particular salt elements to others—will further determine the level to which salinity affects an aquatic ecosystem.

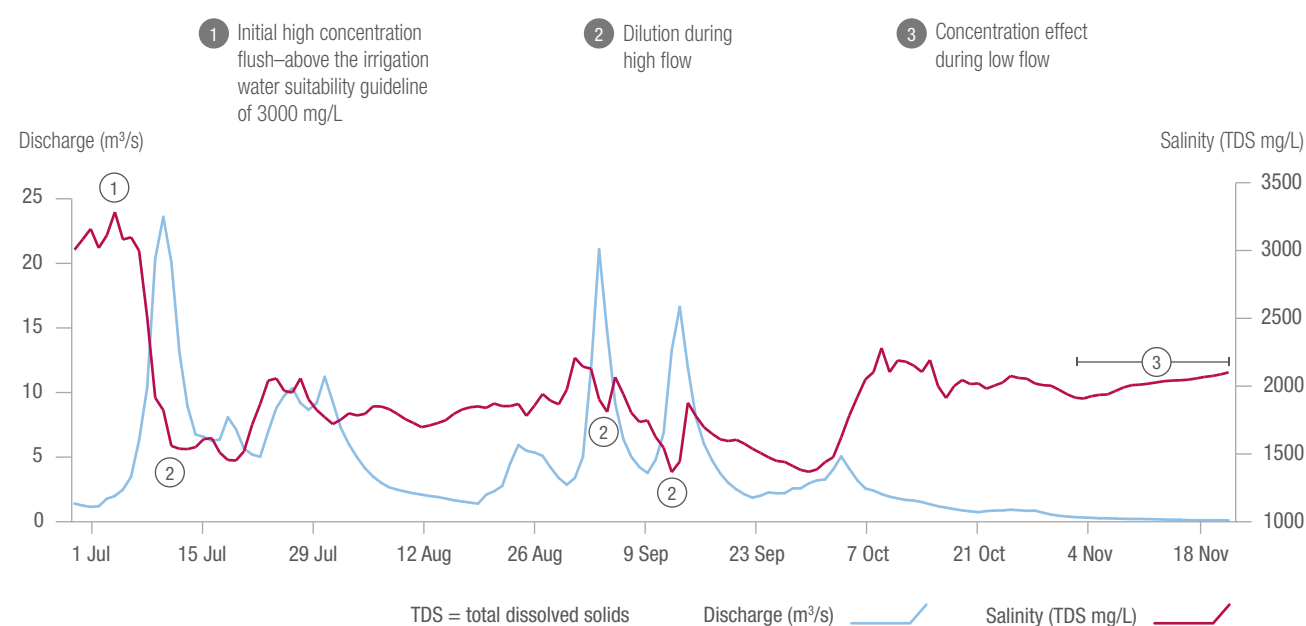


Figure 14. Variability of salinity concentration and discharge between 1 July and 30 November 2016 in the Collie River at Mungilup Tower in Western Australia (station ID 612002)

2.4 GROUNDWATER

The volume of groundwater stored in aquifers is very large compared with the volume of surface water. Globally, groundwater makes up 98 per cent of all non-frozen fresh water. About one-third of the water used in Australia is sourced from groundwater, and, in some places, it is the only water source available.

Groundwater stores typically replenish at a much slower rate than surface water, taking decades or longer to respond to changes in climate and land use, and much greater time frames to flow through large groundwater systems.

Groundwater salinity is highly variable across and between aquifers, and with depth, and is often the biggest factor limiting groundwater use. Groundwater salinity

naturally varies from fresh to hypersaline (i.e. saltier than sea water). Australia has many deep aquifers that contain good-quality groundwater, of which the Great Artesian Basin is the largest. Good-quality groundwater can also occur in shallow aquifers closely connected to rivers.

Groundwater conditions are assessed in this report using trends and status analysis of water levels at selected monitoring bores. Salinity status is also assessed to give context to the trends and demonstrate the spatial variability of groundwater quality. Because aquifers are three-dimensional, varying by location and depth, the trend and status analysis is presented for upper, middle and lower aquifer groups. More information on aquifers in these groups is available on the Bureau's Australian Groundwater Insight web page⁷.

⁷ www.bom.gov.au/water/groundwater/insight

2.4.1 Groundwater levels

There is wide-scale monitoring of groundwater across Australia, as shown on the Bureau's Australian Groundwater Explorer⁸, but the relationship between groundwater levels and resource availability is not straightforward. Although groundwater levels in an aquifer are sometimes compared to levels in a reservoir, this analogy has limitations. Rising levels do not necessarily mean that the resource is improving or that more groundwater is available. In fact, rising levels in areas with very shallow water tables can pose a risk of salinisation, as explained in section 2.3. Similarly, declining levels do not necessarily mean a depleted resource or mismanagement. For example, declining levels could occur as a result of seasonal groundwater extraction, or the levels could return to 'equilibrium' after periods of high rainfall or flooding.

Although groundwater levels measured from bores are one of a few direct measurements available to analyse changing groundwater resources, it is important to assess the long-term trend in these levels, rather than focusing on short-term or localised changes (e.g. because of seasonal pumping). Therefore, for this report, a five-year trend between July 2010 and June 2015 was chosen to identify meaningful changes in groundwater level. The status analysis compares the average groundwater level in 2014–15 with the levels for the previous 20 years.

The trends and status reflect several factors that influence groundwater, including climate, land use and extractions. These influences vary locally, and would typically require local assessments to be fully understood. Bores in shallow aquifers are more likely to respond directly to changes in climate or nearby surface water features, such as rivers or lakes. Deep bores are more likely to respond to long-term climate and land-use changes. Levels in all bores are affected by any nearby groundwater extractions. Examining trend and status data together is a useful way to give context to the trend.

⁸ www.bom.gov.au/water/groundwater/explorer

Figures 15 and 16 show the distribution of trends and the status of groundwater levels at bores across Australia. Based on the availability of water level data, about 21 200 bores were used for the trends and status analysis.

Compared with the 2013–14 assessment the upper aquifers had more bores with a declining trend in levels, although this varied spatially. Along the east coast, more bores showed declining trends in levels and below-average status, especially in alluvial aquifers in the Murray–Darling Basin (Figures 15a and b, top maps), showing a time lag following an increased reliance on groundwater because of a return to drier conditions after La Niña 2010–11. The pattern of trends in levels in the Perth Basin and the Northern Territory was largely unchanged.

The middle aquifers in eastern Australia also had more bores with declining trends in levels than in the 2013–14 analysis. However, the Perth Basin to the west shows an increase in bores with a rising trend, but the status of most bores is below average (Figures 15a and b, middle maps). This change is consistent with decreased extractions from the middle aquifer and an increase in desalination for urban water use in the past five years, as reported in section 3.3 (Figure 29).

Trends and status in the lower aquifers are largely unchanged compared with the 2013–14 assessment (Figures 15a and b, bottom maps).

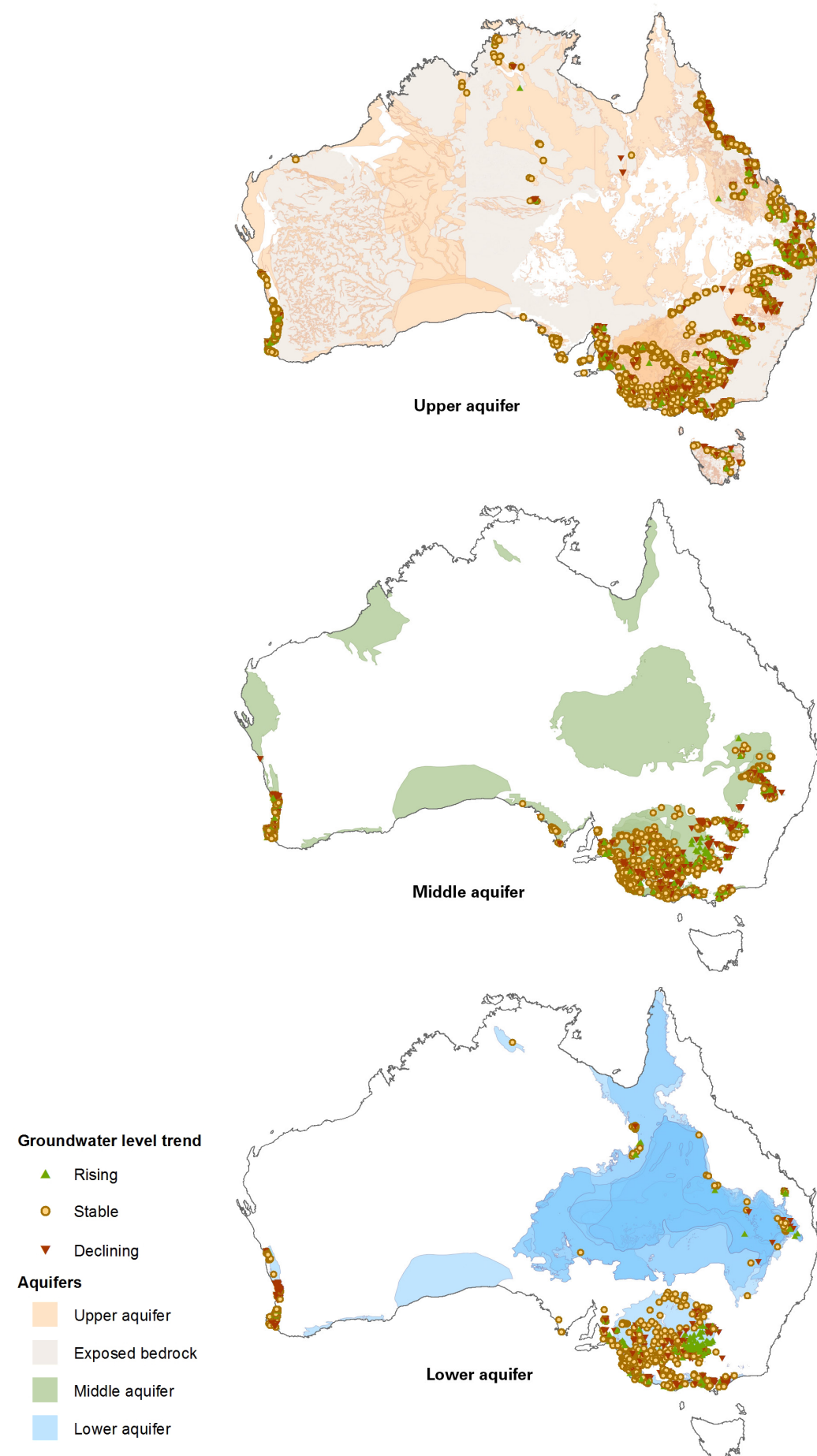


Figure 15a. Groundwater levels for upper, middle and lower aquifers across Australia, including the extent of aquifers and groundwater level trends

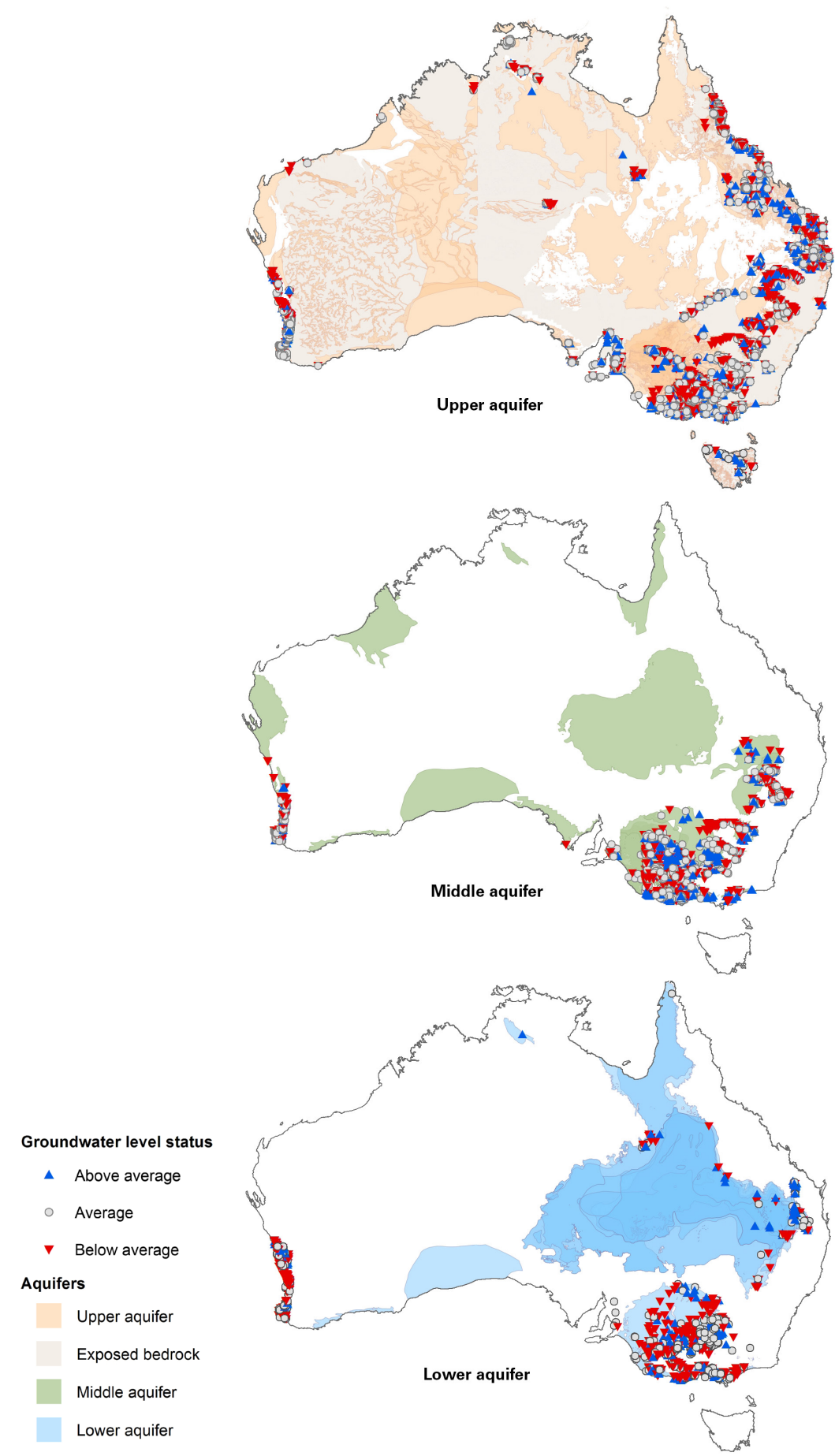


Figure 15b. Groundwater levels for upper, middle and lower aquifers across Australia, including the extent of aquifers and groundwater level status



As shown in Figure 16, in 2014–15, most bores were at average or below-average levels, with either declining or stable levels. The notable exceptions, similar to the 2013–14 assessment, are the lower and middle aquifers in Queensland, where more than 50 per cent of bores have above-average groundwater levels, with many of these rising. However, it is worth noting that this is dominated by bores located around the recharge areas along the southeastern edge of the Great Artesian Basin. Groundwater levels in these bores are affected primarily by recharge resulting from the 2011 rainfall and flooding events, recharge as a result of seasonal rainfall, and decreased groundwater extraction.

2.4.2 Groundwater salinity

Salinity can limit groundwater use and affect groundwater-dependent ecosystems. Groundwater salinity is extremely variable in Australia; groundwater naturally varies from fresh to highly saline, and can be saltier than sea water (35 000 mg/L TDS). Overall, because Australia is largely an arid to semi-arid continent, less than 30 per cent of Australia's groundwater is of fresh-brackish quality (Herczeg 2011). Evaporation and plant transpiration can concentrate the salts contained in rainfall before it replenishes groundwater. These processes can also directly increase groundwater salinity in areas where

groundwater is close to the surface. Groundwater often becomes saltier along its flow path, from recharge to discharge areas, by picking up salts from the dissolution of minerals.

Although the presence of salt in the Australian landscape is natural, the salinity in groundwater and movement of salt into groundwater-dependent ecosystems can be increased by human activities. Similar to stream salinity, increases in groundwater salinity can be caused by:

- increased groundwater recharge because of irrigation, which mobilises salts naturally accumulated in the soil (irrigation salinity)
- increased groundwater recharge because of land clearing, bringing groundwater in close proximity to the land surface, and causing evaporation from the soil surface and salt accumulation (dryland salinity)
- overpumping near the coast, which can cause sea-water intrusion
- pumping-induced inflow of saltier water from adjoining aquifers.

Groundwater salinity can be also reduced at times—for example, when increased recharge from flooding flushes out or dilutes salty groundwater.

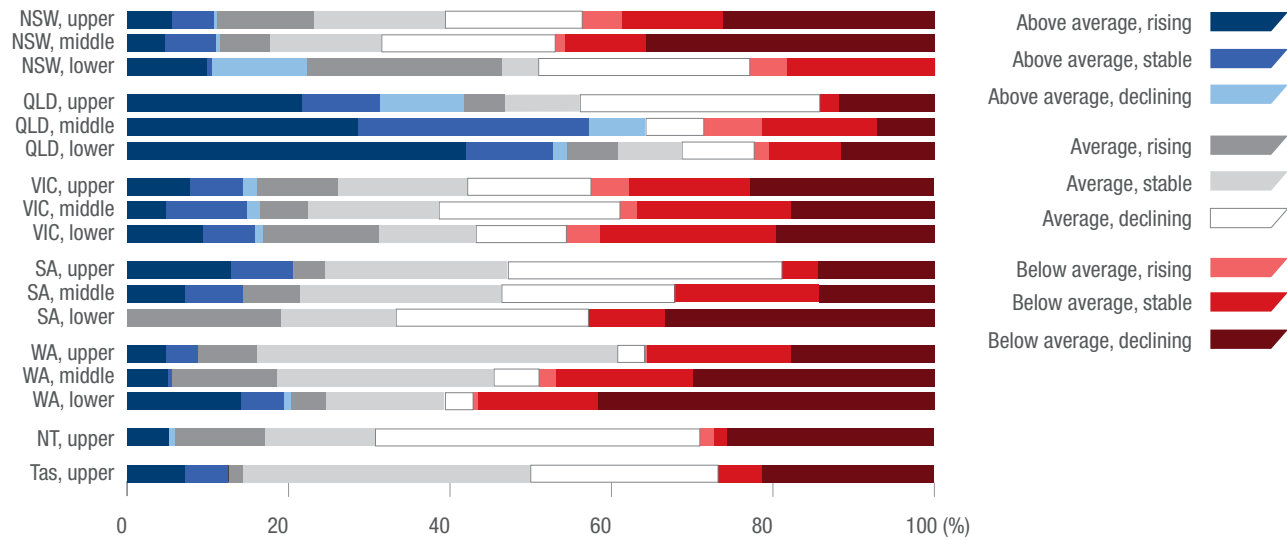


Figure 16. Summary of groundwater level status and trends, by State and Territory, 2014–15

These effects are typically localised. Broad-scale changes in groundwater salinity occur very slowly—over decades or longer; therefore, groundwater salinity is usually monitored infrequently except where human impacts are of concern.

Groundwater salinity and uses have been categorised according to use (Table 2). The limit between brackish and saline water represents roughly the upper salinity tolerance for irrigated crops (3000 mg/L TDS). Figure 17 shows the average groundwater salinity for around 16 500 bores during the past 20 years across Australia by aquifer groups.

Australia has naturally saline groundwater in many places (Figure 17). In particular, the Western Australian tablelands have salty groundwater because they are part of an internally draining surface water and groundwater system, where there are high evaporation rates and limited opportunities to flush away accumulated salt.

In the geological Murray Basin⁹, groundwater is fresher in the east at the margin of the basin, where rainfall recharge and leakage from rivers is higher, and becomes naturally saltier along the westward flow path towards

the River Murray trench. The geological Murray Basin is a groundwater system with little or no opportunity for discharge to the sea, other basins or aquifer systems. Thus, under natural conditions, the major mechanism for salt export in the basin is through the River Murray (Telfer et al. 2008).

The salinity in the lower aquifer within the Great Artesian Basin shows significant regional variability. Typically, salinity increases along the flow from the recharge zones to the deeper parts of the basin. The presence of higher-salinity groundwater coincides with low levels of permeability and low recharge rates. The fresh to marginal-quality groundwater found in the eastern margins is linked to an infiltration of fresh water in the Great Artesian Basin recharge areas. The low-salinity area centred on the southeastern section of the lower aquifer group is also likely to be caused by increased recharge and mixing with other aquifers in areas where low-permeability layers are thin or absent (Ransley et al. 2015).

In the northern areas of Australia, groundwater is mainly fresh because the high seasonal rainfall tends to flush away any salt.

⁹ The geological Murray Basin is an accumulation of sedimentary deposits in the lower regions of the Murray–Darling Basin’s surface drainage area.

Table 2. Groundwater salinity and use^a

Beneficial use	Fresh to marginal (0–1000 mg/L TDS)	Brackish (1000–3000 mg/L TDS)	Saline (3000–35 000 mg/L TDS)	Hypersaline (>35 000 mg/L TDS)
Potable				
Irrigation				
Industry				

mg/L = milligrams per litre; TDS = total dissolved solids or salts

^a Colours in the table match those used in Figure 17.

Source: Western Australian Department of Water (2014)

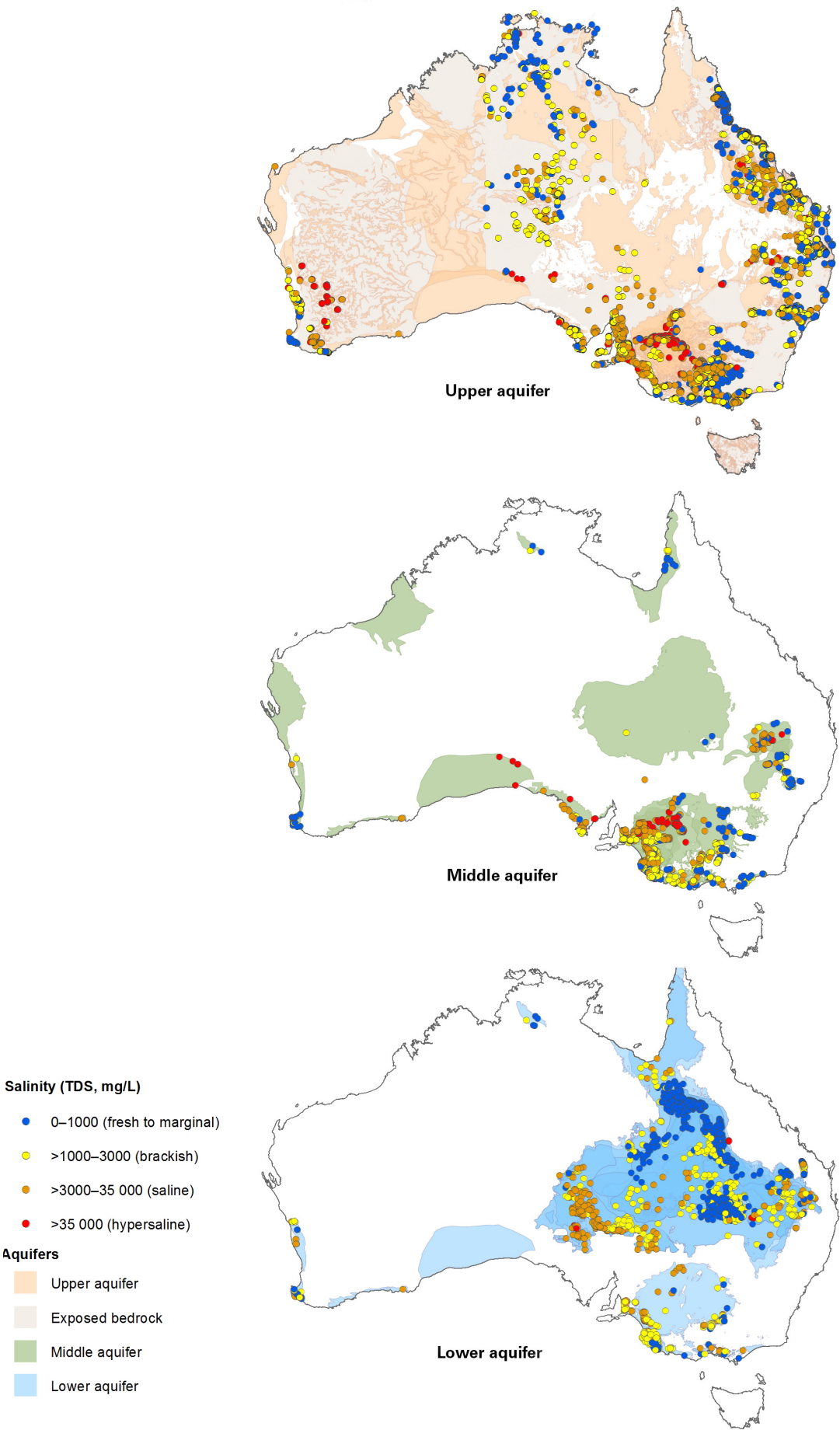


Figure 17. Groundwater salinity (20-year average) in the upper, middle and lower aquifers across Australia, including extent of aquifers

mg/L = milligrams per litre; TDS = total dissolved solids

3 WATER USE

AT A GLANCE

The estimated total bulk water extractions across Australia were 16 700 GL in 2014–15. This is 4 per cent lower than in 2013–14. Water extracted for agricultural purposes accounted for 75 per cent of the total, followed by urban use at 19 per cent.

Volumes of water associated with entitlement trading dropped nationally from 2400 GL during 2013–14 to 1800 GL during 2014–15, but were still higher than in the wet years from 2010–11 to 2012–13. Volumes of water associated with allocation trading during 2014–15 (5800 GL) remained at similarly high levels as during 2013–14 (5500 GL). Both types of trading occur predominantly in the southern Murray–Darling Basin.

About half of all 2014–15 regulated non-environmental surface water diversions (about 6100 GL) and more than 90 per cent of the regulated environmental water diversions (about 1600 GL) occurred in the southern Murray–Darling Basin. Diversions for the environment comprised more than 20 per cent of the total regulated diversions in the southern Murray–Darling Basin.

3.1 WATER-USE MANAGEMENT

The physical availability of water (chapter 2) is the basis on which jurisdictions set limits on the take of water. These limits are necessary to distribute the water between users that have water access licences, and the water needs of the ecosystems and cultural aspects of the riverbeds, floodplains, estuaries and connected wetlands.

Many jurisdictions are involved in water management across Australia, and each provides a variety of rights and licences to users. As a consequence, it is not straightforward to present the total amount of water that users are permitted to take during the year. For example, the Murray–Darling Basin spreads across four States and the Australian Capital Territory, each applying their own water allocation planning rules to provide water for users and the environment. Other States, such as Tasmania and Western Australia, have their own sets of management rules suited to their situations. Hence, providing a national overview of the amount of water that is permitted to be extracted from surface water and groundwater during a particular period requires some generalisation of the information available.

The largest volumes of water under licence in Australia are issued as surface water entitlements in regulated river systems, which are predominantly held by users in the eastern mainland States (Figure 18). Surface water extraction is the preferred option for most large-scale water users, including most irrigation areas and many of Australia's cities. Regulated river systems generally provide higher water security than unregulated river systems because of storages.

Regulated surface water entitlements allow users to draw from surface water reservoirs, based on the allocations given by the water resource manager each year. These allocations give the licence holders an amount of water in their accounts, which they can generally use within the accounting period or (partly) carry over to the next accounting period. These licences are regulated entitlements that come with various security levels, meaning that the allocations given towards the entitlements differ from one licence to another. Holders of unregulated surface water entitlements, along with supplementary entitlement holders in regulated river systems, are allowed to take some of the water as it flows by; the entitlements are often dependent on certain flow conditions being met.

In the central and western States, the largest volume of issued entitlements is for groundwater—these can be either allocated or non-allocated entitlements. The Tasmanian licences largely consist of unregulated surface water entitlements. Because of the year-round availability of water in Tasmanian rivers, complemented by releases from the hydro-electricity generation scheme, flow volumes largely exceed irrigation demand. Hence, there has been no need to issue entitlements that could be limited by allocation announcements.

The volume of water related to the regulated entitlements in Figure 18 does not reflect the security levels of these entitlements. All entitlements in South Australia and the majority of the entitlements in Victoria are high-security entitlements, whereas the majority of entitlements held in New South Wales have a lower security level. The end-of-year allocations against these entitlements are a function of inflows to storages, storage volumes, the climate outlook for the next water year, critical human water needs and an assessment of the ability to meet future requirements. Allocation restrictions are applied to lower-security entitlements before higher-security entitlements. Hence, the relatively larger volume of general-security (lower-security) entitlements in New South Wales has resulted in more variable allocation announcements in the past few years than in Victoria and South Australia (Figure 19). In New South Wales, there was a declining trend in total allocations plus carryover after 2012–13, followed by drier conditions and lower storage volumes in 2013–14 and 2014–15.

In Queensland, although the majority of the entitlements are issued with medium security, they are not as variable as the New South Wales general-security allocations. Most of Queensland’s medium-security entitlement holders draw water from storages in coastal catchments that generally reach full capacity during the wet summer season. Therefore, Queensland generally allocates 100 per cent towards the medium-security entitlements in these catchments.

The total issued surface water and groundwater entitlement and allocation volumes do not necessarily reflect the actual extractions made under these licences in a particular accounting period, which is based on the financial year for most regions in Australia. This is because some users do not use all of the water they are allocated.

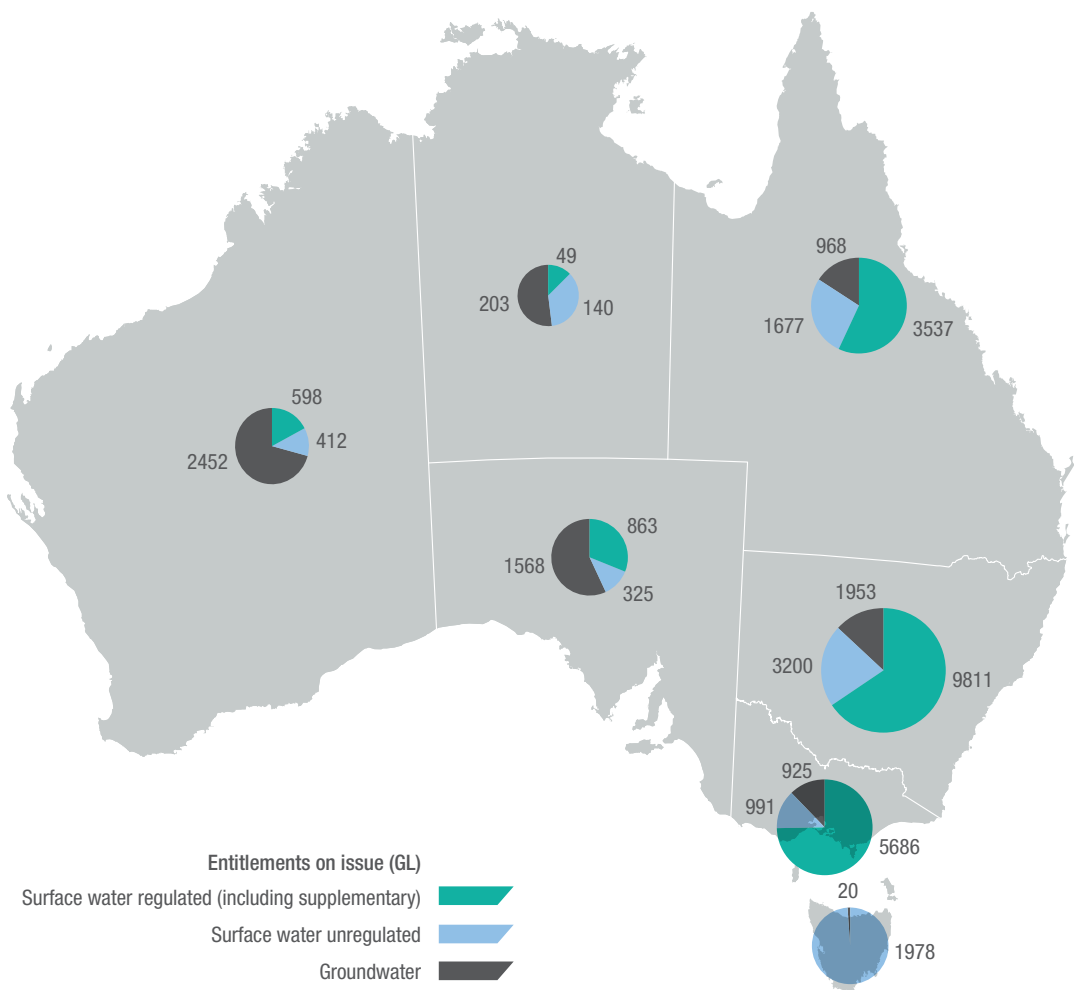


Figure 18. Total volumes of surface water and groundwater entitlements on issue that have an annual access limit against them, June 2015

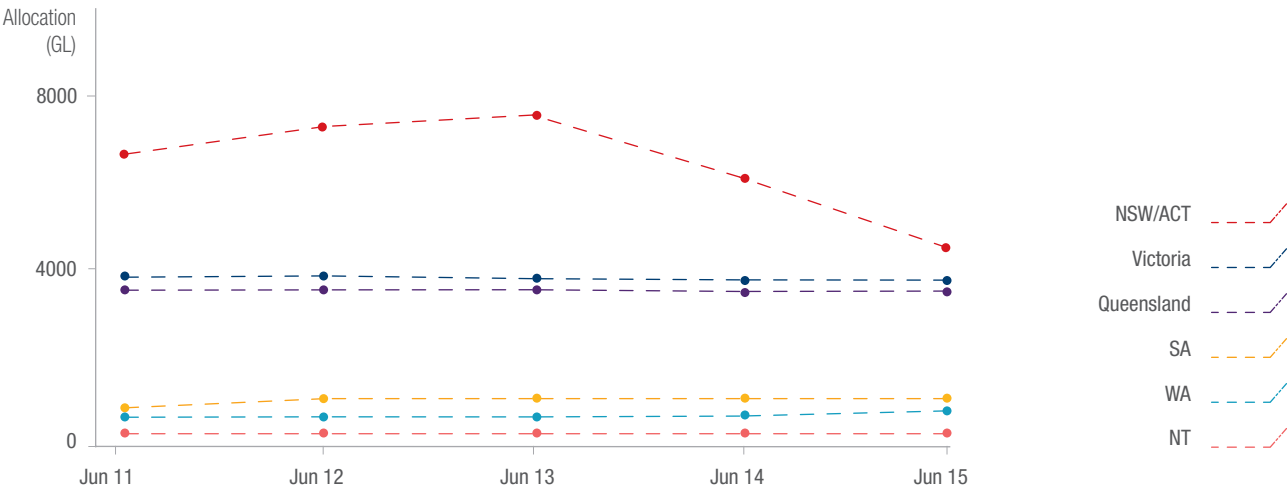


Figure 19. End-of-year volumes of water allocated towards regulated entitlements on issue in each State and Territory, including carryover but excluding supplementary entitlements in New South Wales

3.1.1 Water trade

Australia’s water market facilitates buying and selling of water entitlements and allocations to allow water to move between various urban, agricultural and environmental uses. It also allows for water to be redistributed between hydrologically connected regions, of which the southern Murray–Darling Basin (including the Murrumbidgee,

New South Wales Murray, Victorian Murray, Northern Victoria and South Australian Murray regulated river systems; Figure 20) is by far the largest.

Entitlement trades involve permanent transfers of a water access entitlement. Allocation trades involve the buying and selling of allocated water during a particular year.

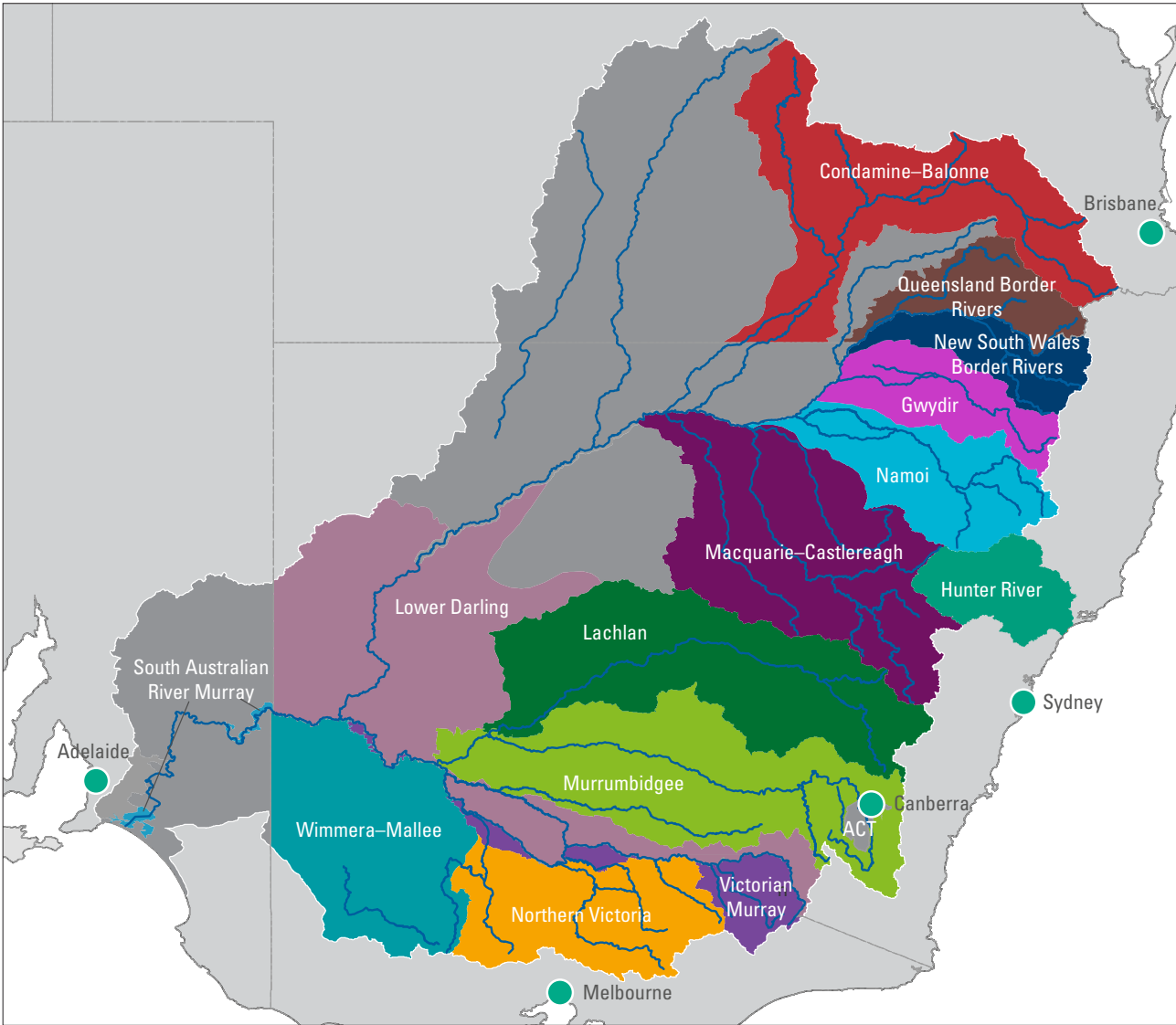


Figure 20. Murray–Darling Basin surface water resource plan areas for regulated river systems and the Hunter regulated river system area

Entitlement trading

Entitlement trading predominantly occurs in the Murray–Darling Basin, accounting for 80–90 per cent of the total volume traded in Australia. Volumes of water associated with entitlement trading dropped nationally from 2400 GL during 2013–14 to 1800 GL during 2014–15, but remained higher than during the wet years from 2010–11 to 2012–13 (Figure 21). Transfers related to Australian Government buybacks and water savings from infrastructure projects are recorded as entitlement trades. From 2012–13, Australian Government acquisitions shifted focus from purchasing entitlements through buyback, to transfers from water savings through infrastructure projects.

Figure 22 shows average prices for high- and general-security entitlements for selected water systems. Robust trading data are only available for a limited number of systems. Prices for entitlement trading have shown a

general decline from 2010–11 to 2013–14, reflecting a decrease in demand for purchasing entitlements with typically high water availability across southeastern Australia. For most of the examples provided in Figure 22, there is an upwards trend following the lows in 2013–14, because of decreasing water availability. In markets outside the southern Murray–Darling Basin, the lack of hydrological connectivity means that trading zones act more as separate markets, with different trading characteristics. An example of this is seen in the Hunter region, where announced allocation levels have consistently been near-full, making general-security entitlements more akin to high-security entitlements, which are accompanied by a higher price.

Overall, entitlement prices tend to be less volatile than allocation prices, because entitlement trading is driven by longer-term changes such as climate, structural changes to farming enterprises and long-term yield.

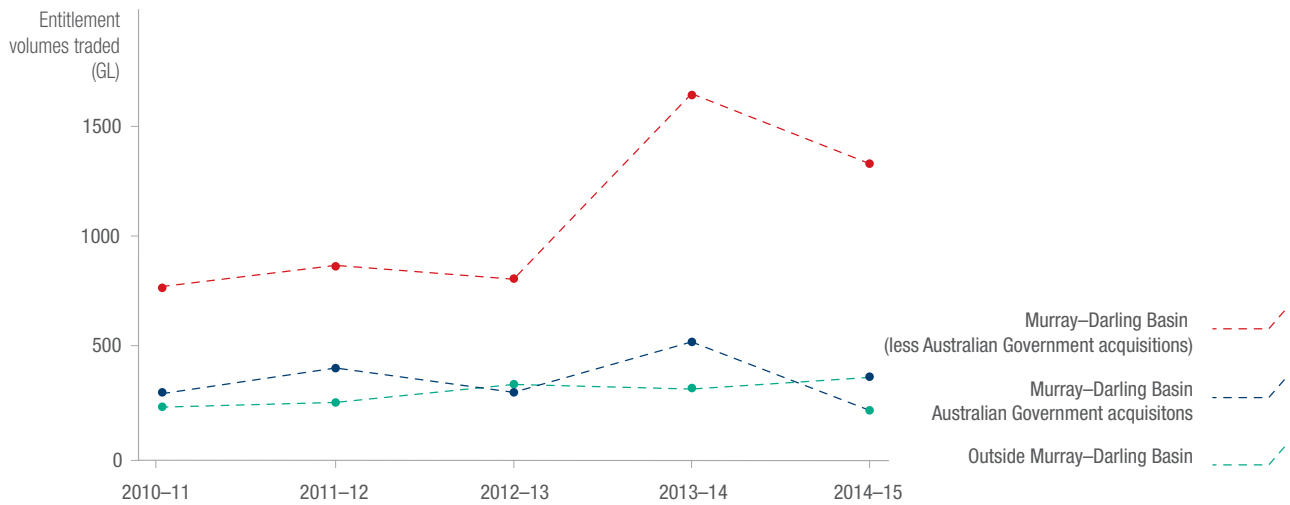


Figure 21. Entitlement volumes traded nationally

Allocation trading

Volumes of water associated with allocation trading during 2014–15 totalled 5800 GL, remaining at similarly high levels as in 2013–14. The southern Murray–Darling Basin dominates allocation trading (Figure 23). For many irrigators and other water managers, water trading has become a normal business tool that helps them to

manage water availability for present and future crop demand. Additionally, environmental water holders have acquired more and more water over the past years, which they can transfer between different catchments in the southern Murray–Darling Basin to facilitate environmental watering events. These transfers are registered as trades and are discussed in section 3.2.

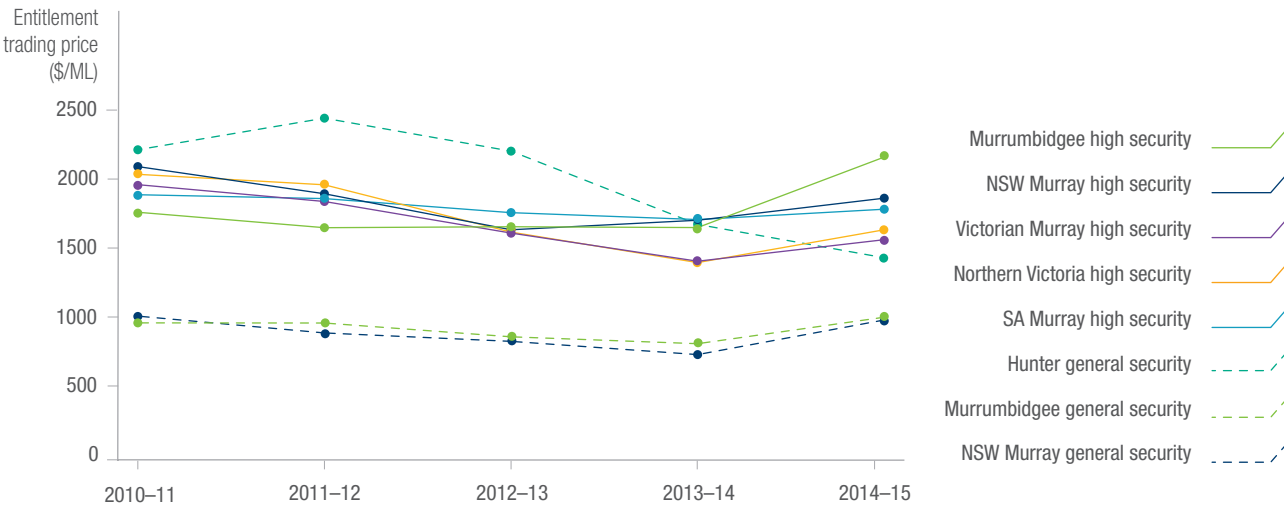


Figure 22. Prices for high- and general-security entitlement trades in selected water systems

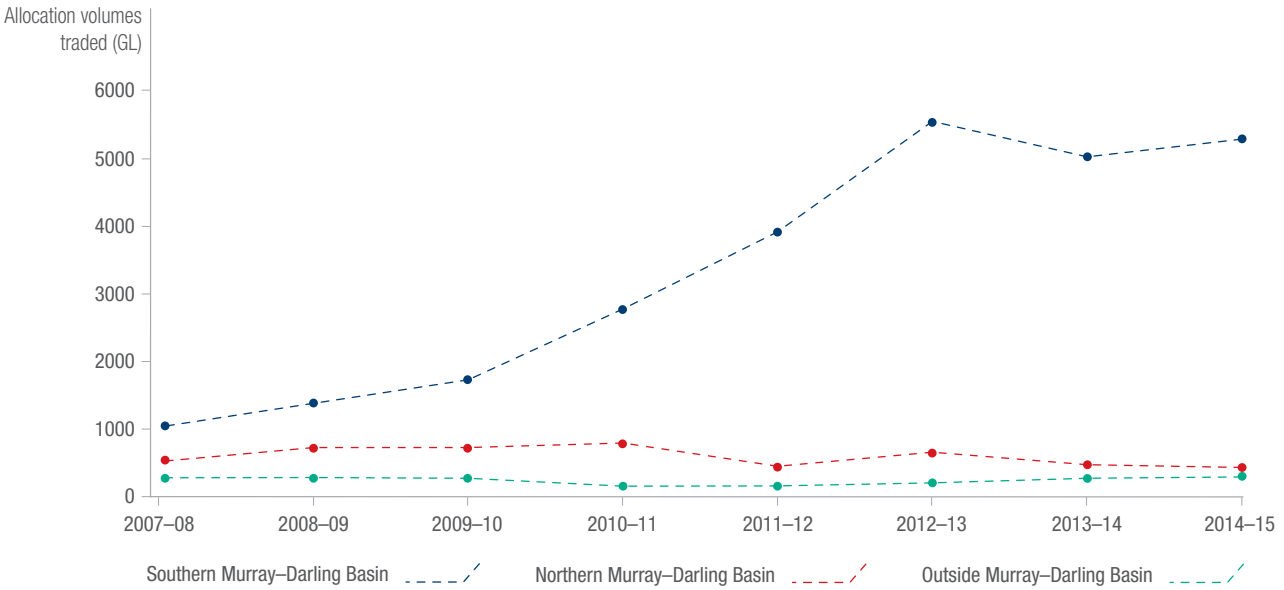


Figure 23. Allocation volumes traded nationally

High prices paid for allocations in 2007–08 reflected a rush to secure water during the height of the 1996–2010 Millennium Drought (Figure 24). Very high prices were paid by horticulturalists who wanted to keep their plantings alive. Allocation prices then fell sharply following the end of the drought years after 2009–10. Since the two wet La Niña years of 2010–11 and 2011–12, prices have started to increase as announced allocations have declined sharply for lower-security entitlements. In 2014–15, lower water availability put upward pressure on prices in the Murrumbidgee River and the River Murray in New South Wales. Prices remain largely the same between regions in the southern Murray–Darling Basin because of the connected nature of the southern basin market.

Internal and interstate allocation trade

Allocation trades in the southern Murray–Darling Basin are dominated by State internal trades. In 2014–15, trade volumes were very similar to those in 2013–14 (Figure 25). Although the total volume of allocated water available for trading dropped in 2014–15, a higher proportion of allocated water was traded.

For the interstate component in the southern basin, large volumes of water were traded into South Australia to facilitate environmental watering along the River Murray and into the Lower Lakes at the river mouth. There was a small amount of interstate trade between New South Wales and Queensland in the Border Rivers regions.

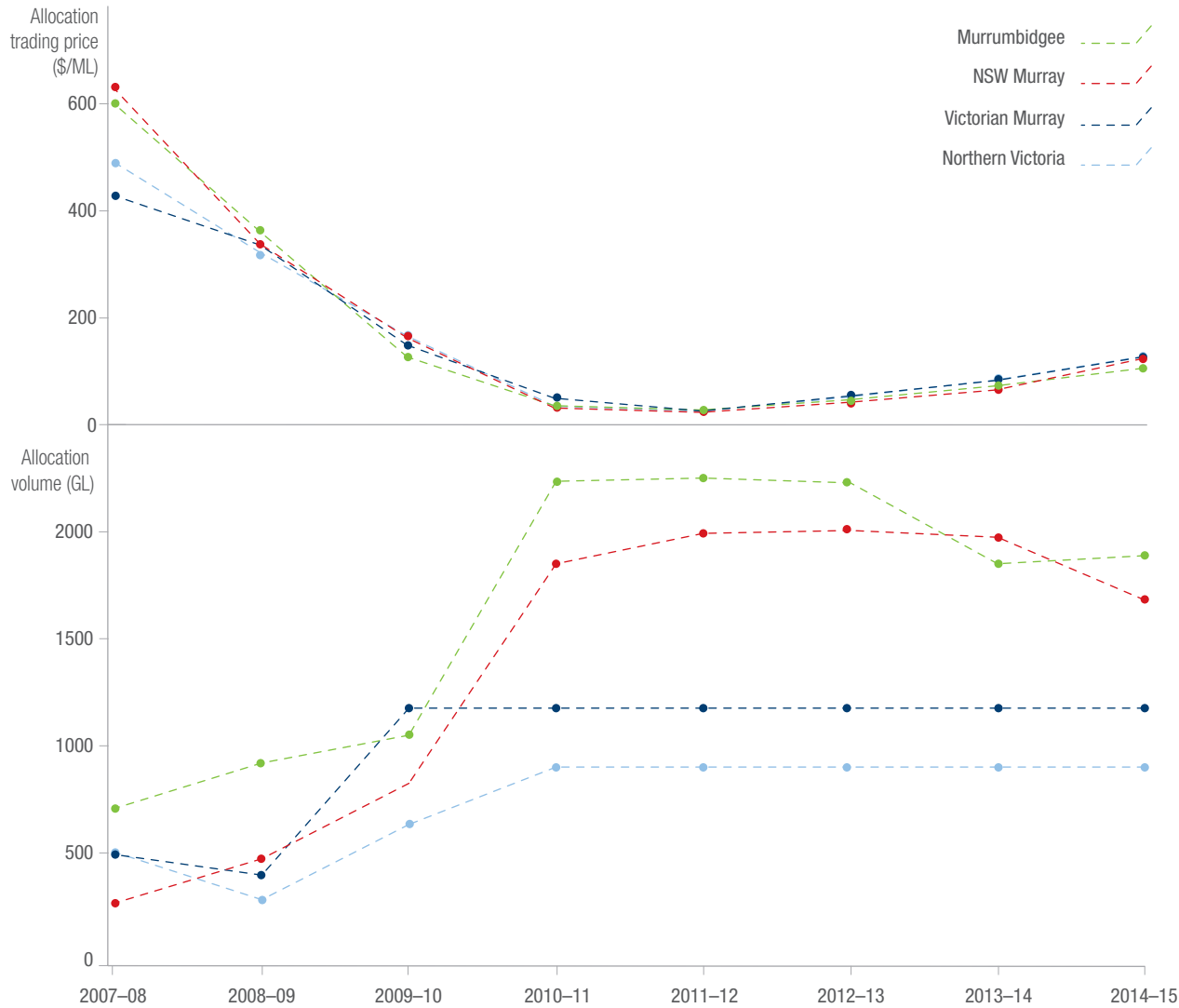


Figure 24. Allocation announcements and allocation trading prices in highest-use regions of the southern Murray–Darling Basin

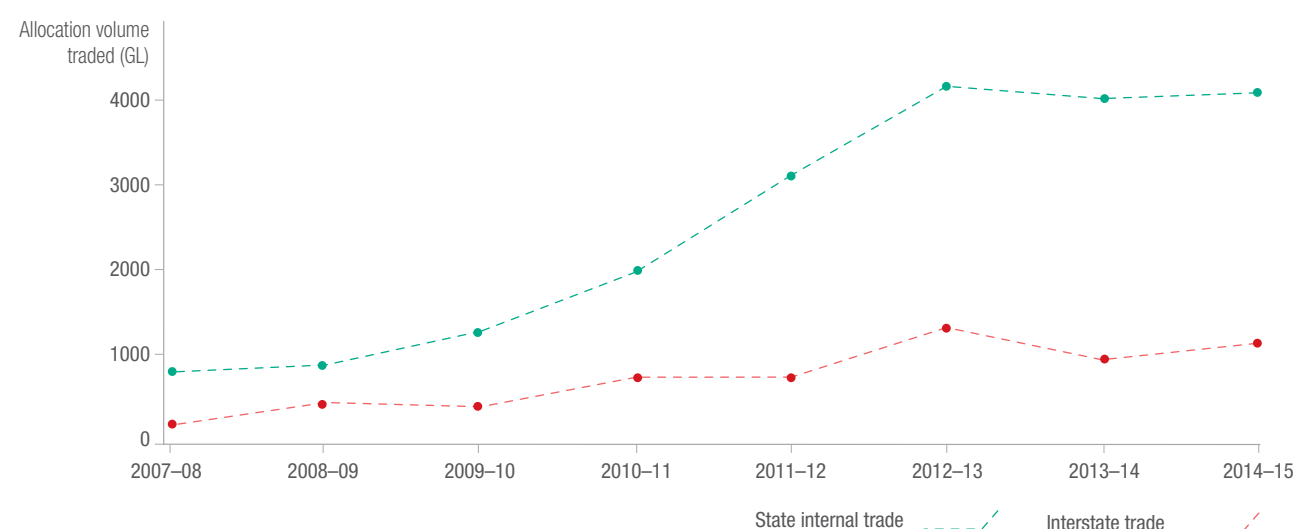


Figure 25. Internal and interstate allocation trades in the southern Murray-Darling Basin

3.2 ENVIRONMENTAL AND CULTURAL WATER

Environmental water availability is managed through operational rules for river flow requirements downstream of each individual dam, along with allocations and trade of environmental entitlements held by the Australian Government and State environmental water holders. The Australian Government environmental water acquisition program targeted only some entitlements in unregulated river systems, which generally allow the holder to divert water under specific flow conditions and mostly result in reduced extractions. The acquisition of surface water entitlements in regulated river systems, on the other hand, allows environmental water holders to target specific goals in periods of high or low flows along different sections of the river, including in wetlands.

In the Murray-Darling Basin, environmental water holders had obtained more than 2500 GL of regulated (high- and low-security) entitlements by June 2015. Almost 90 per cent of these environmental entitlements are situated in the regulated river systems in the southern Murray-Darling Basin. Not only do the southern catchments have large storage volumes to allow for high-security levels and good carryover capacities, but the water can serve multiple purposes as it (partly) continues to flow downstream as part of the River Murray.

3.2.1 Environmental water use

Almost 1600 GL of environmental releases were made from the storages in the southern Murray-Darling Basin during 2014-15 to benefit the aquatic vegetation and native fish at multiple sites along the river, as well as at several waterbird refuges (MDBA 2016). Non-environmental diversions in the southern basin were slightly more than 6000 GL, meaning that more than 20 per cent of all water releases in the southern basin had an environmental purpose in 2014-15. About 600 GL of environmental releases were accomplished by transferring allocations from various upstream catchments in the southern basin to the South Australian Murray region. Added to this, the South Australian holders of environmental water received 200 GL towards their entitlements in 2014-15. Another 800 GL of water was released by the environmental water holders in the upstream catchments in the southern basin.

In the northern Murray-Darling Basin, environmental entitlements can generally only be used in the river system in which they are issued. Lower connectivity levels between the systems prevent most environmental releases from reaching river sections and wetlands further downstream. Lower availability levels because of the dry circumstances in the northern basin have allowed for only limited environmental releases. Nonetheless, 145 GL of water was used to improve the survival chances of native fish in response to the forecasted El Niño and the already dry conditions.

3.2.2 Water for Aboriginal cultural use

Cultural flows have been defined as water entitlements that are legally owned by the Aboriginal nations, and that are of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of these nations (Weir & Ross 2007).

Explicit provision for Aboriginal and other beneficial uses of water continues to be challenging in many parts of Australia where competition for water is strong. The Murray-Darling Basin Plan requires Aboriginal cultural values to be considered in environmental water management prioritisation and decision-making.

One pathway to the provision of water for Aboriginal benefit is by refining the delivery of environmental water. A challenge in doing this is a lack of documented information to bring to the negotiating table. The National Cultural Flows Research Project¹⁰ aims to generate scientifically based evidence for Aboriginal people to use in their efforts to achieve cultural flows. The Aboriginal Cultural Flows Health Indicator has been tested and modified to consistently measure river and wetland health. Both of these projects will generate information to help Aboriginal people negotiate their water needs through water planning processes. An example of how this could be effectively applied is given for the Gunbower Forest wetland (Box 3).

¹⁰ <http://culturalflows.com.au>

BOX 3 ENVIRONMENTAL WATER IN THE GUNBOWER FOREST, VICTORIA

The Gunbower Forest icon site contains diverse and rare wetland habitats, the second-largest river red gum forest in Australia, and vulnerable and endangered flora and fauna (MDBA 2014b). It is the traditional land of the Yorta Yorta nation (middle and southeast area) and the Barapa Barapa nation (northwest area). The Barapa Barapa people made a living on the woodlands, wetlands and floodplain of the Gunbower Forest, and this connection continues.

The Living Murray Indigenous Partnerships Program has funded the Barapa Barapa Traditional Owners, supported by the North Central Catchment Management Authority, to map important cultural sites in the Gunbower Forest. The information will be incorporated into environmental water management plans to enable the social, cultural and spiritual values of the Traditional Owners to be considered in seasonal watering proposals. The mapping project focused on observing results from environmental watering, but has also identified and recorded traditional food, fibre and medicine plants, and sites of cultural significance. Scarred trees, mounds, middens and burial sites have previously been recorded in the Gunbower Forest Ramsar site (Victorian Department of Sustainability and Environment 2003).

In the second half of 2014, 98 GL of environmental water was delivered to Gunbower Forest. Because this is a flow-through system, 37 GL of this remained and inundated about 3800 hectares of the forest, filling wetlands and flowing across large areas of river red gum floodplain (Victorian Environmental Water Holder 2015). Although this was primarily an environmental flow event, cultural benefits have also been achieved. This is a good example of how the environmental water holders can incorporate Aboriginal interests into their use of water.

3.3 BULK WATER EXTRACTIONS

3.3.1 Total bulk water extractions

The total volume of bulk water extractions is defined as all licensed water extractions made from rivers, storages, high-yielding aquifers, and recycling and desalination plants that are not used for environmental and cultural purposes.

The estimated total volume of bulk water extractions across Australia was 16 700 GL in 2014–15. This volume is 4 per cent lower than the estimated 17 400 GL of water extracted in 2013–14. Water extracted for agricultural purposes accounted for 75 per cent (12 600 GL) of the total, with water extractions for urban use following at 19 per cent (3100 GL) (Figure 26). Other uses included in the total are estimates of mining and (non-hydro) power generation activities, 650 GL and 350 GL, respectively.

The values presented here differ from *Water in Australia 2013–14* (Bureau of Meteorology 2015), because some calculation methods and definitions have changed. This will improve the consistency between estimates over time (past and future), better aligning them with the information provided to the Bureau, which has an explicit focus on licensed (and metered) bulk water extractions.

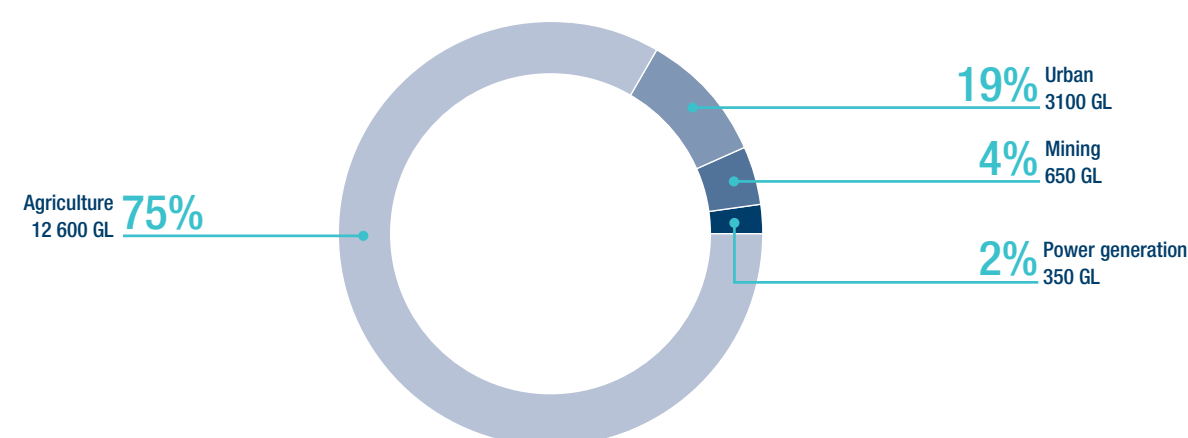


Figure 26. Total bulk water extractions, by use category, 2014–15

The new method excludes the following water-use activities that fall outside this definition:

- Water use from on-farm dams or tanks—although this supports farm water supply, it is not considered as a bulk extraction, as it is not always licensed with an explicit water access licence and is rarely metered. An estimate of about 1200 GL of water use from farm dams was given in the Australian Bureau of Statistics *Water use on Australian farms, 2014–15* report (ABS 2016).
- Land-use changes—any land-use activity that alters the natural soil water balance (such as forestry, irrigation, dryland agriculture and urban developments) can result in more or less water reaching surface water and groundwater resources. As an example, the National Water Commission estimated 2100 GL of reduction in surface water and groundwater recharge because of forestry activities throughout Australia (NWC 2010). However, this activity is not often linked to an explicit water access licence, and little information is available for related activities.

Also excluded are the following water-use activities, which are often controlled by means of water access licences, but for which accurate water extraction volumes are not available:

- Floodplain harvesting—this is the taking of water from a floodplain (i.e. after it leaves a watercourse during a flood) and often storing it in large tanks. This water is only available infrequently, but it can involve significant volumes. However, this activity is largely unmetered, and therefore no information is available about it.

- Rural town water supply—the estimate for urban water extractions only includes data from utilities represented in the *National performance report 2014–15, urban water utilities* (Bureau of Meteorology 2016b). This excludes water sourced by many towns in rural areas throughout Australia, for which data are unavailable.
- Stock and domestic groundwater extractions—most stock and domestic bore extractions are unmetered. In 2010, the National Water Commission provided an estimate of around 1100 GL for this activity (NWC 2010), but updated information is not available.
- Riparian, and stock and domestic surface water rights—many landowners have direct access to surface water from their property, and many have a basic right to extract water from this resource for non-irrigation purposes. Although licensed, these extractions are often unmetered.

Water use by the hydro-electricity sector is also excluded. Although this is the biggest user of water in Australia (in 2013–14, it used around 73 000 GL; ABS 2015), the water is returned to the river and becomes available for use again downstream.

3.3.2 Agricultural water extractions

The total water extracted for agricultural use from surface water and groundwater resources in Australia in 2014–15 is estimated at 12 600 GL (9900 GL surface water, 2700 GL groundwater; Figure 27). This volume can be almost fully attributed to irrigation activities. It dropped by about 6 per cent from the previous year, following lower allocation announcements for general-security entitlements in New South Wales, and lower unregulated water

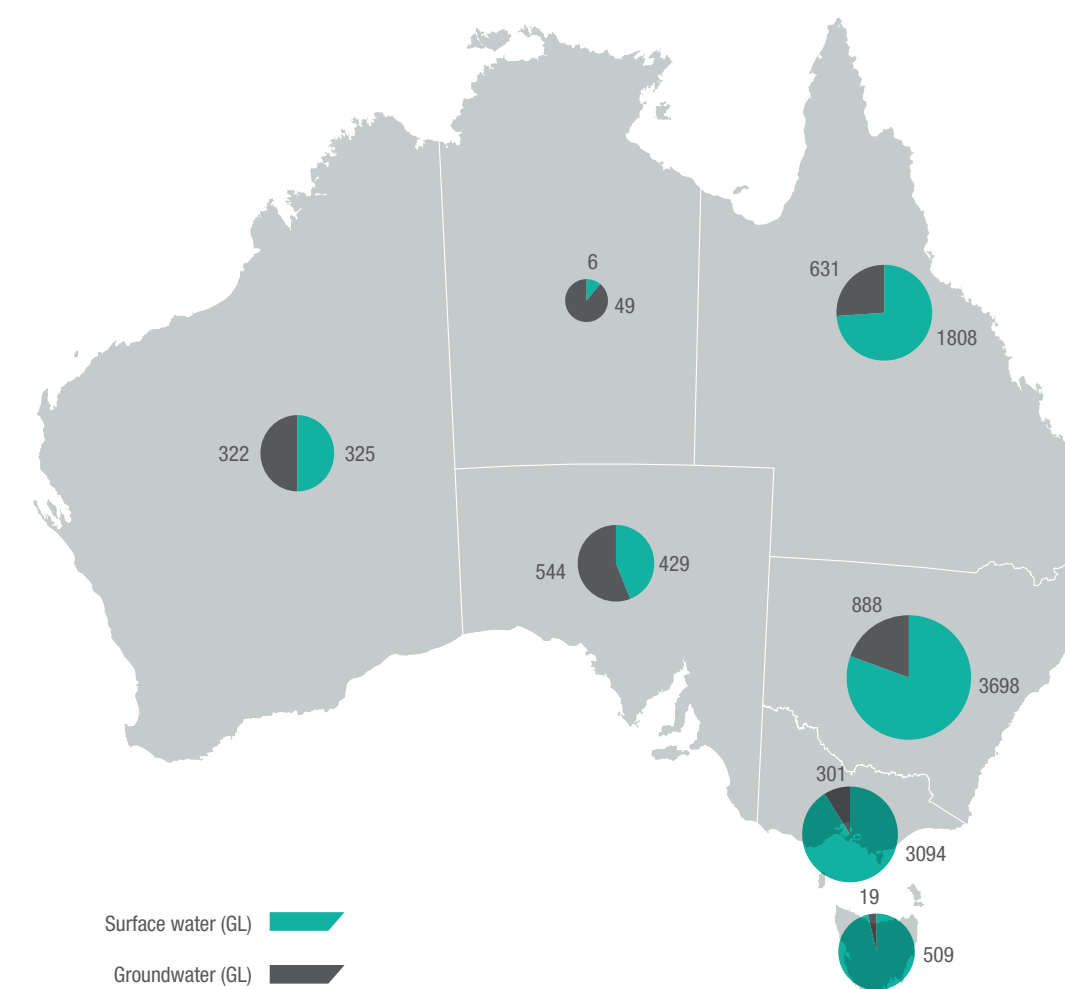


Figure 27. Comparison of agricultural water extractions in each State and Territory, and relative proportion of surface and groundwater use in each jurisdiction

extractions because of the absence of required flow conditions in many of the northern Murray–Darling Basin catchments. Some of this reduction was counterbalanced by an increased use of surface water from high-security allocations in northern Victoria and an increase in groundwater use in South Australia, particularly in the Limestone Coast region. Nationally, surface water extractions for agricultural use decreased by about 9 per cent, or 1000 GL, whereas groundwater extractions increased by about 9 per cent, or slightly more than 200 GL.

These data were based on non-urban diversions in the National Water Account 2015¹¹ and supplemented by data sourced online or received directly from State providers for regions outside National Water Account regions. Groundwater estimates were substituted by data from *Water use on Australian farms 2014–15* (ABS 2016) when the initial estimates were considered to be too low, given existing knowledge about the number of groundwater bores in the specific State or Territory.

Further analysis of water-use information for non-urban purposes is not included because consistent information across the whole country is not available. The Bureau is working with the State and regional data custodians to develop better standards for reporting water-use data to address these inconsistencies. More detailed information on major agricultural water-use regions in Australia is presented in section 3.4.

3.3.3 Water sourced by urban utilities

The total water extracted by urban utilities in 2014–15 was 3100 GL, which includes recycled water used for urban purposes (Bureau of Meteorology 2016b). The urban water-use estimate of 3900 GL in last year's report included a rough estimate of self-extracted water use in regional Australia, which is not included in this year's volume. Applying this year's calculation method for 2013–14 would result in a less than 1 per cent increase in water extracted for urban use.

Urban water use is much less variable between years than agricultural water use. However, urban water use is still partly driven by climatic conditions, particularly rainfall and temperature. Because of the variable climate across Australia, use varies markedly between utilities (Figure 28).

Of Australia's metropolitan areas, Melbourne and South East Queensland (including Brisbane and the Gold Coast) have the lowest urban water use per property (in 2014–15, 214 kL/property and 234 kL/property, respectively). Regional Victoria and Queensland have significantly higher urban water use per property (in 2014–15, 349 kL/property and 345 kL/property, respectively). Per-property water use in regional urban areas is generally higher than in capital cities, reflecting a greater proportion of water used for outdoor purposes. This pattern was stronger in Queensland and Victoria, particularly in the past three years, because of the prolonged dry conditions in southern Queensland and western Victoria. Similarly, regional urban water use per property in South Australia appears to be much higher than in Adelaide.

In contrast, urban water use in greater Sydney and Canberra is similar to the rest of New South Wales (between 270 and 290 kL/property in 2014–15). This is mainly because regional utilities are mostly concentrated along the coastal strip, where rainfall is higher on average than in inland regions.

Urban water use per property in both Darwin and regional Northern Territory is much higher than elsewhere in Australia (in 2014–15, 671 kL/property and 654 kL/property, respectively), most likely driven by the high outdoor water demands in the arid climate of Alice Springs and during the dry season in Darwin. Perth and regional Western Australia have higher urban water use per property than urban centres along the eastern seaboard (in 2014–15, 320 kL/property and 353 kL/property, respectively).



Source: Bureau of Meteorology (2016b)

Figure 28. Urban water use per property for capital cities and regional urban areas in each State and Territory

3.3.4 Sources of water for the capital cities

The sources of water available to urban water utilities are a function of the geographical relationship between the urban centres they supply and the potential water sources. The mix of these sources used at any given time is driven by a combination of climatic and economic factors. Utilities typically aim to minimise the cost of service provision within the constraints of the resources available. To meet their urban consumptive needs, many of Australia's urban centres have traditionally relied on surface water and, to a lesser extent, on groundwater sources. Increased demand driven by population growth and changes in the reliability of existing sources, following changes to water quality and climatic conditions, have resulted in a need for additional water supply sources. Financial, environmental and social constraints mean that there is little opportunity to develop more of the traditional supply sources. As a result, utilities and bulk water suppliers across the country are developing non-traditional supply sources such as desalination and recycling, and exploring options for stormwater and rainwater harvesting.

Sydney, Melbourne, South East Queensland and Canberra still largely rely on surface water (Figure 29). Recent years of above-average rainfall in Sydney and South East Queensland have seen these centres return to sourcing the majority of their urban water needs from surface water. South East Queensland sourced almost all urban water in 2014–15 from surface water, and has done so since 2011–12. Above-average rainfall in the region has maintained reservoirs at high levels (see section 2.2.2). Despite drier-than-average conditions across Canberra and Melbourne since 2012–13, these centres have continued to meet their urban water needs from surface water, relying on their large surface water storage capacities.

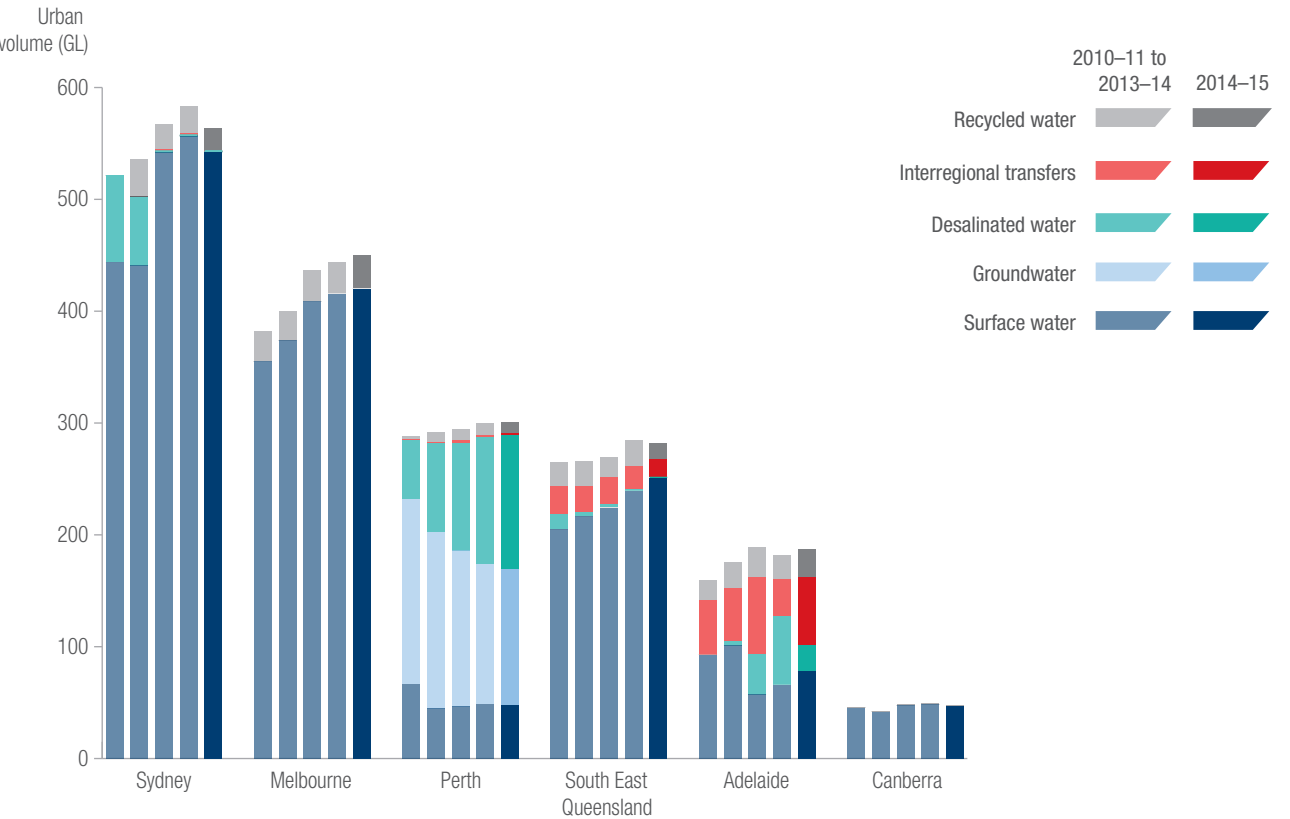
Adelaide, which historically relied on a mix of surface water and transfers from the River Murray, has responded to drought and longer-term climate shifts by diversifying its supply sources. Since 2011, Adelaide's supply has been supplemented by desalinated sea water. However, despite increasingly dry conditions around Adelaide, less of Adelaide's urban demand was met through desalinated

11 www.bom.gov.au/water/nwa/2015/

water in 2014–15 than during the previous two years. This was because of high storage inflows in the autumn and early winter of 2014, and also because of the end of the Adelaide Desalination Plant proving period in December 2014, after which the plant's production went into operational standby. Adelaide has also drawn more water from the River Murray, which is independent of Adelaide's local climate.

Desalination has also become an increasingly important source of urban water in Perth, because southwest Western Australia has faced declining streamflow trends since the 1970s (Bates et al. 2008). Perth draws more water from groundwater and desalination than from surface water.

Recycled water is used in all cities, particularly in Adelaide and Melbourne, where it provided 13 per cent and 8 per cent, respectively, of urban water for 2014–15.



Source: National Water Account 2015¹²
Figure 29. Volumes of water sourced for urban use in Australia's major cities

¹² www.bom.gov.au/water/nwa/2015

3.3.5 Water use for mining and power generation
Agricultural and urban water users are the main bulk water extractors in Australia, but there are others, including operators of mines and power plants.

The total estimate for water consumption in mining, based on the Australian Bureau of Statistics estimate for the past three years, is around 650 GL per year (ABS 2015). Mining water demand is typically sourced from local rivers and aquifers. Groundwater and desalinated water are mostly used in the more arid regions of Australia, where many of the mines are located. Surface water use is more common in the eastern coastal regions, predominantly for coalmining.

The total estimate for water use in electricity generation (excluding hydro-electricity) is around 350 GL per year (ABS 2015). Electricity generation mostly uses surface water, with many large power plants having a high-security entitlement within a regulated river system.

3.4 ASSESSING AUSTRALIA'S MAJOR SUPPLY SYSTEMS

3.4.1 Availability versus use
Australia's largest water-use volumes occur in regulated supply systems that source water from large storages. Systems such as these allow a broad annual water balance assessment, comparing water availability with the actual use in the system. To do so, the following general indicators are applied:

- Physical water availability—the storage volume of the major supply dams at the start of the year, plus the annual inflows into these dams during the year.
- Water-use permissions—the total allocations announced during the year, plus the allocation carryover from the previous year, plus the net allocation trade during the year.
- Actual water use—the total allocated diversions from the storage systems requested by holders of regulated entitlements during the year.

Figures 30 to 32 present the water balance picture between surface water availability and use for major urban and irrigation supply systems with more than 100 GL annual use and for which data were available. The data shown include environmental availability and use to display the full permission and use volumes, and because a distinction between commercial and environmental volumes was not available for all systems.

Inflows into dams are modelled, with the runoff estimated by the Australian Water Resources Assessment modelling system¹³ except for the Perth system, where data were supplied from the Water Corporation¹⁴.

¹³ www.bom.gov.au/water/landscape
¹⁴ www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams/streamflow

Comparison between the three indicators provides a simplified view of how physical water availability influences water-use permissions, and how these permissions affect actual use in terms of time and volume. These broad generalisations do not describe how the water supply systems operate under their water management plans.

As mentioned above, Australia's northern regions have high physical water availability throughout the year. As a result, use permissions and use vary little between years, with generally full allocations announced against the entitlements. The total annual use in these regions is more a function of crop demand, following varying climatic conditions during the growing season, rather than of allocated water availability.

In the Ord River Irrigation Scheme, allocations in 2014–15 increased by 120 GL because new entitlements were made available. A new licence was issued to Kimberley Agricultural Investment Pty Ltd in the autumn of 2015 for water diversion to the Goomig Farmlands. Because allocations for the Ord River Irrigation Scheme are generally 100 per cent, the full 120 GL increase is shown in Figure 30.

The northern Murray–Darling Basin catchments (regions 1 to 4 in Figure 31) and the Lachlan catchment all show a clear trend of increasing physical water availability coming out of the 1996–2010 Millennium Drought. Use permissions and actual use followed this trend, generally with a one-year time lag. This is a consequence of annual strategic planning by irrigators, using carryover as a security to provide higher water-use permissions in the following year.

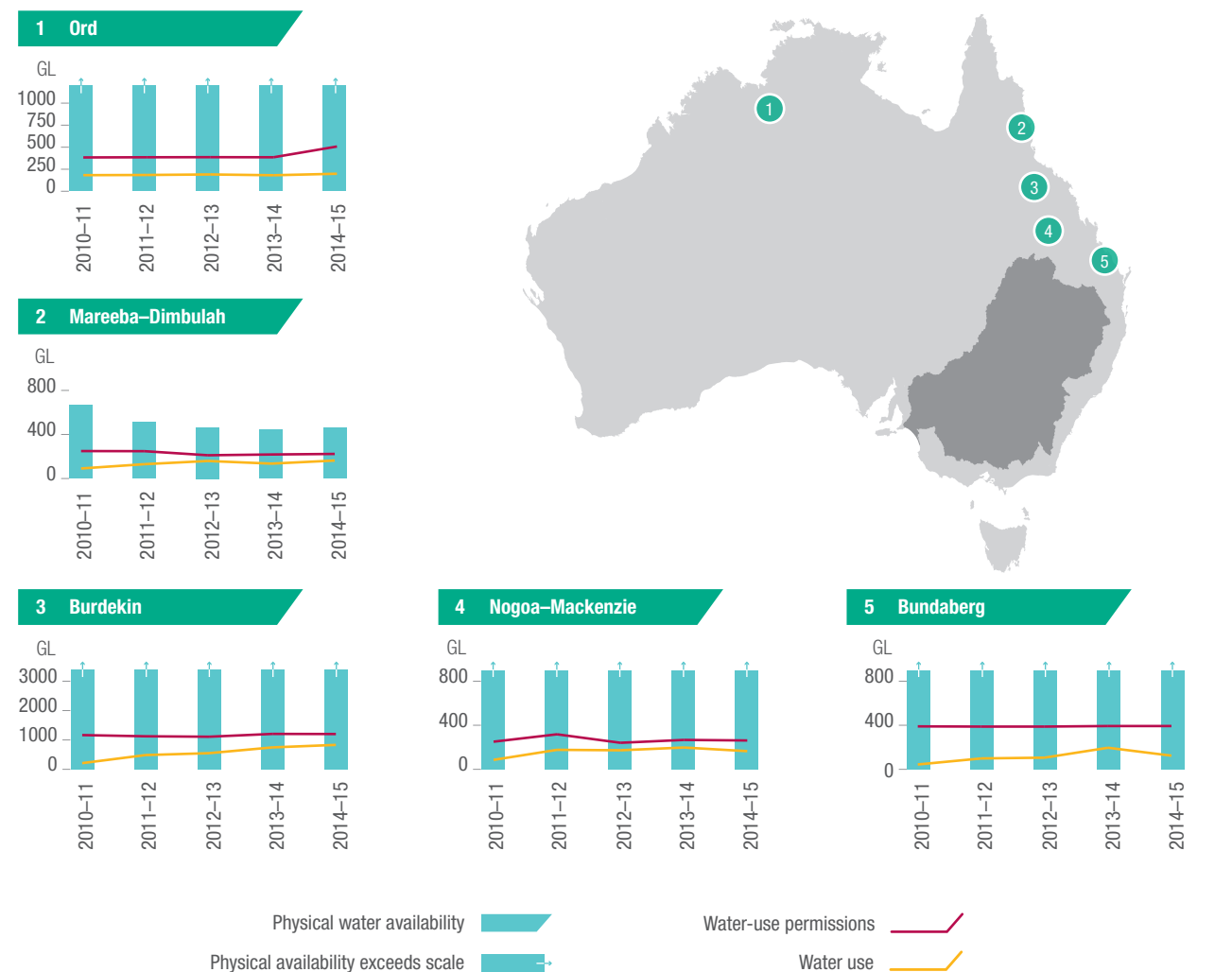


Figure 30. Availability in northern Australia of surface water versus water permissions and actual diversions in regulated systems with more than 100 GL of annual use

If farmers are not confident that they will have enough water for their crops during the next year, they are likely to reduce their potential water demands for the next year by adjusting their plantings. If more water becomes available through the year, the choice of crops cannot be adjusted and the remaining water allocations have a high chance of being carried over to the next year. This increases the water availability for the following year, unless allocation announcements in that year drop substantially. This behaviour also increases the water use for the following year, because farmers have more confidence about water availability, and thus plant more crops or crops with higher water demands. In 2014-15, physical availability and

water-use permissions were the lowest in the past five years, with annual use approaching total annual water-use permissions, meaning that carryover for 2015-16 will be very low in these regions (see section 3.4.2).

The southern Murray-Darling Basin catchments (regions 6 to 8 in Figure 31) have less variability in physical water availability volumes, because of larger storage capacities and slightly less variable rainfall conditions between years compared with the northern Murray-Darling Basin catchments. In the southern Murray-Darling Basin, the past five years of water availability have been adequate, and, as a consequence, carryover volumes varied

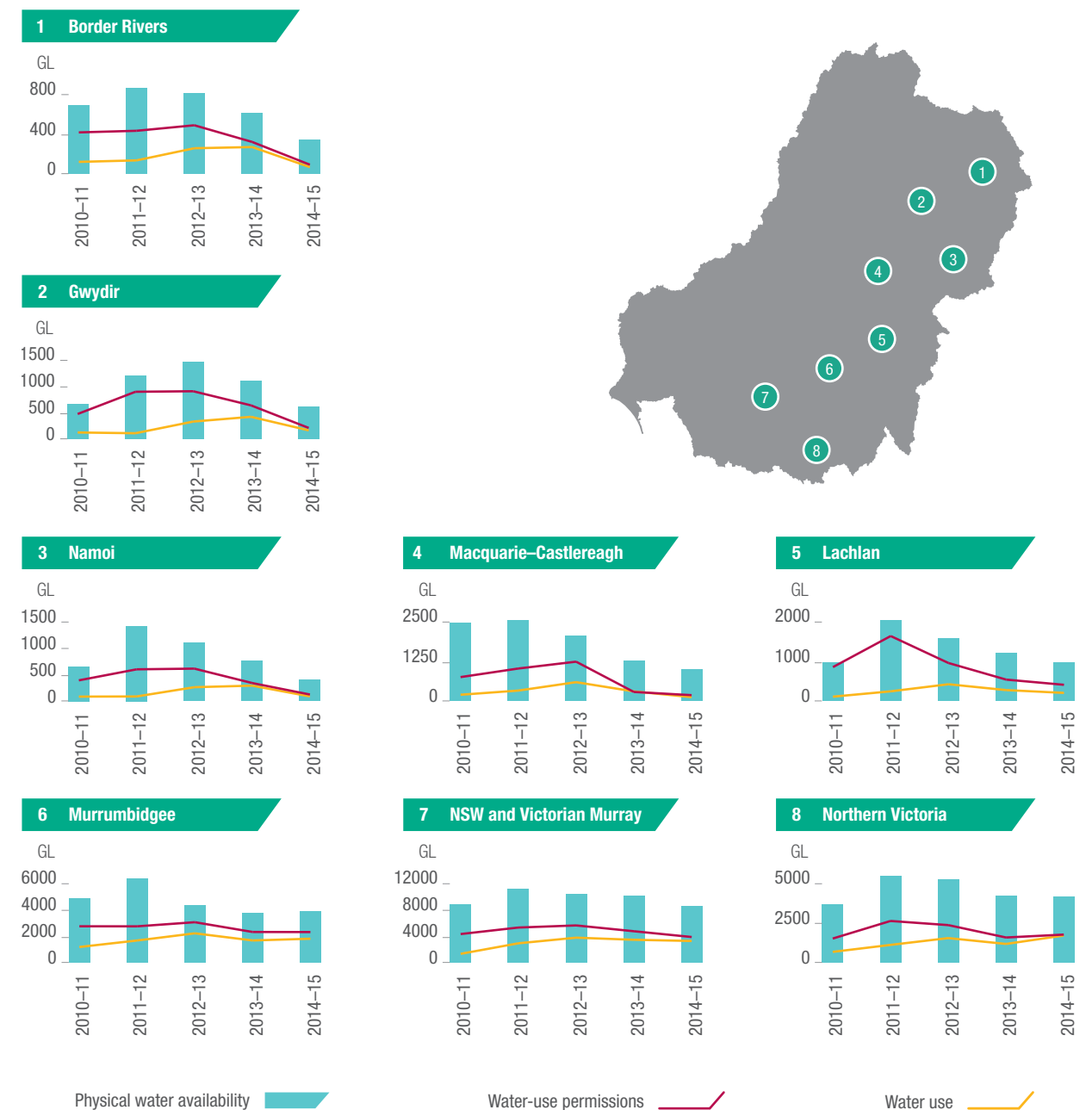


Figure 31. Availability in the Murray-Darling Basin of surface water versus water permissions and actual diversions in regulated systems with more than 100 GL of annual use

little between years. The annual volume of water-use permissions closely followed physical water availability. Irrigators planned their crop types and volumes under high-security conditions during the past four to five years, which resulted in fairly stable use levels in the past three years, particularly in the New South Wales Murray and Victorian Murray systems.

As mentioned previously, the New South Wales Murray, Victorian Murray and Murrumbidgee water planning areas are where most environmental entitlements are issued, meaning that use patterns in Figure 31 are also influenced by environmental water releases. Particularly in the past two years, the volume of water use has moved towards the volume of water-use permissions, meaning that carryover volumes are decreasing.

Comparing urban systems in Figure 32 shows that relatively high water availability levels in South East Queensland and Sydney result in a slow but steady increase in use, which largely mimics the population growth. Melbourne has high water-use permissions because of the particular allocation rules that are applied. Physical water availability and urban water use in Melbourne, however, follow a pattern similar to the South East Queensland and Sydney regions.

In contrast, water-use permissions in Adelaide and Perth are not as closely linked to physical availability, because different management rules apply. In Perth, and to some extent in Adelaide, surface water use is largely related to the inflows the storages receive, which are relatively low. These storages are also topped up with desalinated water and groundwater, further obscuring the story told by the physical water availability indicator alone.

Urban water supply is supplemented by other sources (see Figure 29) and, therefore, total water use in these regions is less variable than regulated surface water use only.

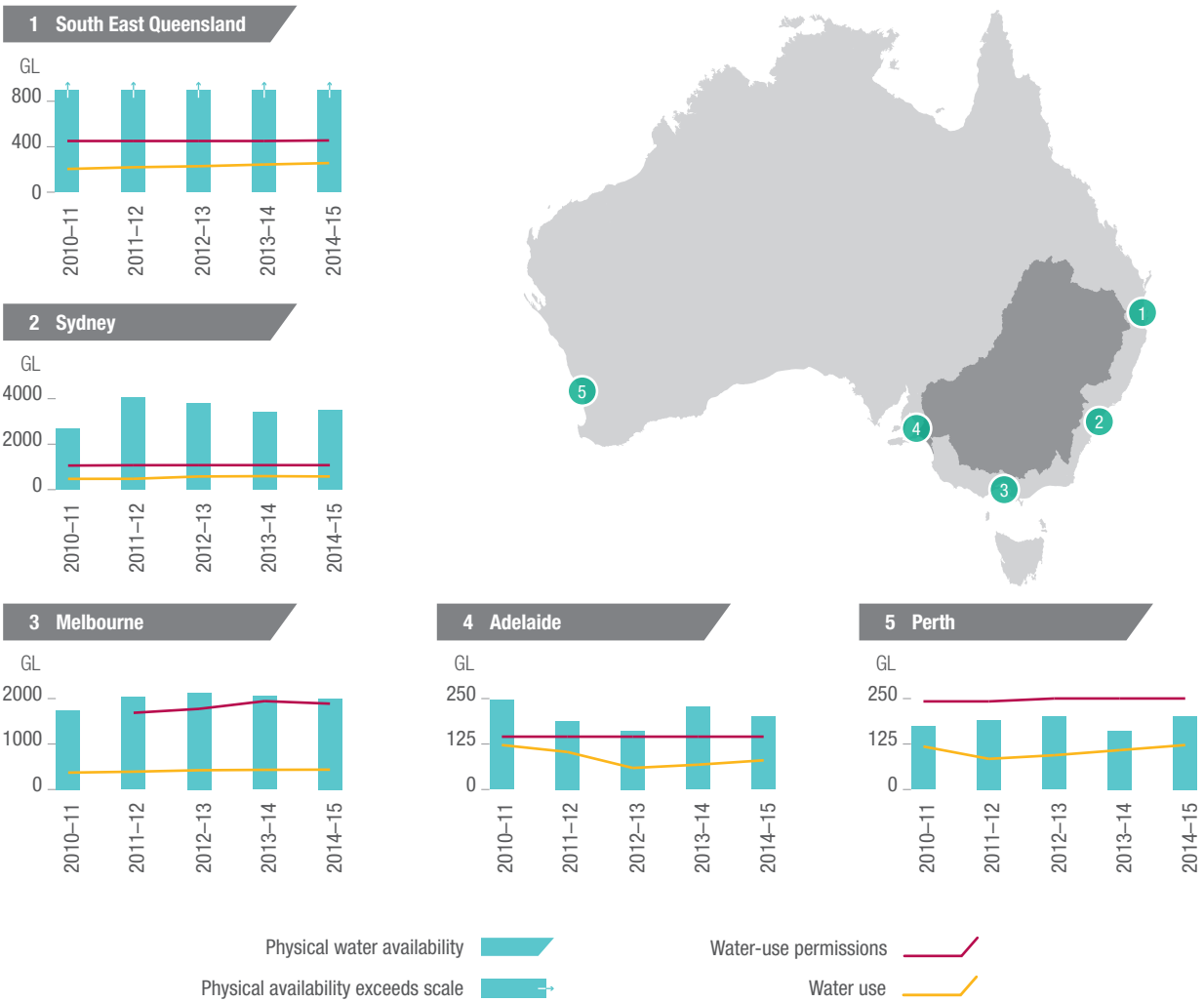


Figure 32. Availability in major cities of Australia of surface water versus water permissions and actual diversions in regulated systems with more than 100 GL of annual use

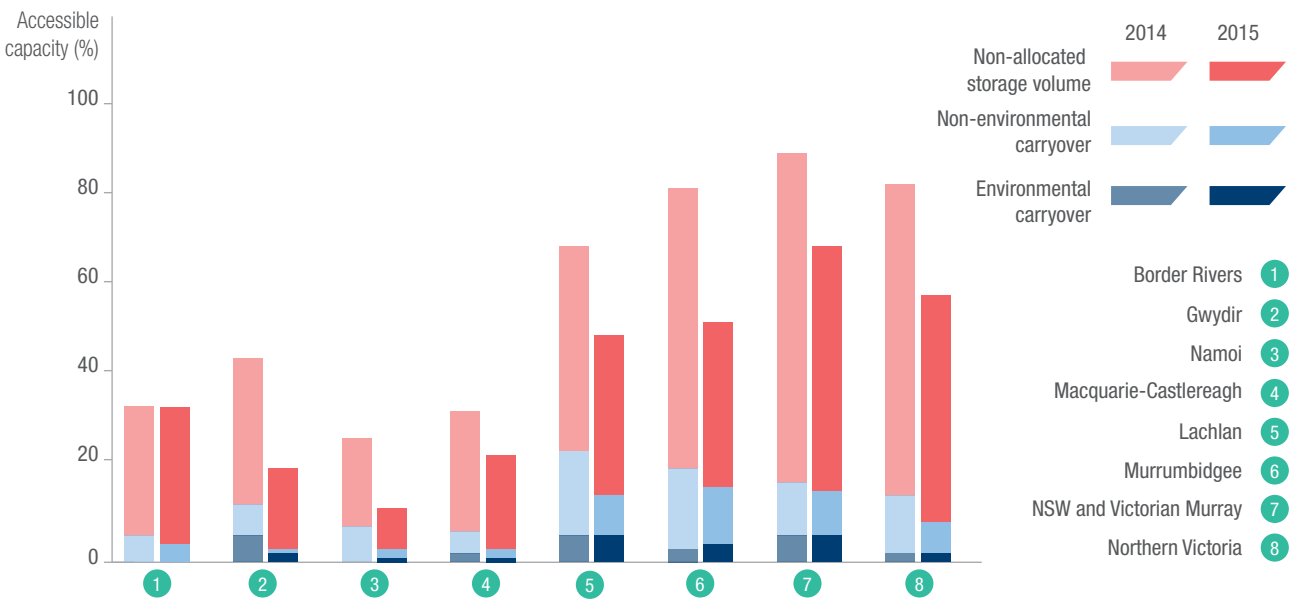
3.4.2 Allocation carryover

Allocation carryover occurs when water allocations are not fully used within the allocation period and are permitted to be transferred to the next period. At the start of 2015-16, storage volumes for the major supply systems that facilitate carryover were generally lower than at the beginning of 2014-15 (Figure 33). Total carryover volumes have dropped as well. However, there was minimal change in the environmental carryover volumes between the start of 2014-15 and the start of 2015-16. The majority of carryover volume decreases were absorbed by non-environmental entitlement holders. This is likely the consequence of the application of a longer-term strategy by environmental water holders in comparison with the business strategies applied by irrigators.

Also, the non-allocated residual storage volumes have dropped substantially, except in the Border Rivers catchments. This had implications for the announcement

of opening allocations in 2015-16, which were mostly zero for the general- and medium-security entitlement holders in the New South Wales and Queensland parts of the Murray-Darling Basin. Moreover, even some high-security entitlement holders were given less than 100 per cent opening allocations for 2015-16.

Allocation carryover is one of the key mechanisms that allow irrigators and other water users to better plan their future business activities. Saving water for next year gives a higher level of confidence that the total water needs for that year will be satisfied, because the need for additional allocation announcements is lower. Following the lower carryover levels at the start of 2015-16, it is to be expected that many irrigators have adopted a conservative strategy regarding the 2015-16 growing season, which will likely be reflected in lower surface water diversion volumes for 2015-16 in the Murray-Darling Basin.



Note: The catchment numbers on this graph match the numbers on Figure 31.

Figure 33. Storage volumes at 1 July 2014 and 2015, including environmental and non-environmental carryover from the previous year

GLOSSARY

Aboriginal water	Water resources of an area that are recognised or used by Aboriginal peoples for their social, spiritual and cultural values.
accessible storage capacity	The volume of water that a water storage can hold between the minimum supply level and full supply level; equal to the total storage capacity excluding the dead storage capacity. It is the sum of this capacity that is reported for a collection of water storages. See the Bureau's water storage diagram web page for more information. (www.bom.gov.au/water/waterstorage/glossary.shtml#diagram)
aquifer	An underground layer of saturated rock, sand or gravel that absorbs water and allows it to pass freely through pore spaces.
bore	A hole drilled in the ground, a well or any other excavation used to access groundwater. May be used for observation of groundwater (including water level, pressure or water quality).
catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
climate	The average long-term weather conditions in a particular area. See the Bureau's climate web page for more information. (www.bom.gov.au/climate/glossary/climate.shtml)
confined aquifer	An aquifer overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer. Typically, groundwater in a confined aquifer is under a pressure significantly greater than atmospheric pressure.
dead storage	In a water storage, the volume of water stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.
desalination	The process of removing salt from brackish or saline water.
drought	A long period of abnormally low rainfall, especially one that adversely affects agriculture and other human activities. See the Bureau's web page on drought for more information. (www.bom.gov.au/climate/glossary/drought.shtml)
ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
El Niño	Refers to the extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions. See the Bureau's Weather and Climate web page on El Niño for more information. (www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml?bookmark=elnino).
El Niño–Southern Oscillation (ENSO)	The oscillation between the El Niño climate phase and the La Niña climate phase, usually over several years. See the Bureau's web page on ENSO for more information. (www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml?bookmark=enso)
electrical conductivity	In relation to water, the capacity of the water to transmit a flow of electricity; this is a common measure of the salinity of the water.

entitlement security	The frequency with which water allocated under a water access entitlement is able to be supplied in full.
entitlement system	A jurisdictional gazetted instrument (e.g. water sharing plan), subordinate to the overarching State or Territory water rights legislation, intended to share the portion of the total water resource it covers.
environmental flow	The streamflow required to maintain appropriate environmental conditions in a waterway or water body.
environmental water	Water that is available or preserved, to achieve environmental outcomes, including ecosystem function, biodiversity, water quality and water resource health.
environmental water release	Release of water from infrastructure, such as a surface water storage, for the benefit of the environment.
evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour. In relation to water resource assessment and water accounting, evaporation refers to the movement of water from the land surface (predominantly liquid) to the atmosphere (water vapour). The liquid water at the land surface that may be available for evaporation includes surface water, soil water, water within vegetation, and water on vegetation and paved surfaces.
evapotranspiration	The sum of evaporation and plant transpiration from the earth's land surface to the atmosphere.
farm dam	Small water storage, usually managed by the landowner, with a capacity usually less than 100 ML. The volume includes dead storage.
floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.
groundwater	Subsurface water in soils and geological formations that are fully saturated.
groundwater level	The level of groundwater in an aquifer, typically measured in a groundwater bore. In the case of an unconfined aquifer, the groundwater level is equal to the water table level.
groundwater management plan	A document providing information about groundwater access for users. It may include rules about transferring licence entitlements, and arrangements that allow carryover of groundwater entitlements. It may also outline water sharing arrangements during times of water shortage.
groundwater recharge	The infiltration or ingress of water to the saturated part of a geological layer. Infiltration of precipitation and its movement to the water table is a form of natural recharge. Other forms of recharge are flooding and irrigation. Artificial recharge can also occur through various means, including bore injection.
irrigation right	A right issued by an irrigation entity and granted from the entity's bulk water access entitlement.
La Niña	The extensive cooling of the central and eastern Pacific Ocean. In Australia (particularly eastern Australia), La Niña events are associated with an increased probability of wetter conditions. See the Bureau's Australian Climate Influences web page on La Niña for more information. (www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml)

Millennium Drought	The prolonged period of dry conditions experienced in much of southern Australia from late 1996 to mid-2010.
potable water	Water that is intended for use as drinking water and should materially meet the Australian Drinking Water Guidelines 2004, or equivalent.
rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge.
recycled water	Treated sewage effluent. Includes water extracted by sewer mining and subsequently treated. Does not include treated urban stormwater.
regulated river	River on which a licensed entitlement regime exists with centralised allocation, and from which orders may be placed for upstream release of a licensed allocation. A necessary, but not sufficient, condition for a river to be regulated is that it is located downstream of a surface water storage. Note: the term ‘river’ can be replaced with ‘channel’ and retain the same meaning.
residential water	The total amount of metered and estimated non-metered, potable and non-potable water supplied to residential properties.
riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
salinity	The concentration of soluble salts in a solution, soil or other medium.
soil moisture	The water content in the unsaturated zone of a soil profile.
stock and domestic water use	Use of water for domestic consumption (e.g. drinking, cooking, washing, watering household gardens, filling swimming pools associated with domestic premises) and to water stock on a property. Does not include water used for irrigating crops that will be sold, bartered or used for stock fodder, for washing down machinery sheds, or for intensive livestock operations.
storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
storage level	The elevation of the water surface in a water storage at a particular time and date, measured relative to a specified datum, typically the Australian Height Datum. See the Bureau’s water storage diagram web page for more information. (www.bom.gov.au/water/waterstorage/glossary.shtml#diagram)
storage system	A water storage or group of water storages from which releases and diversions are the main source of water for users within the boundaries of a particular region, normally aligning with a river catchment.
storage volume	The volume of water stored at a particular time and date. It excludes the dead storage volume and is therefore the volume of water that can be accessed under normal circumstances without the installation of additional infrastructure.
streamflow	The flow of water in streams, rivers and other channels.
surface water	Includes: (a) water in a watercourse, lake or wetland, and (b) any water flowing over or lying on land, (i) after having precipitated naturally or (ii) after having risen to the surface naturally from underground.
total dissolved solids (TDS)	The sum of all particulate material dissolved in water. Usually expressed in terms of milligrams per litre (mg/L). It can be measured by evaporating the solvent and measuring the mass of residues left or may be estimated from the electrical conductivity of the water.
total storage capacity	The entire volume of water contained by the water storage at full supply level, which is equal to the sum of the accessible storage capacity and the dead storage capacity. See the Bureau’s water storage diagram web page for more information. (www.bom.gov.au/water/waterstorage/glossary.shtml#diagram)

transpiration	The release of water vapour from parts of plants, especially through the stomata of leaves.
unconfined aquifer	An aquifer whose upper surface is a water table that is free to fluctuate in equilibrium with atmospheric pressure.
unregulated river	A river where there is no entitlement system at all or where there is an entitlement system that does not allow orders to be placed for upstream release of a licensed allocation. Note: the term ‘river’ can be replaced with ‘channel’ and retain the same meaning.
urban water	The total residential, commercial, municipal, industrial and other water supplied by urban water utilities.
water access entitlement	A perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan.
water allocation	The specific volume of water allocated to water access entitlements in a given season or given accounting period, and defined according to rules established in the relevant water plan.
water quality	The physical, chemical and biological characteristics of water. Water-quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact, and the health of ecosystems.
water resource	All natural water (surface water and groundwater) and alternative water sources, such as recycled or desalinated water, that has not yet been abstracted or used.
water resource plan	A plan for the management of a water resource.
water restrictions	Any constraints or restrictions placed on water use by an infrastructure operator, local council, or State or Territory government.
water right	A generic term for the range of different tradeable and non-tradeable water rights across Australia. These might include water access entitlements, water allocations, water-use rights, delivery rights, irrigation rights and works approvals.
water sharing plan	A legislated plan that establishes rules for managing and sharing water between ecological processes and environmental needs of the respective water source (river/aquifer). It manages water access licences, water allocation and trading, extraction, operation of dams and management of water flows, and use and rights of different water users.
water table	The groundwater surface in an unconfined aquifer or confining bed at which the pore pressure is atmospheric. It can be measured by installing shallow wells extending a few metres into the saturated zone and then determining the water level in those wells.
water trade	A transaction to buy, sell or lease a water right, in whole or in part, from one legal entity to another.
water-use right	A right that allows use of water by specifying location of the use (plot) and/or purpose of the use.
wetland	An area of land whose soil is saturated with moisture, either permanently or intermittently. Wetlands are typically highly productive ecosystems. They include areas of marsh, fen, parkland and open water. Open water can be natural or artificial; permanent or temporary; static or flowing; and fresh, brackish or salt. Wetlands may include areas of marine water, as long as the depth at low tide does not exceed six metres.

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