# South East Coast (NSW)

# 4 South East Coast (NSW)

## 4.1 Introduction

This chapter examines water resources in the South East Coast (NSW) region in 2011–12 and over recent decades. It starts with summary information on the status of water flows, stores and use. This is followed by descriptive information for the region including the physiographic characteristics, soil types, population, land use and climate.

Spatial and temporal patterns in landscape water flows are presented as well as an examination of the surface and groundwater resources. The chapter concludes with a review of the water situation for urban centres and irrigation areas. The data sources and methods used in developing the diagrams and maps are listed in the Technical Supplement.

## 4.2 Key information

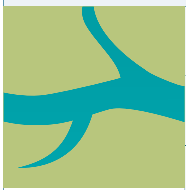
Table 4.1 gives an overview of the key components of the data and information in this chapter

Table 4.1 Key information on water flows, stores and use in the South East Coast (NSW) region

**Landscape water flows**

| | Region average | Difference from 1911–2012 long-term annual mean | Decile ranking with respect to the 1911–2012 record |
|---|---|---|---|
| Rainfall | 1,265 mm | +25% | 9th—above average |
| Evapo-transpiration | 919 mm | +12% | 9th—above average |
| Landscape water yield | 352 mm | +84% | 10th—very much above average |

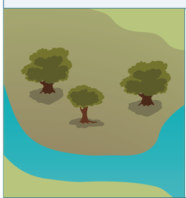
**Streamflow (at selected gauges)**

| | | |
|---|---|---|
|  | Annual totals: | Above average flow throughout the region, locally very much above average |
| | Salinity: | Annual median electrical conductivity predominantly below 1,000 µS/cm (Hunter River basin only) |
| | Flooding: | Minor to moderate flooding in many rivers, locally major flooding in the north |

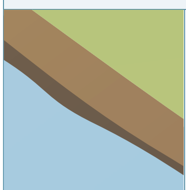
**Surface water storage (comprising about 83% of the region's total capacity of all major storages)**

| | Total accessible capacity | 30 June 2012 | | 30 June 2011 | | Change | |
|---|---|---|---|---|---|---|---|
| | | accessible volume | % of total capacity | accessible volume | % of total capacity | accessible volume | % of total capacity |
|  | 3,853 GL | 3,658 GL | 95% | 3,049 GL | 79% | +609 GL | +16% |

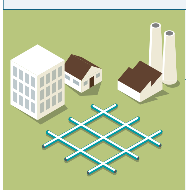
**Wetlands inflow patterns (for selected wetlands)**

| | | |
|---|---|---|
|  | Hunter Estuary wetlands: | Above average flows throughout the year, with particularly high flows in November, February and March |

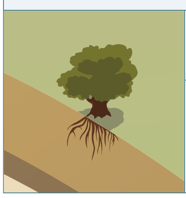
**Groundwater (in selected aquifers)**

| | | |
|---|---|---|
|  | Salinity: | Scattered areas of saline groundwater (≥3,000 mg/L), particularly in coastal aquifers |

**Urban water use (Sydney)**

| | Total use in 2011–12 | Total use in 2010–11 | Change | Restrictions |
|---|---|---|---|---|
|  | 528 GL | 544 GL | –16 GL (–3%) | Water Wise Rules |

**Annual mean soil moisture (model estimates)**

| | | |
|---|---|---|
|  | Spatial patterns: | Very much above average soil moisture levels in the centre and north of the region, above average in the south |
| | Temporal patterns in regional average: | Above average to very much above average regional average soil moisture throughout the year |

## 4.3 Description of the region

The South East Coast (NSW) region covers all of coastal New South Wales, and has a total area of 129,500 km². The western and eastern boundaries of the region are defined by the Great Dividing Range and the coast. The northern boundary is defined as the New South Wales–Queensland border, and the southern boundary reflects the dividing line between the Towamba and East Gippsland river basins.

The southern part of the region has extensive forested headwaters, large areas of national park and state forest, important wetlands, river estuaries and fresh water swamps. The main catchments are those of the Shoalhaven, Clyde, Deua, Tuross, Bega and Towamba rivers. Subsections 4.3.1–4.3.4 give more detail on physical characteristics of the region.

The region has a population of over 6 million people, just under one third of Australia's total population (Australian Bureau of Statistics [ABS] 2011b), and includes Australia's largest and most densely populated city, Sydney.

Figure 4.1 highlights the major population centres in the region. These include Newcastle, the Central Coast and Wollongong, Further discussion of the region's population distribution and urban centres can be found in subsections 4.3.6 and 4.6 respectively.

Nature conservation is the main feature of the region (44%) followed by dryland pasture (37%). In the north of the region, subtropical cropping is common, and a mix of irrigated and dryland cropping is practised depending on the frequency of rainfall. In the mid-coast area, irrigated agriculture is common and mostly occurs in the Hunter River basin. Irrigation concerns mainly wine grapes and dairy pasture. In the south of the region, irrigation of broadacre and dairy farming enterprises occurs in the Hawkesbury–Nepean and Bega river basins. Section 4.7 has more information on the region's agricultural activities.

The region has a warm temperate climate with a moderate and generally reliable rainfall due to the presence of the Great Dividing Range. The proximity of the coast moderates weather extremes. Subsections 4.3.7 and 4.3.8 provide more information on the rainfall patterns and deficits across the region.

The Clarence River is the largest in the region in terms of annual discharge into the sea (Figure 4.1). The Hawkesbury and Hunter river basins are similar in size and form two important systems in the region in terms of urban and irrigation water supply.

Groundwater systems in the region that generally provide good potential for extraction include:

- Surficial sediment aquifer (porous media— unconsolidated);
- Tertiary basalt aquifer (fractured rock); and
- Mesozoic sediment aquifer (porous media—consolidated).

A more detailed description of the surface water and groundwater status in the region is given in section 4.5.

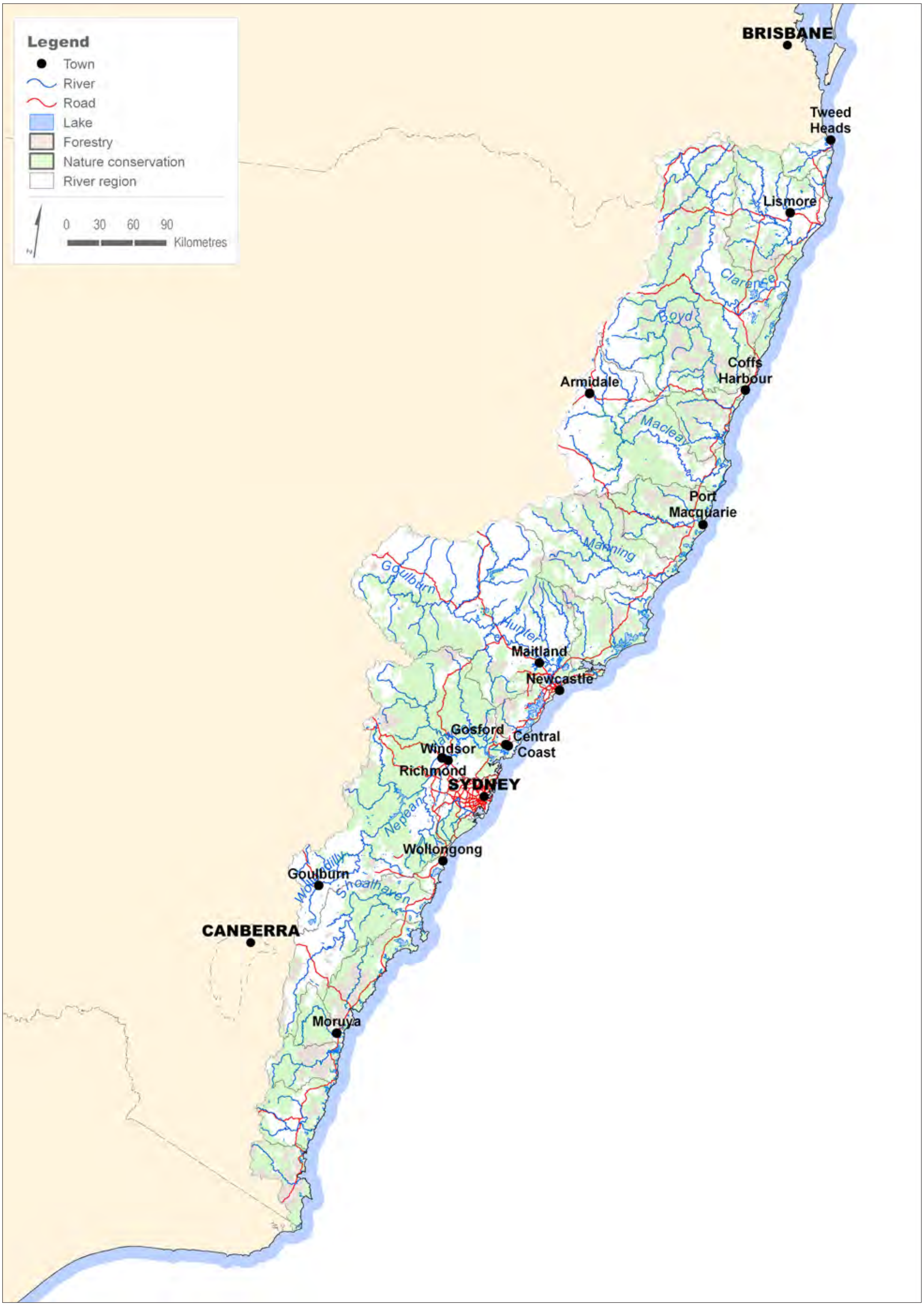



Figure 4.1 Major rivers and urban centres in the South East Coast (NSW) region

### 4.3.1 Physiographic characteristics

The physiographic map in Figure 4.2 shows areas with similar landform evolutionary histories (Pain et al. 2011). These can be related back to similar geology and climatic impacts which define the extent of erosion processes. The areas have distinct physical characteristics that can influence hydrological processes.

The South East Coast (NSW) region has three physiographic provinces, namely:

- Kosciuszkan Uplands (13%): dissected high uplands on various resistant rocks, with isolated high plains;
- Macquarie Uplands (34%): deeply dissected sandstone plateaus over most of the area with rolling basalt uplands and sandstone cliffs in the northwest; and
- New England–Moreton Uplands (53%): dissected plateau margin on igneous and metamorphic rocks with coastal lowlands on weak sedimentary rocks, with littoral and alluvial plains.


Figure 4.2 Physiographic provinces of the South East Coast (NSW) region

## 4.3.2 Elevation

The western border of the South East Coast (NSW) region is clearly defined by the crest of the Great Dividing Range. The crest runs almost parallel with the coastline, with the exception of the western borders of the Hunter River basin.

As shown in Figure 4.3, the region contains many mountain ranges that belong to the Great Dividing Range (information was obtained from the Geoscience Australia website, www.ga.gov.au/topographic-mapping/digital-elevation-data.html). It also contains some plateaus and an almost continuous stretch of low-lying coastal areas.

The highest mountains in the region can be found west of Coffs Harbour, with peaks reaching altitudes of 1,500 m above sea level.

The crest of the Great Dividing Range forms the western border of the region, all the way from the north to the south. Altitudes on this crest line vary between less than 600 m at the western part of the Hunter River basin to more than 1,200 m in both the north and the south.

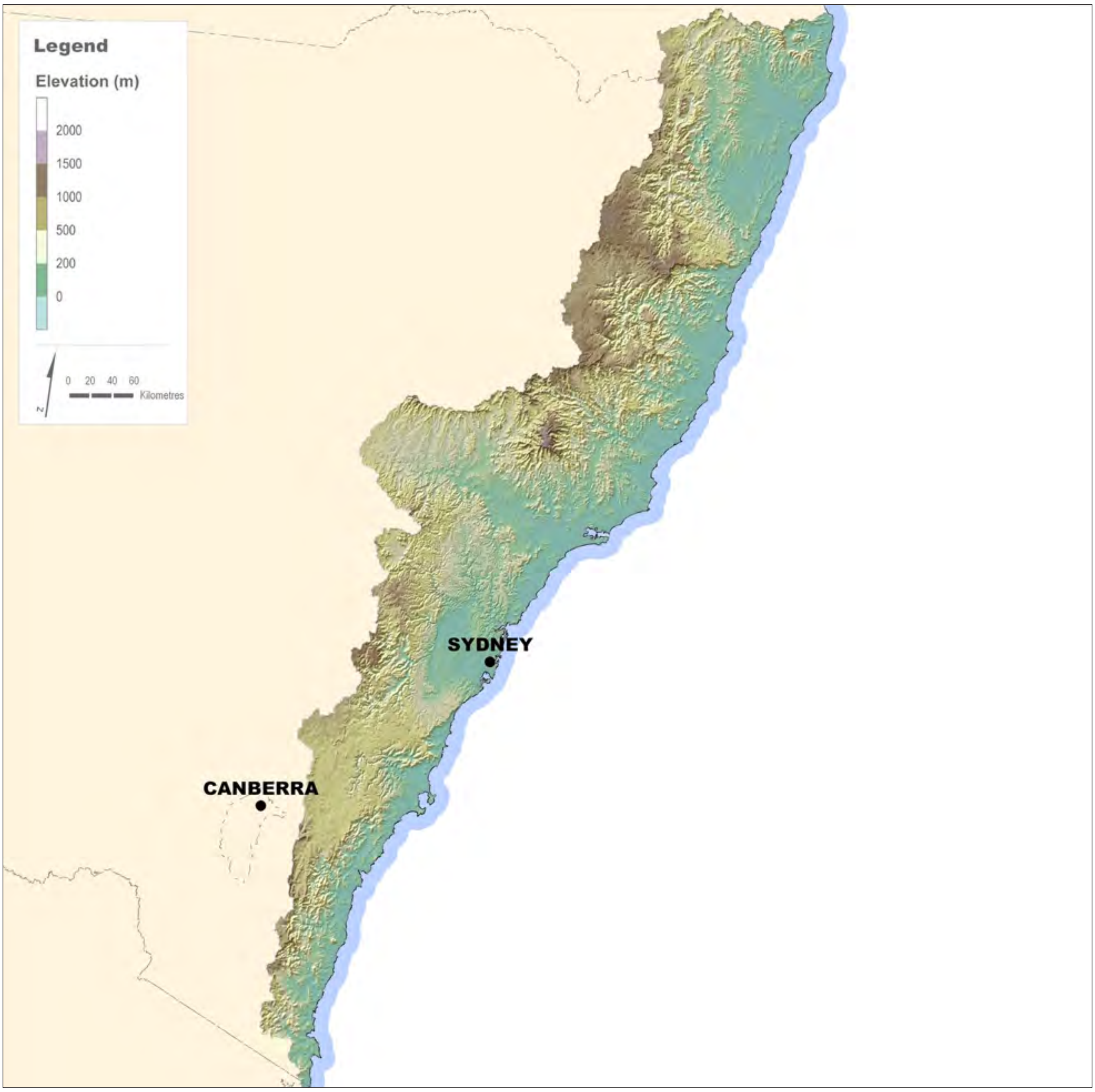



Figure 4.3 Ground surface elevations in the South East Coast (NSW) region

### 4.3.3 Slopes

Areas with steep slopes provide higher run-off generating potential than flat areas. Table 4.2 shows the extent of steep slopes in the South East Coast (NSW) region. This is greater than for other regions in mainland Australia. The slopes were derived from the elevation information used in the previous section.

Table 4.2 Proportions of slope classes for the region

| Slope class (%) | 0–0.5 | 0.5–1 | 1–5 | > 5 |
|---|---|---|---|---|
| Proportion of region (%) | 4.9 | 4.5 | 29.9 | 60.7 |

The steep slopes in Figure 4.4 in particular show the wide escarpments of the western plateau. The eastern part of the plateau forms most of the water divide of the river basins. In fact, the highest peaks of the Great Dividing Range in this region are not necessarily located on the border of the region.

The steep slopes of the Great Dividing Range only come close to the coast around Sydney and Coffs Harbour. Also, the coastal plains of the south coast are relatively narrow.

Due to the steep slopes in the region, rivers rapidly accumulate run-off. As a consequence, high intensity rainfall often cause flash flooding in the narrow flat coastal strip. Recent years have provided clear examples of such flood in the region.

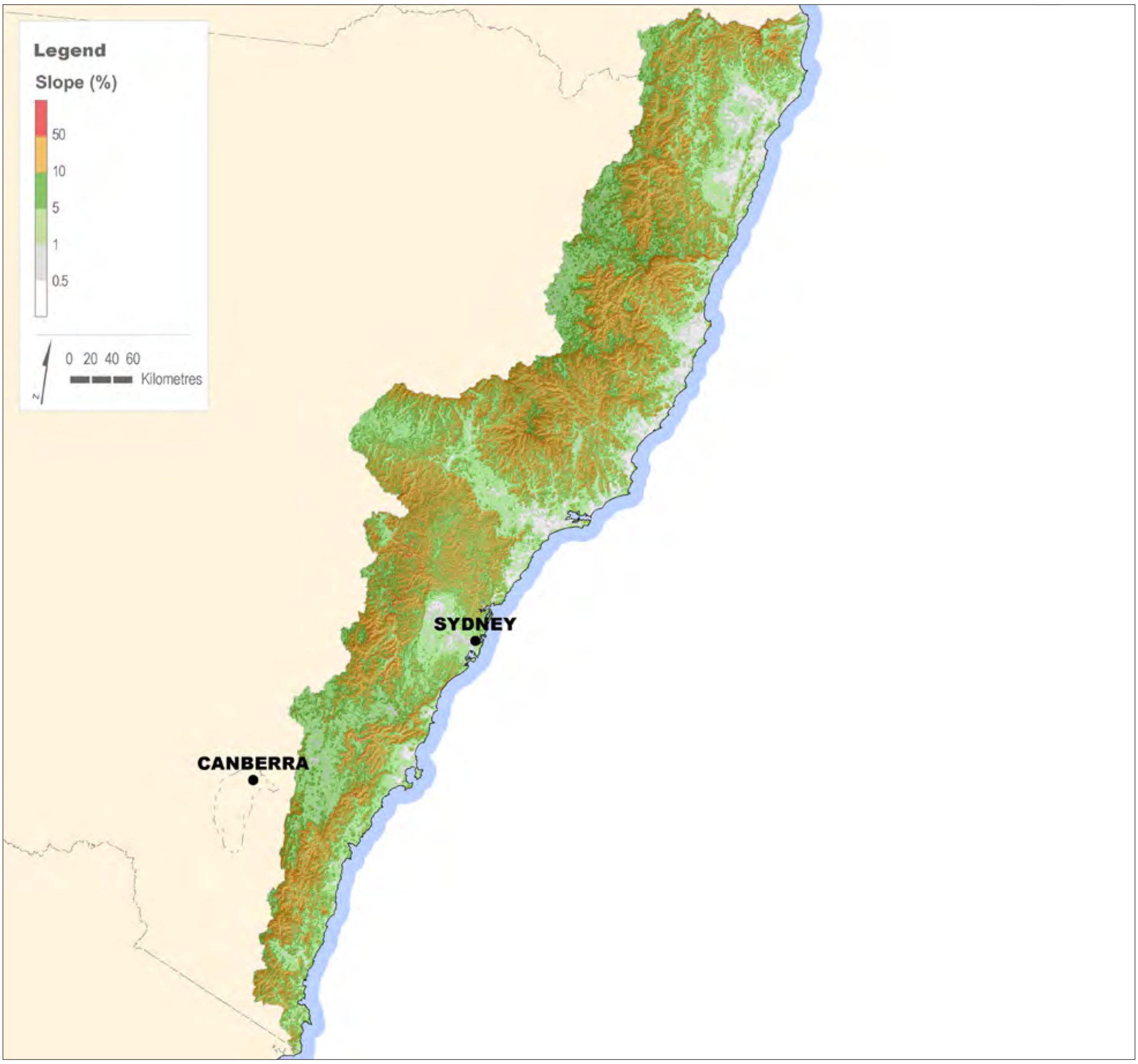



Figure 4.4 Surface slopes in the South East Coast (NSW) region

### 4.3.4 Soil types

Soils play an important role in the hydrological cycle by distributing water that reaches the ground. Water can be transported to rivers and lakes via the soil surface as run-off or enter the soil and provide water for plant growth as well as contributing to groundwater recharge.

The nature of these hydrological pathways and the suitability of the soils for agricultural purposes are influenced by soil types and their characteristics. Soil type information was obtained from the Australian Soil Resource Information System website (www.asris.csiro.au).

About 87% of the South East Coast (NSW) region is covered by five soil types, namely kandosols, dermosols, kurosols, sodosols and tenosols (Figure 4.5 and Figure 4.6).

Kandosols are structureless soils and are often very deep (up to three metres or more). They do not have a strongly contrasting texture and do not contain carbonate throughout their profile. They are low in chemical fertility and are well drained. With only moderate water-holding capacity compared with other soil types, they only have low to moderate agricultural potential. In this region, they are mostly present in pastures and areas used for nature conservation.

Soils with higher agricultural potential and moderate to high chemical fertility are dermosols. These soils are mostly present in the northern and southern parts of the region. They are well structured and have a high water-holding capacity, and they are mostly present in areas used for forestry and nature conservation.

Another soil type common in this region is kurosol. Soils of this type are strongly acidic (pH < 5.5) and have an abrupt increase in clay in the soil profile. Their use for agriculture is limited due to low chemical fertility and low water-holding capacity. Kurosols are mostly present in improved dairy pastures and areas used for forestry.

Sodosols are widely distributed across the region and have low agricultural potential due to a low nutrient status and low permeability. They present a clear change in texture as the clay and sodium content increases with depth. This can cause soil dispersion and instability which can give rise to a high risk of erosion (tunnel and gully erosion) as well as dryland salinity.

In the central to northern part of the region, tenosols are the common soil type. They have a weak profile development and, due to their low chemical fertility and water-holding capacity, limited agricultural potential.

The other soil types that have minimal representation in the South East Coast (NSW) region are chromosols, vertosols, hydrosols, ferrosols, podosols and rudosols (0.5–4%).

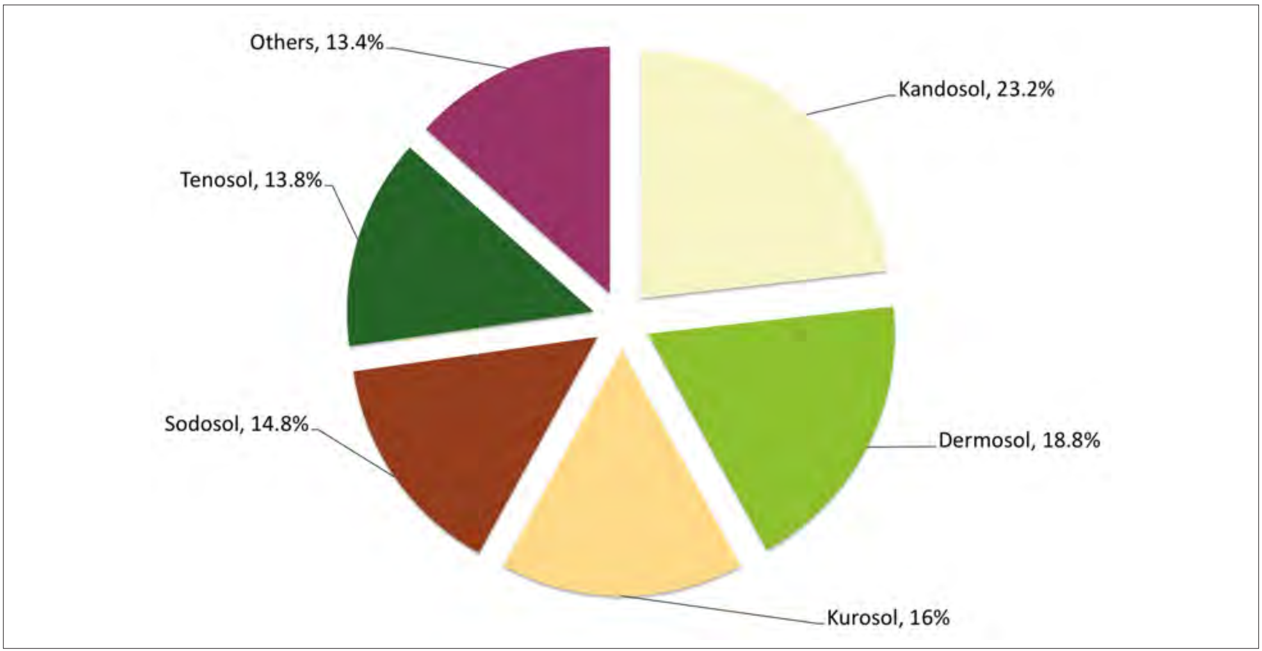



Figure 4.5 Soil types in the South East Coast (NSW) region

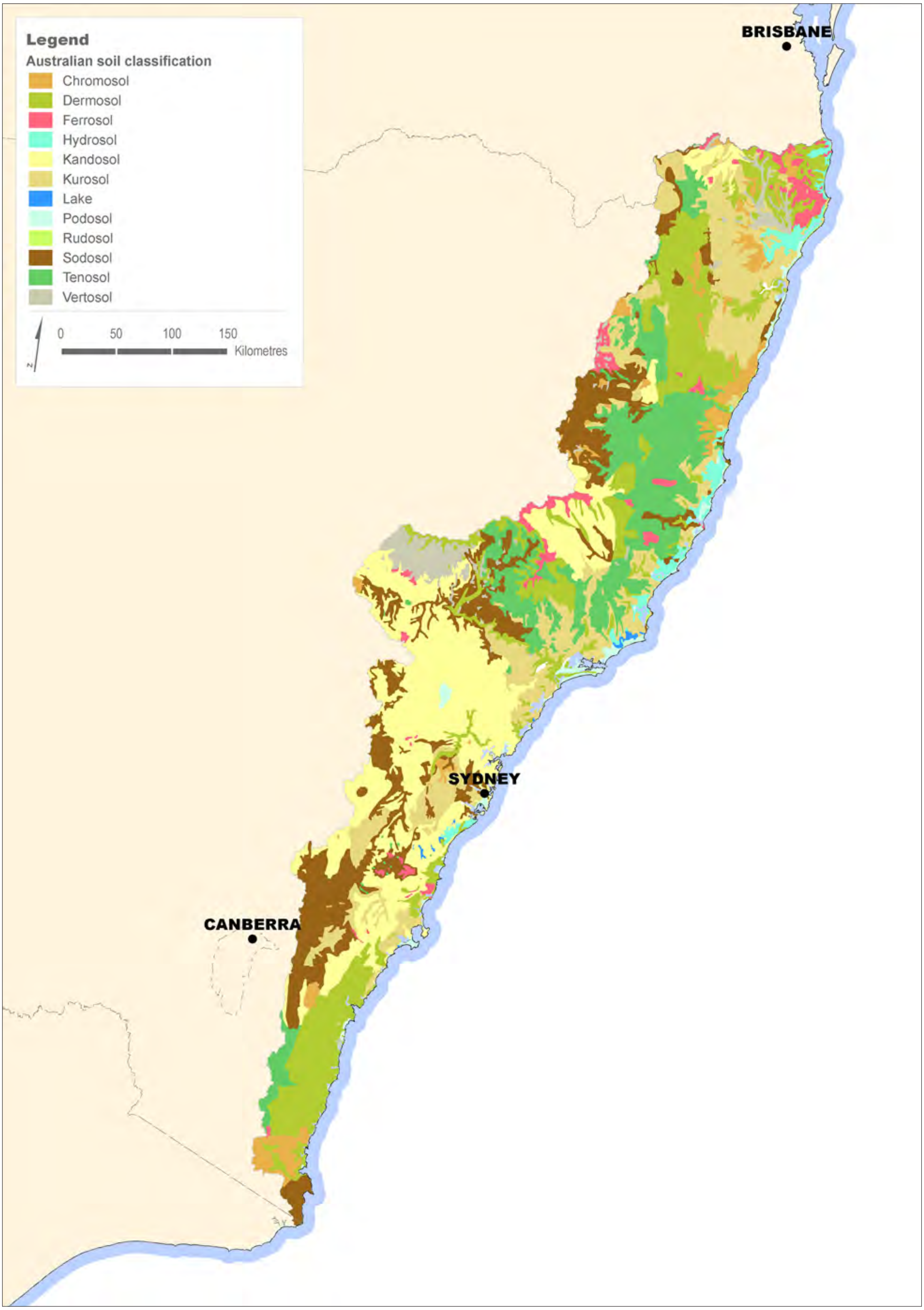



Figure 4.6 Soil type distribution in the South East Coast (NSW) region

### 4.3.5 Land use

Figure 4.7 presents land use in the South East Coast (NSW) region (data from data.daff.gov.au/anrdl/metadata_files/pa_luav4g9abl07811a00.xml). The main feature of the region is nature conservation (44%) followed by dryland pasture (38%).

In the north of the region, subtropical cropping is common and a mix of irrigated and dryland cropping is practised depending on the reliability of rainfall.

In the mid-coast area, irrigated agriculture is common and mostly occurs in the Hunter River basin. This mainly consists of wine grapes and dairy pasture (Figure 4.8).

In the south of the region, irrigation of broadacre and dairy farming enterprises occurs in the Hawkesbury–Nepean and Bega river basins.

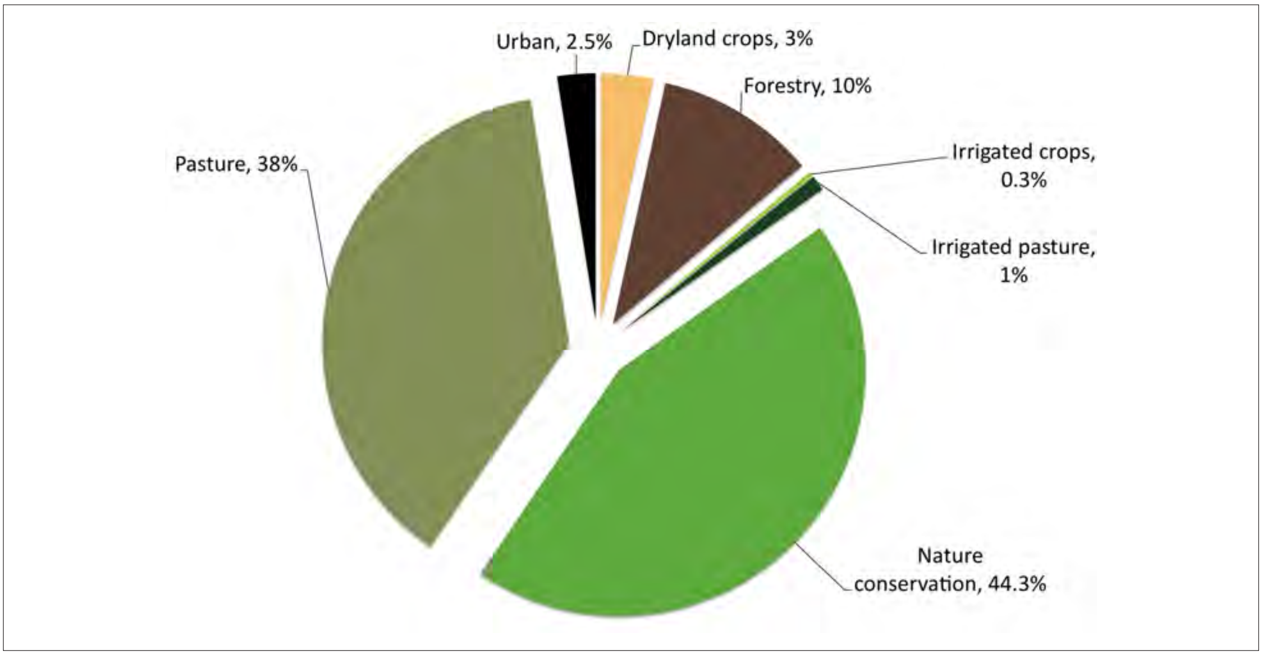



Figure 4.7 Land use in South East Coast (NSW) region

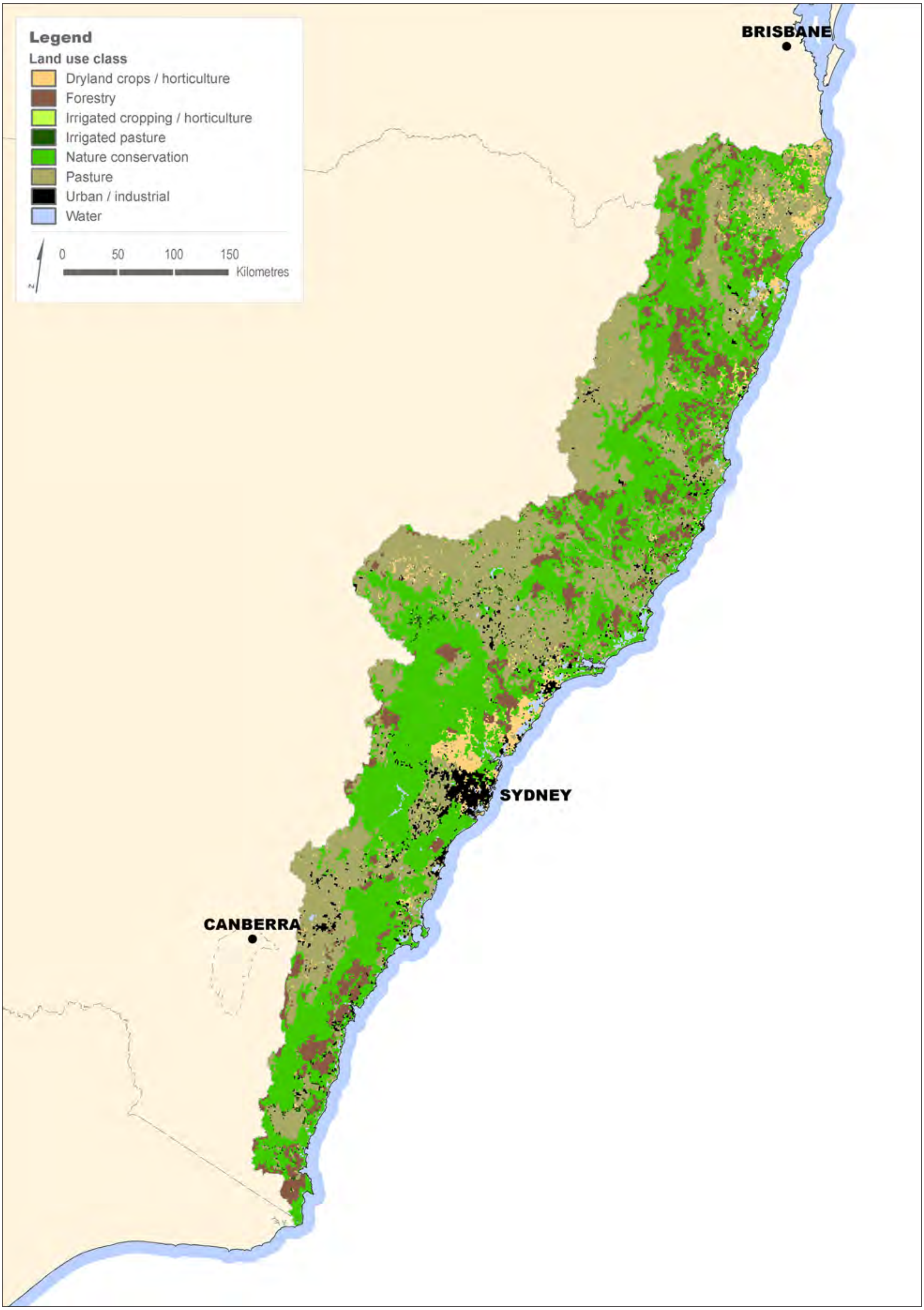



Figure 4.8 Land use distribution in the South East Coast (NSW) region

## 4.3.6 Population distribution

The South East Coast (NSW) region has over 6 million people which constitutes almost 33 % of all Australians (ABS 2011b). The most densely populated areas are along the coastal fringes (Figure 4.9).

Sydney is Australia's largest and most densely populated city. Other major urban areas such as Newcastle, the Central Coast and Wollongong are located in a narrow coastal strip in the north and south of Sydney.

Newcastle and Wollongong have strong links with mining and heavy industries such as steel production.

In the Hunter Valley, agricultural and mining are major drivers for a number of small urban centres.

The coastal centres of Port Macquarie, Coffs Harbour, Ballina and Byron Bay are supported by large agricultural production, tourism, fisheries and mining. In the north, Taree, Kempsey, Grafton and Lismore support large agricultural districts, mostly located adjacent to major rivers. Armidale is a major population centre near the western boundary of the region.

South of Wollongong and the Illawarra district agriculture, fisheries and tourism are key drivers for population centres.

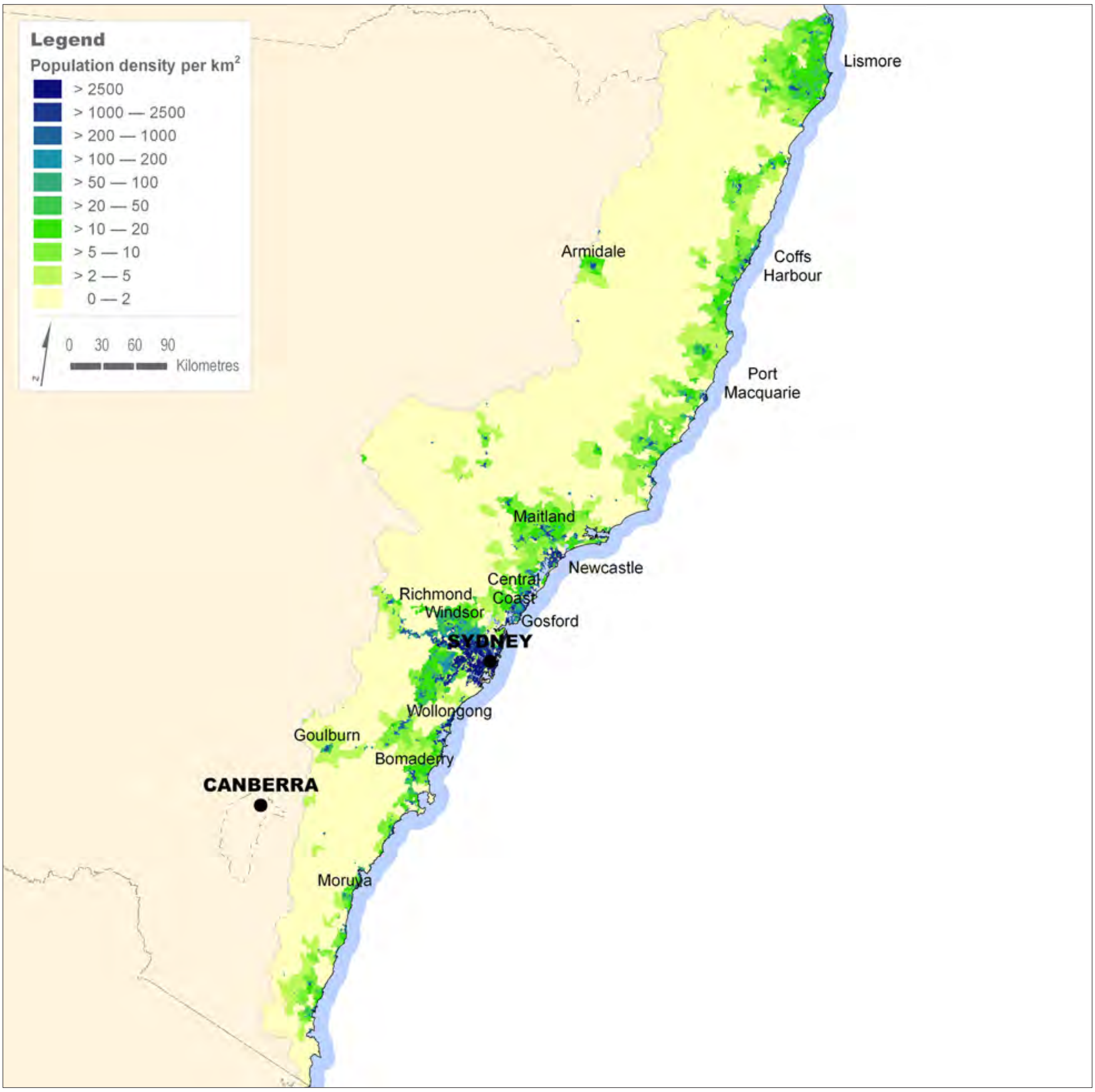



Figure 4.9 Population density and distribution in the South East Coast (NSW) region

### 4.3.7 Rainfall zones

The South East Coast (NSW) region has a warm temperate climate with moderate and generally reliable rainfall due to the presence of the Great Dividing Range in the west. The proximity of the coast moderates weather extremes. Median rainfall exceeds 350 mm throughout the region (Figure 4.10).

The northern half of the region has summer dominant rainfall, with median rainfall remaining high but decreasing westwards from patches with over 1,200 mm per year along the coast to between 650 mm and 1,200 mm inland.

The southern part of the region has a mixture of summer dominant rainfall amongst more uniform rainfall zones. The coastal mountains and plateaus are a major influence on the rainfall patterns that cause substantial climatic differences on a small spatial scale.

For more information on this and other climate classifications, visit the Bureau of Meteorology's (the Bureau's) climate website: bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp

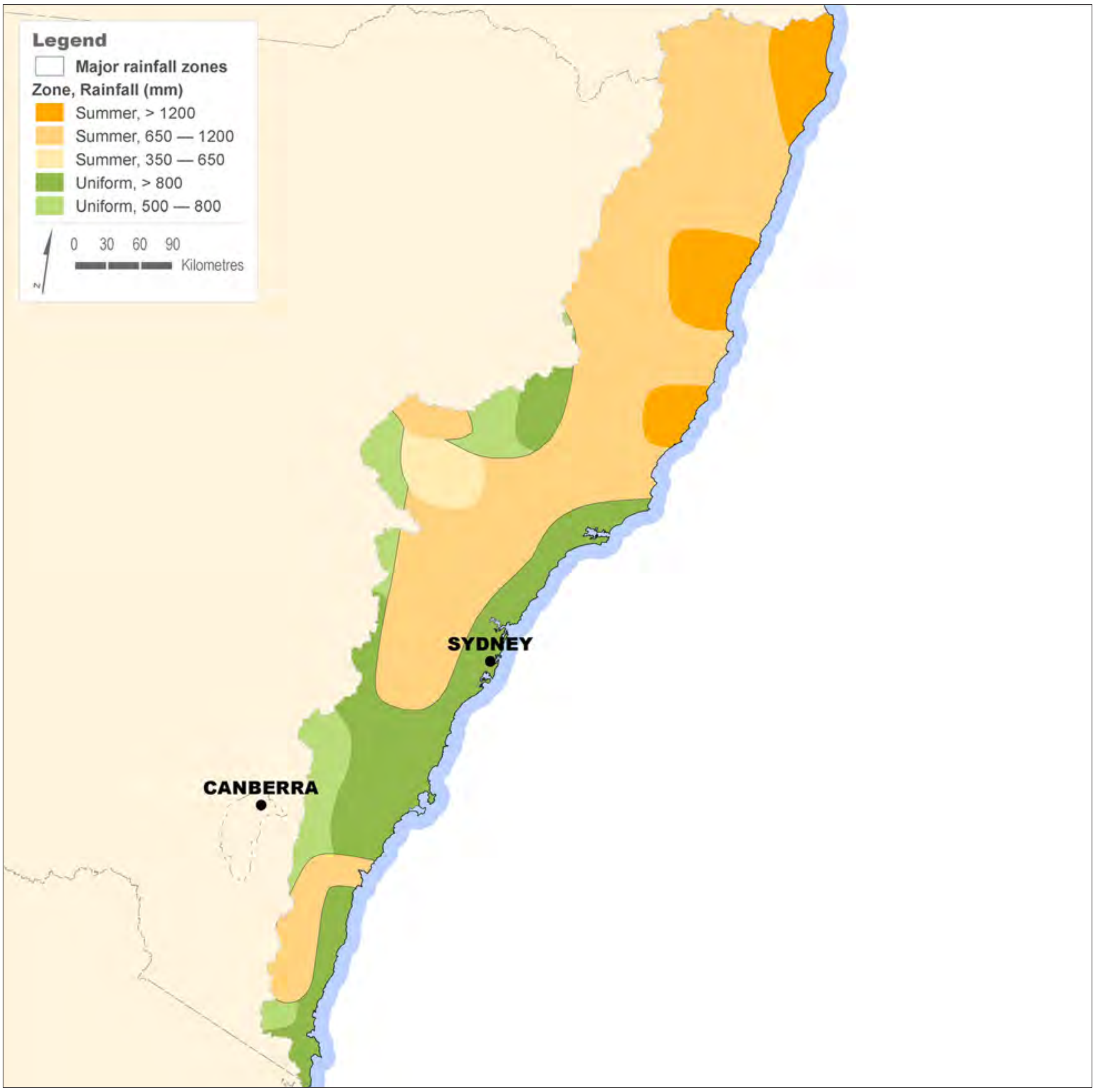



Figure 4.10 Rainfall zones in the South East Coast (NSW) region

## 4.3.8 Rainfall deficit

The rainfall deficit indicator, that is, rainfall minus potential evapotranspiration, gives a general impression about which parts of the region are likely to experience moisture deficits over the period of a year. The South East Coast (NSW) has a distinct rainfall deficit pattern.

Most inland areas experience a deficit of water over the year (Figure 4.11). Substantial deficits can be expected in the Hunter River basin. This basin contains major irrigation areas that must rely on surface water storages to supply enough water to the crops.

Along the coast, many areas experience an abundance of water over the year. In these areas, the land cover is mainly dominated by forests (either production forests or subtropical rainforests).

For more information on the rainfall and evapotranspiration data, see the Bureau's maps of average conditions: www.bom.gov.au/climate/averages/maps.shtml

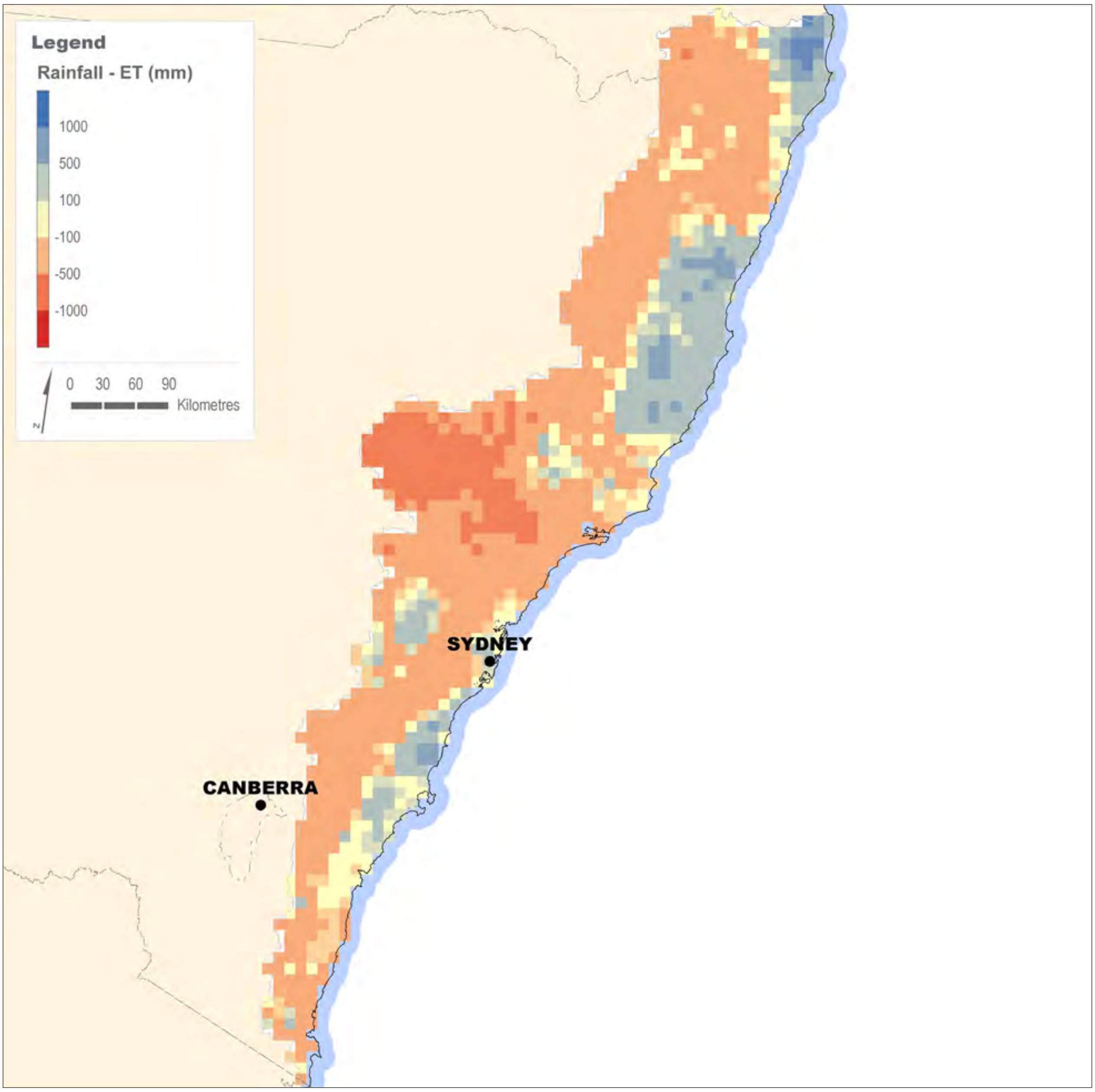



Figure 4.11 Rainfall deficit distribution for the South East Coast (NSW) region

## 4.4 Landscape water flows

This section presents analyses of the spatial and temporal variation of landscape water flows (rainfall, evapotranspiration and landscape water yield) across the South East Coast (NSW) region in 2011–12. National rainfall grids were generated using data from a network of persistent, high-quality rainfall stations managed by the Bureau. Evapotranspiration and landscape water yields were derived using the landscape water balance component of the Australian Water Resources Assessment System (Van Dijk 2010). These methods and associated output uncertainties are discussed in Introduction and addressed in more detail in the Technical Supplement.

Figure 4.12 shows the region has a seasonal rainfall pattern with a wetter summer and a drier winter period. Average monthly evapotranspiration totals generally follow those of rainfall. The region's monthly landscape water yield history shows a pattern of low yield in the period September–December, which increases during January–March and remains higher throughout April–July.

The 2011–12 year was a relatively wet year throughout. Rainfall was only below the historic median in May 2012. The wet La Niña-influenced summer period (November 2011–April 2012) contributed to particularly high monthly rainfall.

Evapotranspiration also remained above the historic median throughout the year. The monthly totals mainly stayed between the 50th and 90th percentile of the historic records.

The monthly landscape water yield for 2011–12 exceeded the 75th percentile in the first ten months of the year, only returning back to historic median levels in May 2012, due to the relatively low rainfall in that month. February and March, in particular, had very much above average high landscape water yields that coincided with the many floods that occurred in the region's north (early February) and in the central and southern parts of the region (early March).

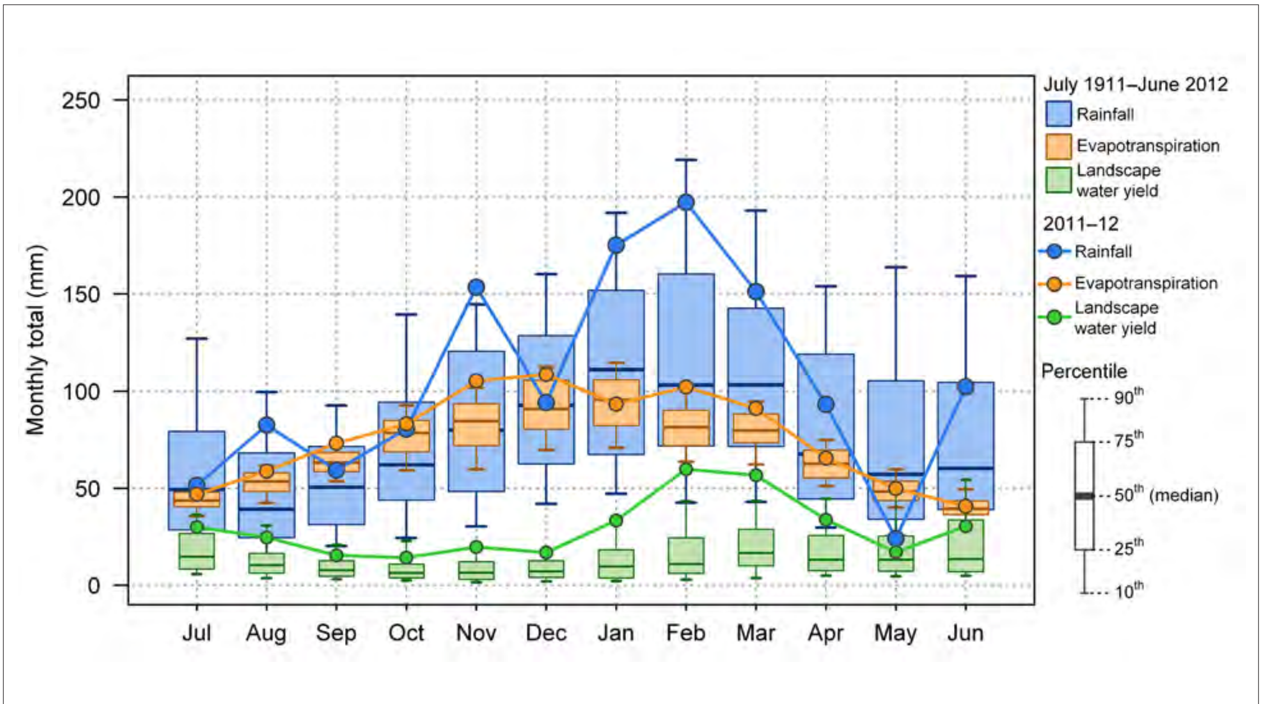



Figure 4.12 Landscape water flows in 2011–12 compared with the long-term record (July 1911–June 2012) for the South East Coast (NSW) region

### 4.4.1 Rainfall

Rainfall for the South East Coast (NSW) region for 2011–12 is estimated to be 1,265 mm. This is 25% above the region's long-term average (July 1911–June 2012) of 1,013 mm. Figure 4.13a shows that the highest rainfall occurred adjacent to the coast with annual totals exceeding 1,800 mm in many areas for 2011–12, especially in the north. The majority of the inland areas had rainfall ranging between 600 mm and 1,200 mm for 2011–12.

Rainfall deciles for 2011–12 indicate above average rainfall for the majority of the region over the course of the year (Figure 4.13b). Some inland areas in the region's north received average rainfall. Very much above average rainfall was recorded in the uphill areas of the central west, including large parts of the Blue Mountains, and in the coastal zone surrounding Sydney.

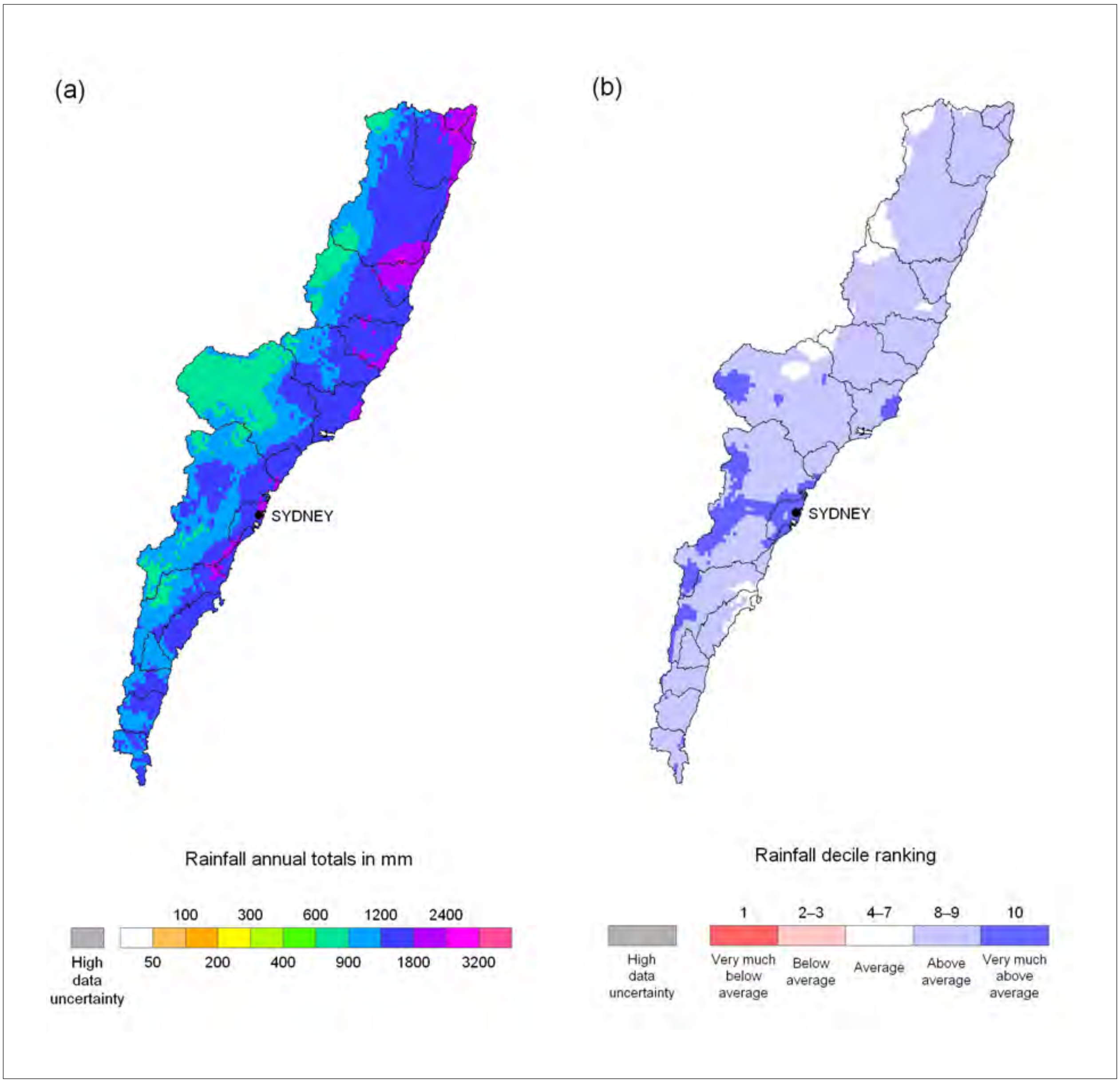



Figure 4.13 Spatial distribution of (a) annual rainfall in 2011–12 and (b) their decile rankings over the 1911–2012 period for the South East Coast (NSW) region

### Rainfall variability in the recent past

Figure 4.14a shows annual rainfall for the region from July 1980 onwards. Over this 32-year period the annual average was 1,014 mm, varying from 772 mm (2002–03) to 1,508 mm (1988–89). Temporal variability and seasonal patterns since 1980 are presented in Figure 4.14b.

Figure 4.14a also indicates the presence of cyclical patterns in annual rainfall over these 32 years. The pattern is apparent in the summer and winter periods' moving averages (Figure 4.14b), although the pattern is less evident in the summer period than it is for the winter period.

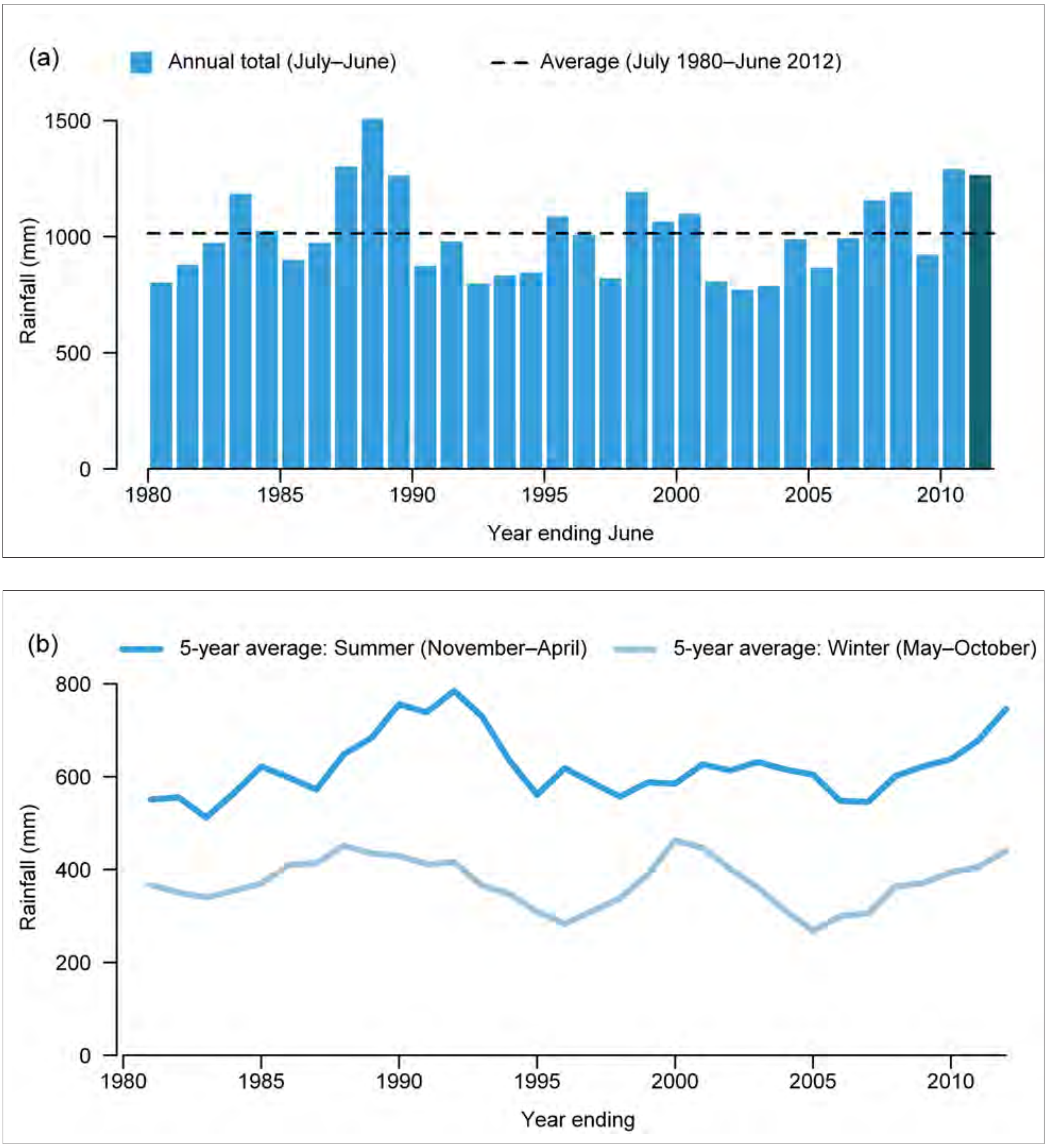



Figure 4.14 Time-series of (a) annual rainfall, and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South East Coast (NSW) region

## Recent trends in rainfall

Figure 4.15a presents the spatial distribution of the trends in annual rainfall for July 1980–June 2012. These are derived from linear regression analyses on the time-series of each model grid cell. The statistical significance of the trends is provided in Figure 4.15b.

Figure 4.15a shows that since 1980 a strong increase in rainfall has occurred in large parts of the north of the region. In contrast, the south has a pattern of predominantly decreasing rainfall.

Figure 4.15b, however, indicates that with the exception of some relatively small areas in the northern half of the region the trends are not statistically significant.

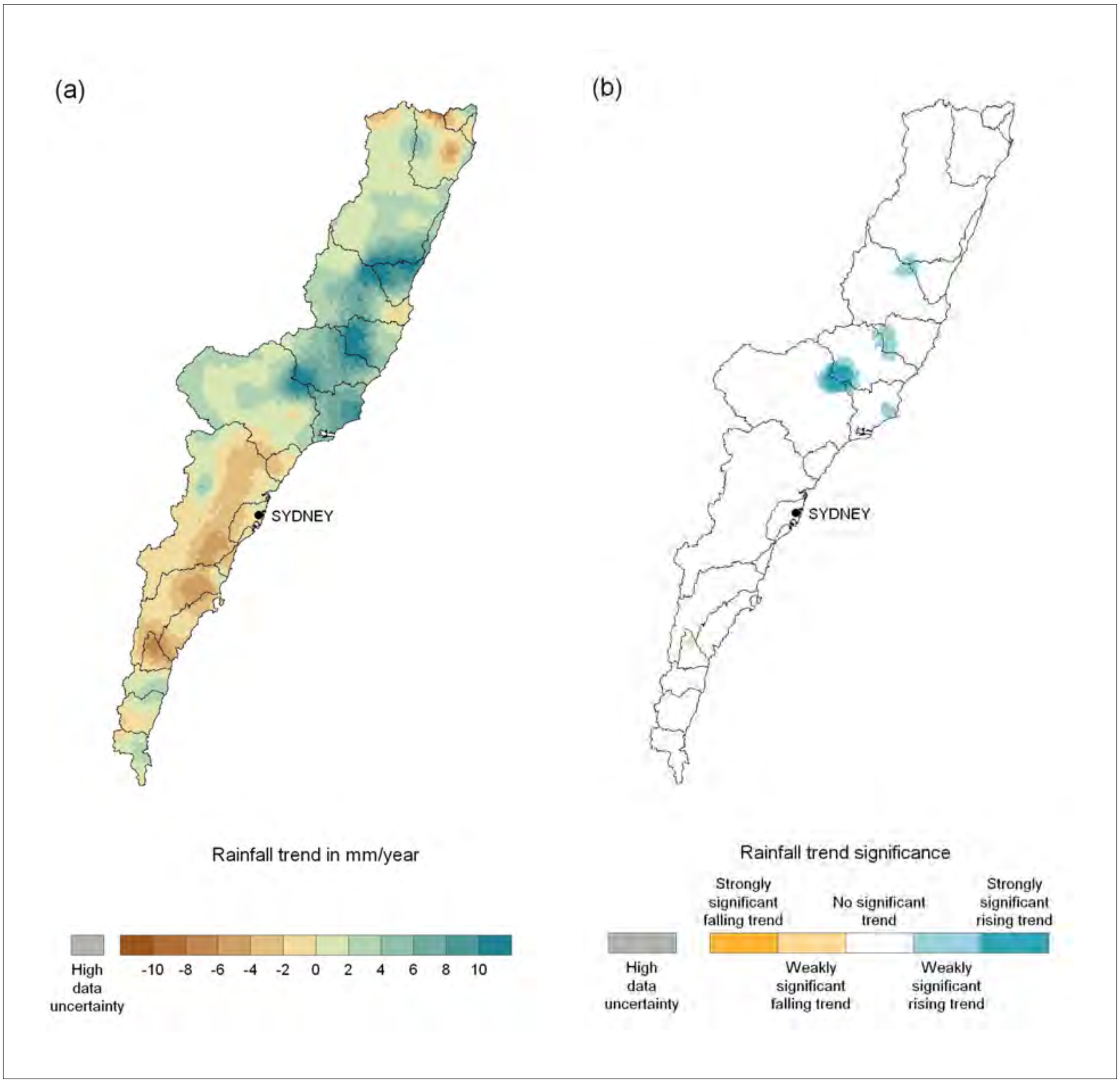



Figure 4.15 Spatial distribution of (a) trends in annual rainfall from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South East Coast (NSW) region

## 4.4.2 Evapotranspiration

Modelled annual evapotranspiration for the South East Coast (NSW) region for 2011–12 is estimated to be 919 mm. This is 12% above the region's long-term (July 1911– June 2012) average of 819 mm. The spatial distribution of annual evapotranspiration in 2011–12 (Figure 4.16a) shows a west–east gradient of increasing totals. Evapotranspiration was highest along the north coast with annual totals exceeding 1,200 mm in some areas for 2011–12.

Evapotranspiration deciles for 2011–12 indicate above average totals across most of the region (Figure 4.16b) with very much above average totals along the Sydney and central coast and more to the north. The high evapotranspiration was possible due to the high rainfall (Figure 4.13b) and the resulting high wetness levels of the soils.

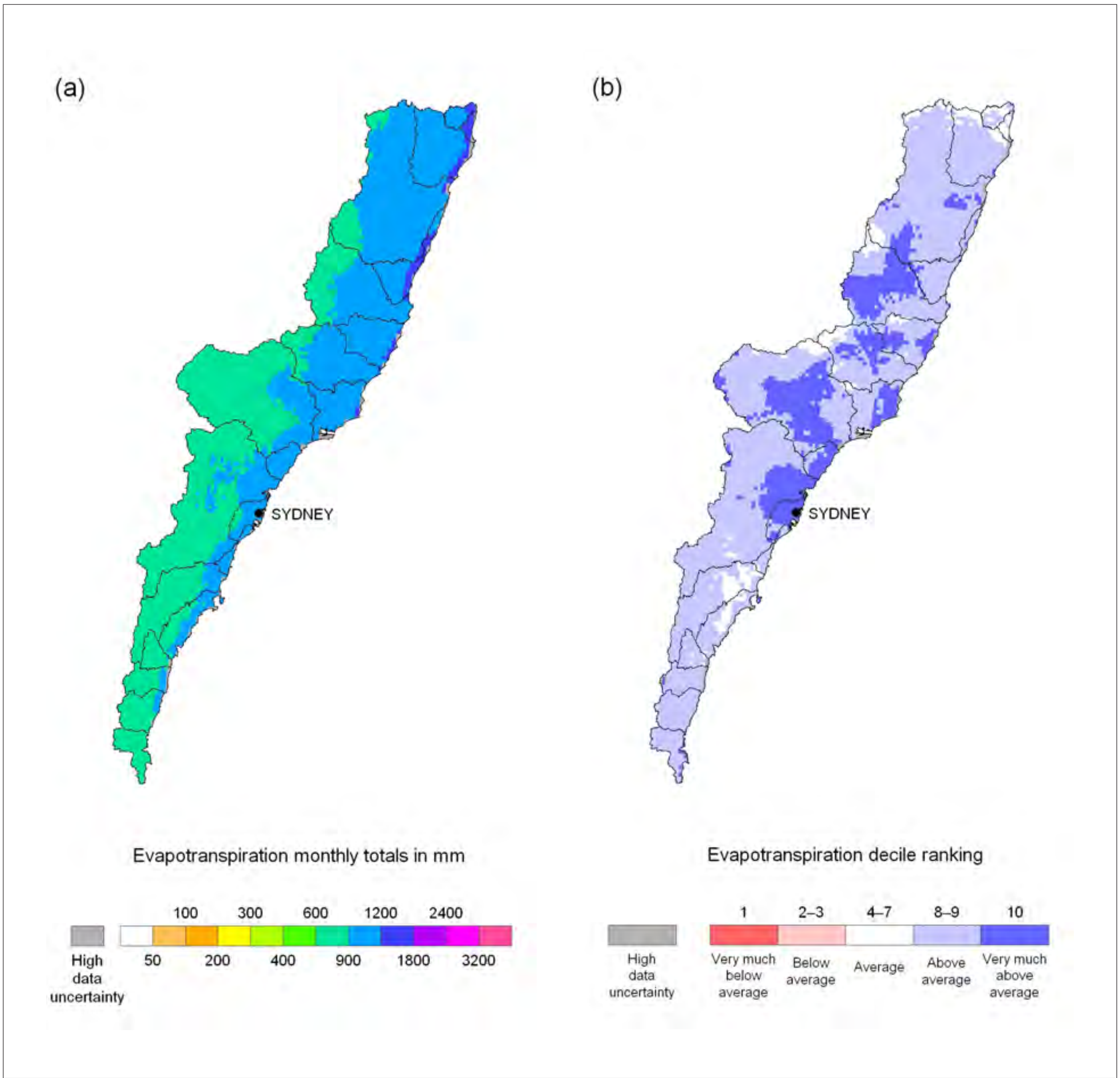
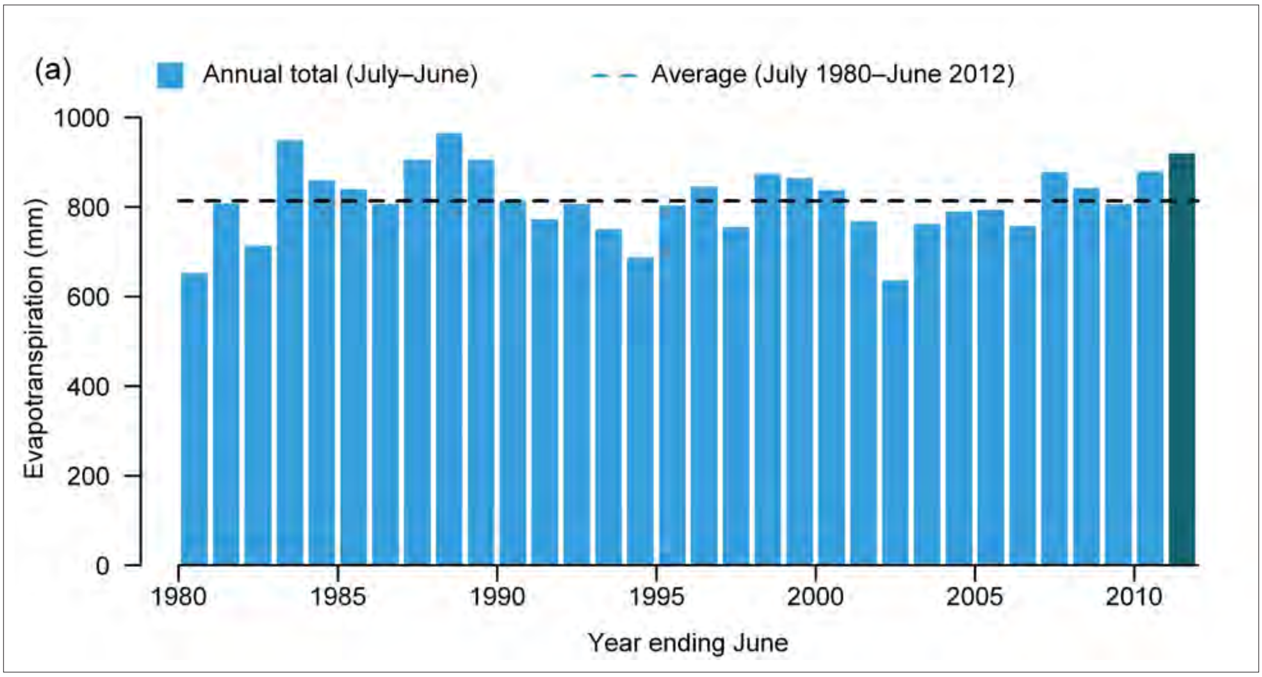



Figure 4.16 Spatial distribution of (a) modelled annual evapotranspiration in 2011–12, and (b) their decile rankings over the 1911–2012 period for the South East Coast (NSW) region

### Evapotranspiration variability in the recent past

Figure 4.17a shows annual evapotranspiration for the region from July 1980 onwards. Over this 32-year period the annual evapotranspiration average was 814 mm, varying from 636 mm (2002–03) to 964 mm (1988–89). Temporal variability and seasonal patterns (over the summer and winter periods) since 1980 are presented in Figure 4.17b.

Summer periods showed consistently higher evapotranspiration than the winter period. The higher temperatures and the higher rainfall amounts during these periods contribute to this. Compared with the seasonal rainfall (Figure 4.14b), the cyclical time-series of seasonal evapotranspiration is less pronounced (Figure 4.17b).



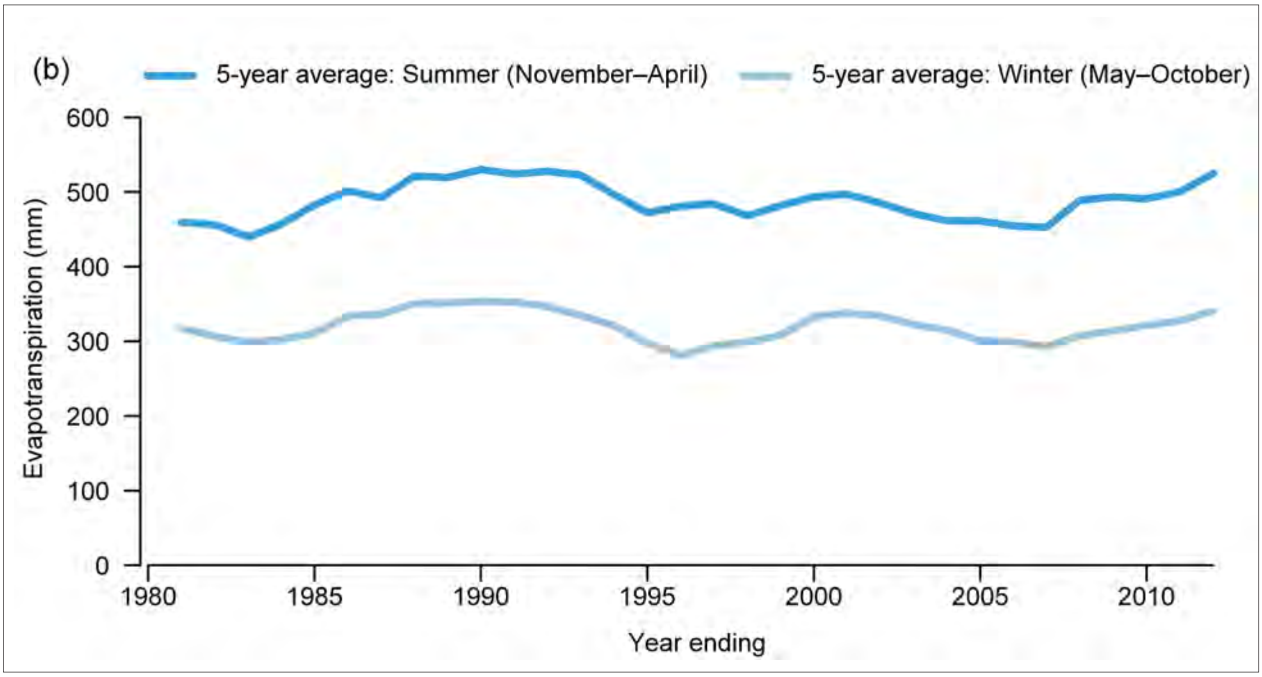




Figure 4.17 Time-series of (a) annual evapotranspiration, and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South East Coast (NSW) region

### Recent trends in evapotranspiration

Figure 4.18a presents the spatial distribution of the trends in modelled annual evapotranspiration for 1980–2012. These are derived from linear regression analyses on the time-series of each model grid cell. The statistical significance of the trends is provided in Figure 4.18b.

Figure 4.18a shows that since 1980 trends are weakly positive in the central northern part of the region. In the south and the far north, the trends are mostly neutral to weakly falling.

As shown in Figure 4.18b, the trends are generally only statistically significant in small parts of the region where trends are generally showing increasing evapotranspiration. In most of the area, however, the trends have no statistical significance.

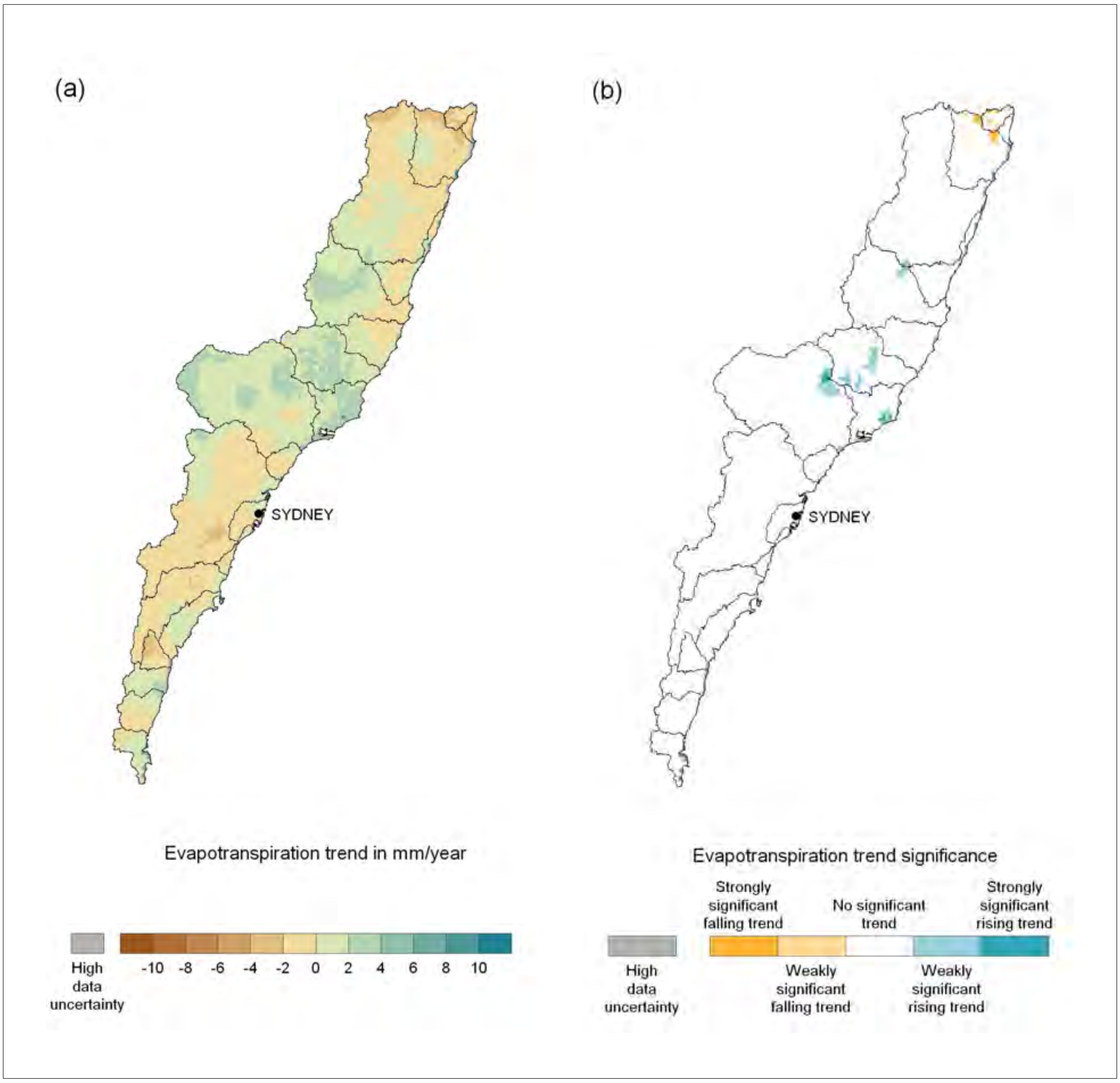



Figure 4.18 Spatial distribution of (a) trends in annual evapotranspiration from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South East Coast (NSW) region

### 4.4.3 Landscape water yield

Modelled landscape water yield for the South East Coast (NSW) region for 2011–12 is estimated to be 352 mm. This is 84% above the region's long-term (July 1911–June 2012) average of 191 mm.

Figure 4.19a shows the spatial distribution of landscape water yield for 2011–12. The highest landscape water yields are observed in areas adjacent to the coast, locally exceeding 900 mm.

The landscape water yield was substantially lower inland, with some areas not exceeding 50 mm (especially in the Hunter Valley).

The decile-ranking map for 2011–12 (Figure 4.19b) shows above average landscape water yields throughout the region. Some areas recorded very much above average landscape water yield, partly reflecting the pattern of rainfall deciles in Figure 4.13b.

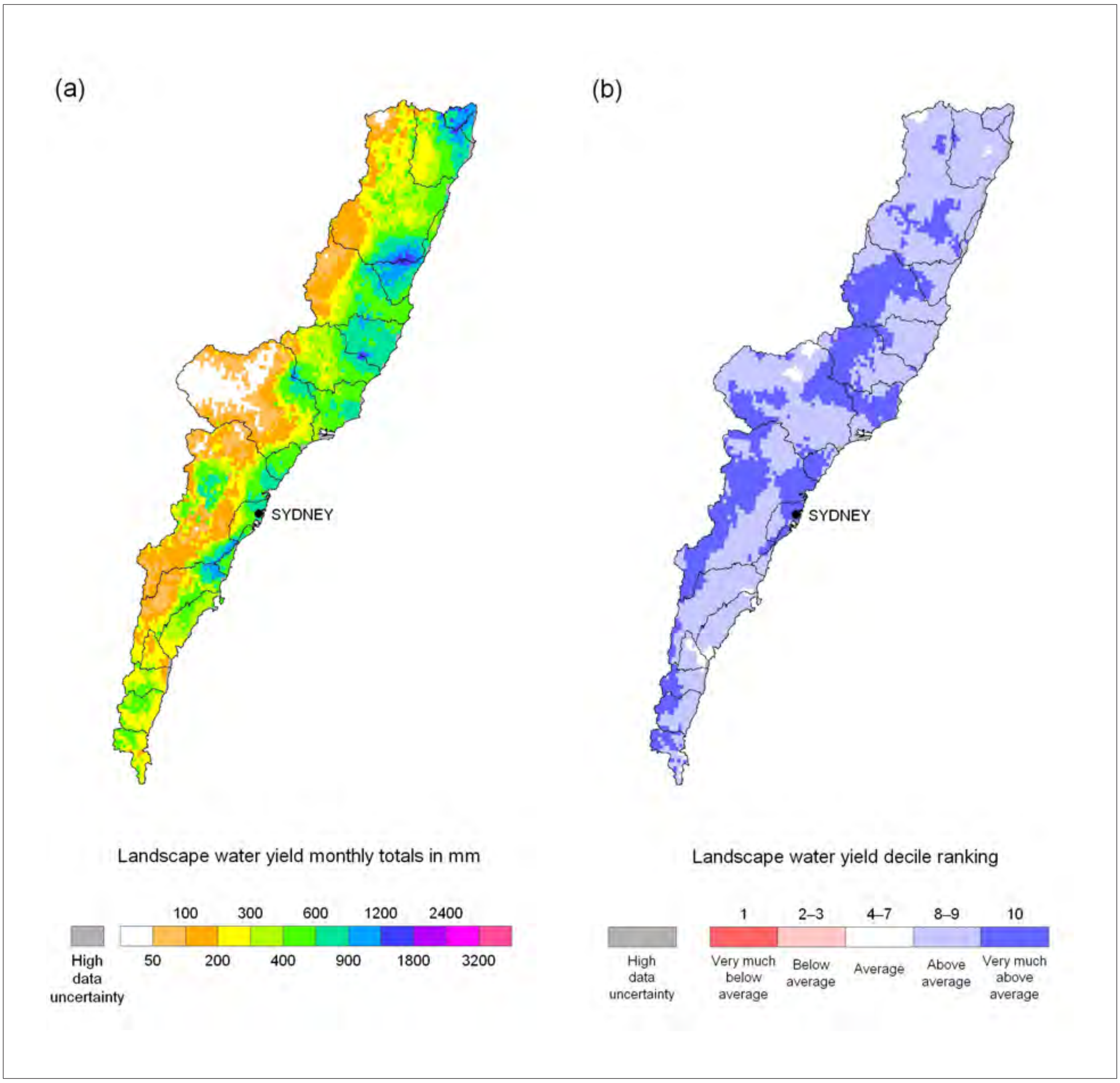



Figure 4.19 Spatial distribution of (a) modelled annual landscape water yield in 2011–12, and (b) their decile rankings over the 1911–2012 period for the South East Coast (NSW) region

### Landscape water yield variability in the recent past

Figure 4.20a shows annual landscape water yield for the South East Coast (NSW) region from July 1980 onwards. Over this 32-year period, average annual landscape water yield was 193 mm, varying from 82 mm (1992–93) to 441 mm (1988–89). Temporal variability and seasonal patterns (over the summer and winter periods) since 1980 are presented in Figure 4.20b.

Landscape water yield is equally distributed between the summer and winter periods. This is a result of higher landscape water yields in the south in the winter period, and in the north in the summer period.

Both periods show a distinct inter-annual cyclic variability driven by the region's rainfall dynamics (see Figure 4.14b).

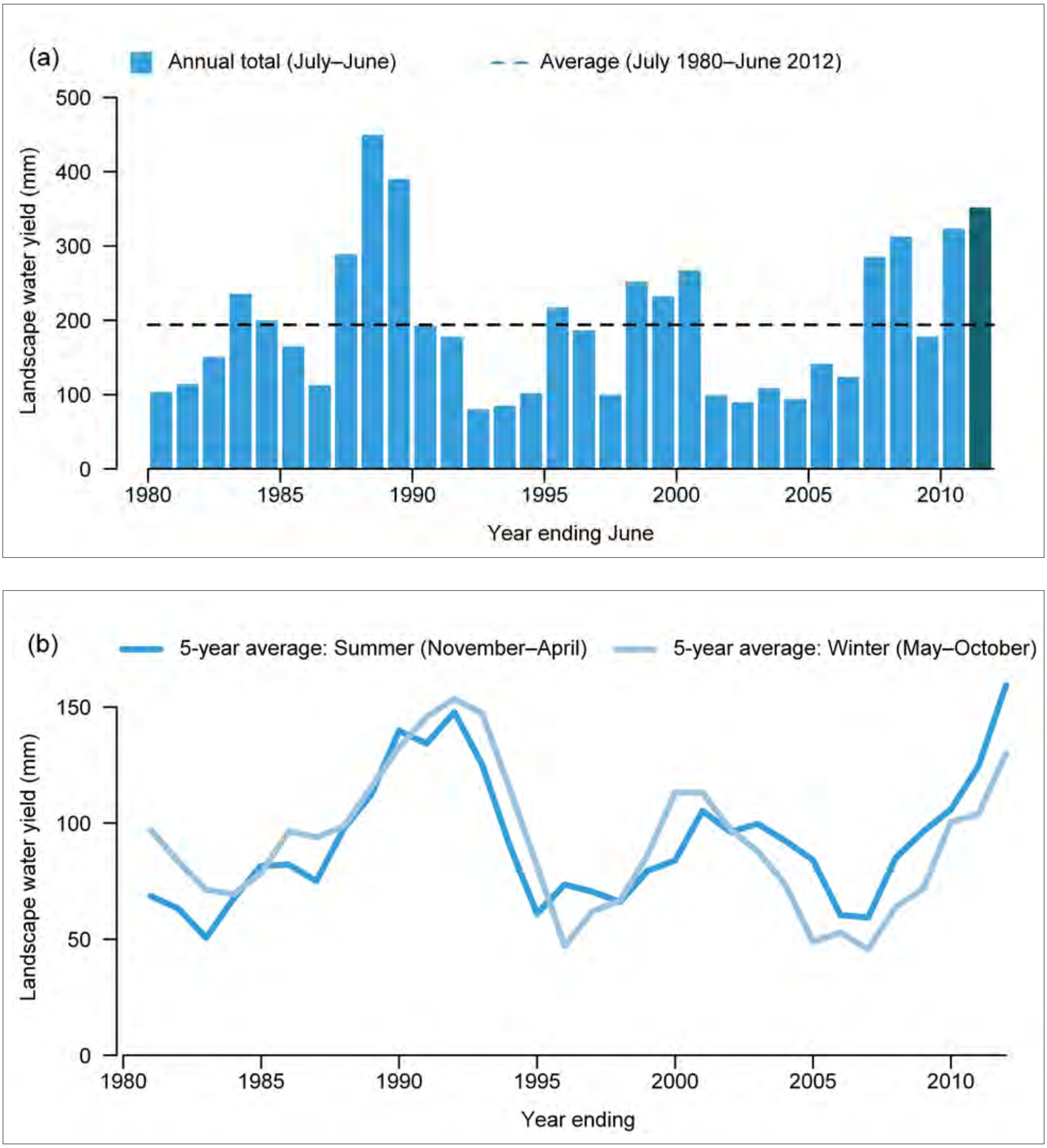



Figure 4.20 Time-series of (a) annual landscape water yield and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South East Coast (NSW) region

## Recent trends in landscape water yield

Figure 4.21a shows the spatial distribution of the trends in modelled annual landscape water yield for 1980–2012. These are derived from linear regression analyses on the time-series of each model grid cell. The statistical significance of the trends is provided in Figure 4.21b.

Figure 4.21a shows that since 1980, trends are rising in the central northern part of the region. In the south and the far north the trends are mostly neutral to weakly falling.

As shown in Figure 4.21b, the trends are generally only statistically significant in some central northern parts of the region, where trends are generally showing increasing landscape water yield. In most of the area, however, the trends have no statistical significance. A minor exception can be found in the Moruya River basin in the south, where a strongly significant falling trend is identified.

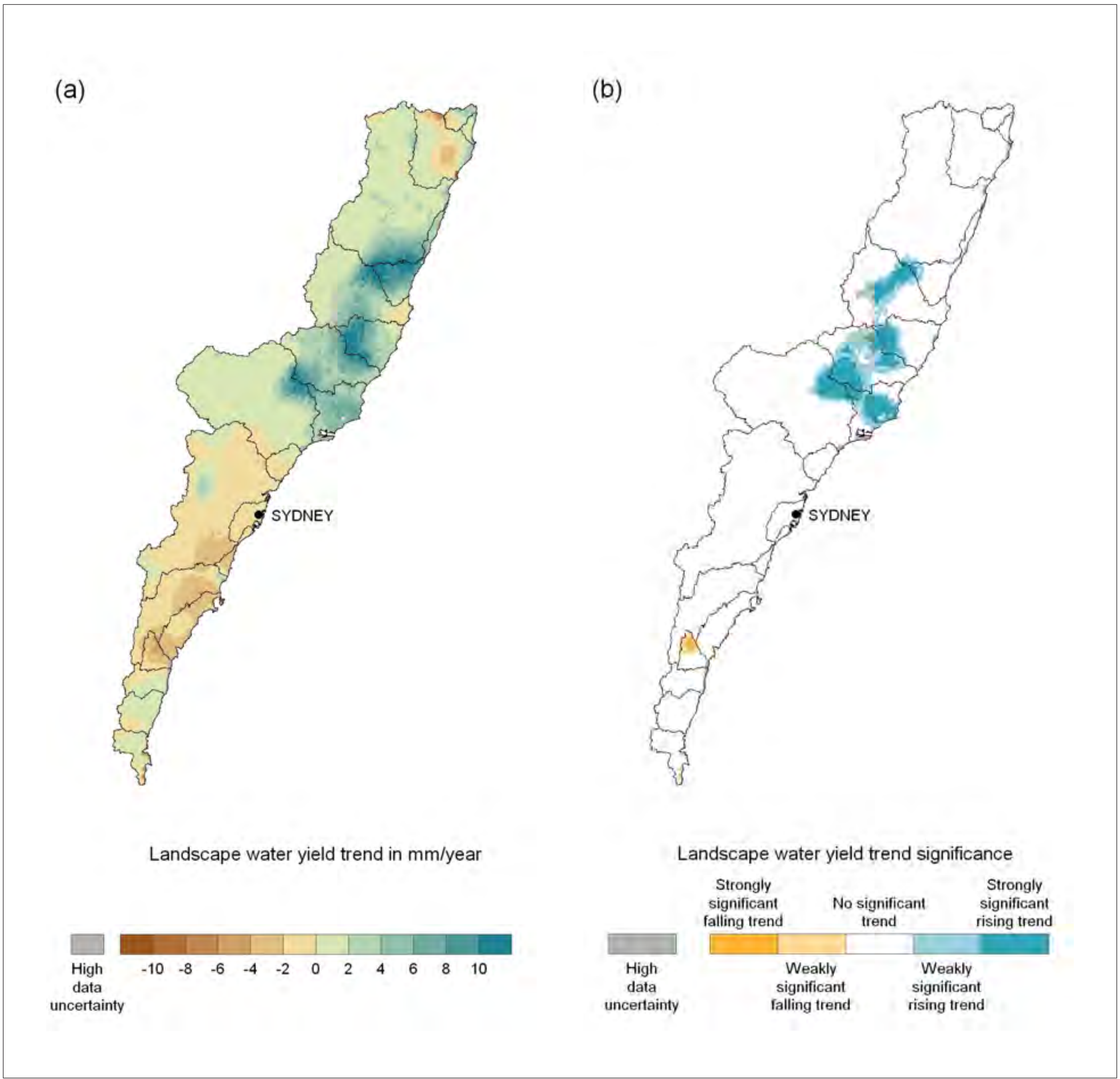



Figure 4.21 Spatial distribution of (a) trends in annual landscape water yield from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South East Coast (NSW) region

## 4.5 Surface water and groundwater

This section examines surface water and groundwater resources in the South East Coast (NSW) region in 2011–12. Rivers, wetlands and storages are discussed to illustrate the state of the region's surface water resources.

The region's watertable aquifers and salinity are described. No data was available at the Bureau in a suitable format for a detailed analysis of individual aquifers.

### 4.5.1 Rivers

There are 20 river basins in the South East Coast (NSW) region, varying in size from 500–22,000 $km^2$ (Figure 4.22).

The Clarence River is the largest in the region in terms of annual discharge into the sea. The Hawkesbury and Hunter rivers are two important systems in the region in terms of urban and irrigation water supply.

The rivers are all perennial, although in times of drought some may almost stop flowing. River flows in the region generally show distinct seasonal variations.

Hawkesbury River at Little Wobby, New South Wales | Catherine Marshall

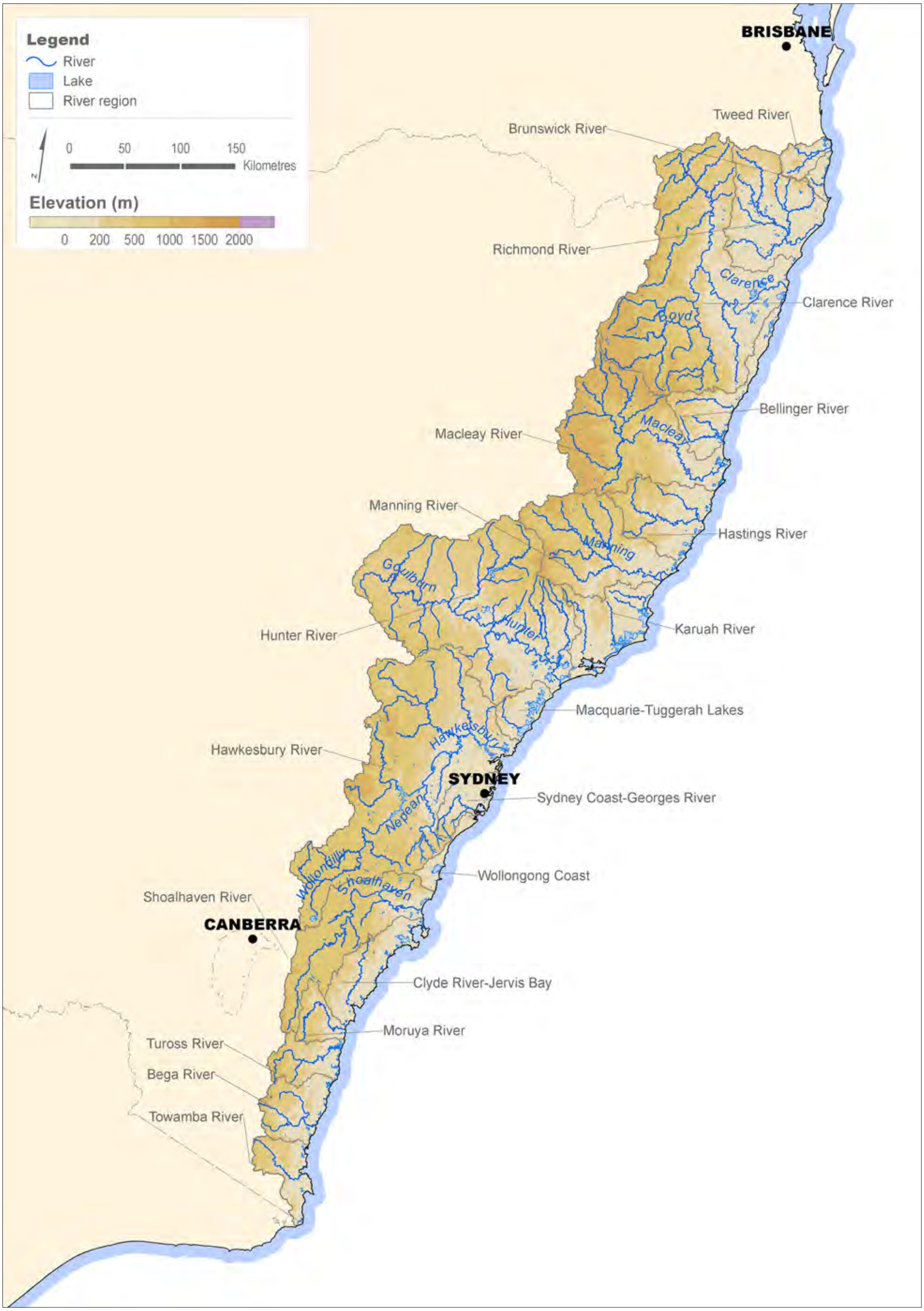



Figure 4.22 Rivers and catchments in the South East Coast (NSW) region

### 4.5.2 Streamflow volumes

Figure 4.23 presents an analysis of flows at 31 monitoring sites during 2011–12 relative to annual flows for the period from July 1980–July 2012. Monitoring sites with relatively long records across 15 geographically representative river catchments were selected (see Technical Supplement for details). The annual flows for 2011–12 are colour-coded according to the decile rank at each site over the 1980–2012 period.

The flows from monitoring gauges generally reflect the mostly above average to very much above average modelled landscape water yield results shown in Figure 4.19b.

High run-off, generated in the upstream reaches of the rivers, caused above average to very much above average flows in all rivers. Very much above average flows were observed at five sites located on rivers in the northwest, central east and south of the region. Above average total flows were recorded at 26 monitoring sites distributed across the entire region.

Flow deciles for summer (November 2011–April 2012) are similar to total annual flows for 2011–12 as shown in Figure 4 23. This is not surprising given that the greatest volume of flows in the region, particularly in the north and some areas in the south, occurs over the summer months. While flows in the region's centre and central north were above average over the year, flows in most of these rivers were relatively high over the summer period. There are a few monitoring sites that did not show this pattern, such as low flows observed in the summer period on the Hunter River in the centre of the region.

### 4.5.3 Streamflow salinity

Figure 4.24 presents an analysis of streamflow salinity for 2011–12 at 20 monitoring sites in the region. The sites with at least a five-year data record were selected for analysis. The results are presented as electrical conductivity (EC, µS/cm at 25 °C). This is a commonly used surrogate for the measurement of water salinity in Australia. Standard EC levels for different applications, such as for drinking water or types of irrigation, are provided in the Technical Supplement. The median annual EC values are shown as coloured circles. The size of the circle depicts the variability in annual EC, shown as the coefficient of variation (CV), being the standard deviation divided by the mean. Stream salinity data were only available in the Hunter River basin.

The median EC values for most of the selected monitoring sites in the main rivers fall in the range 0–1,000 µS/cm, an amount that is suitable for most irrigation uses. Some creeks in the Hunter River basin fall outside of this range (see Figure 4.24).

Of the 20 monitoring sites, 40% had median EC values below 500 µS/cm, and 45% were between 500–1,000 µS/cm. Only 5% of the monitoring sites had a median EC above 1,500 µS/cm. The higher median salinities all occurred in the centre and central west of the Hunter River basin.

Stream salinity was above 2,000 µS/cm at only one of the 20 monitoring sites. This was in Bayswater Creek at Liddell in the Hunter River basin. High salinity in the Bayswater Creek is due to saline discharges from coal mining, and wastewater from power generation (Environmental Protection Agency 2001) and saline groundwater input in the river.

The CV was relatively low for the most of the sites. The CV in EC is typically related to the variability in annual flow at the monitoring site.

Of the 20 monitoring sites, 10% of them had a CV below 20%, and 90% of the sites had a CV between 20% and 60%. These monitoring sites were located on the Hunter River basin towards the central part of the region.

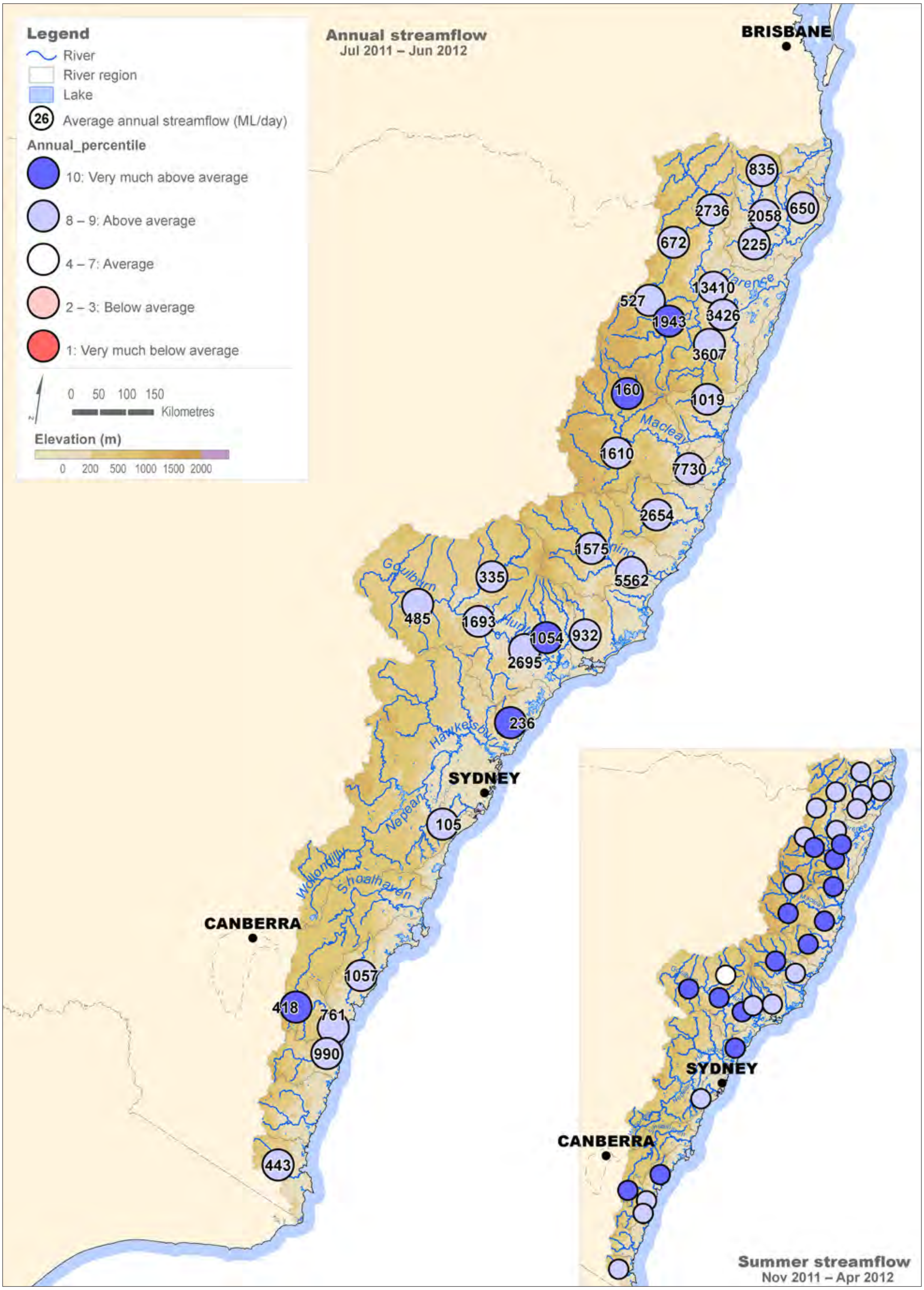



Figure 4.23 Average annual and summer period flow volumes at selected sites for 2011–12 and their decile rankings over the 1980–2012 period in the South East Coast (NSW) region

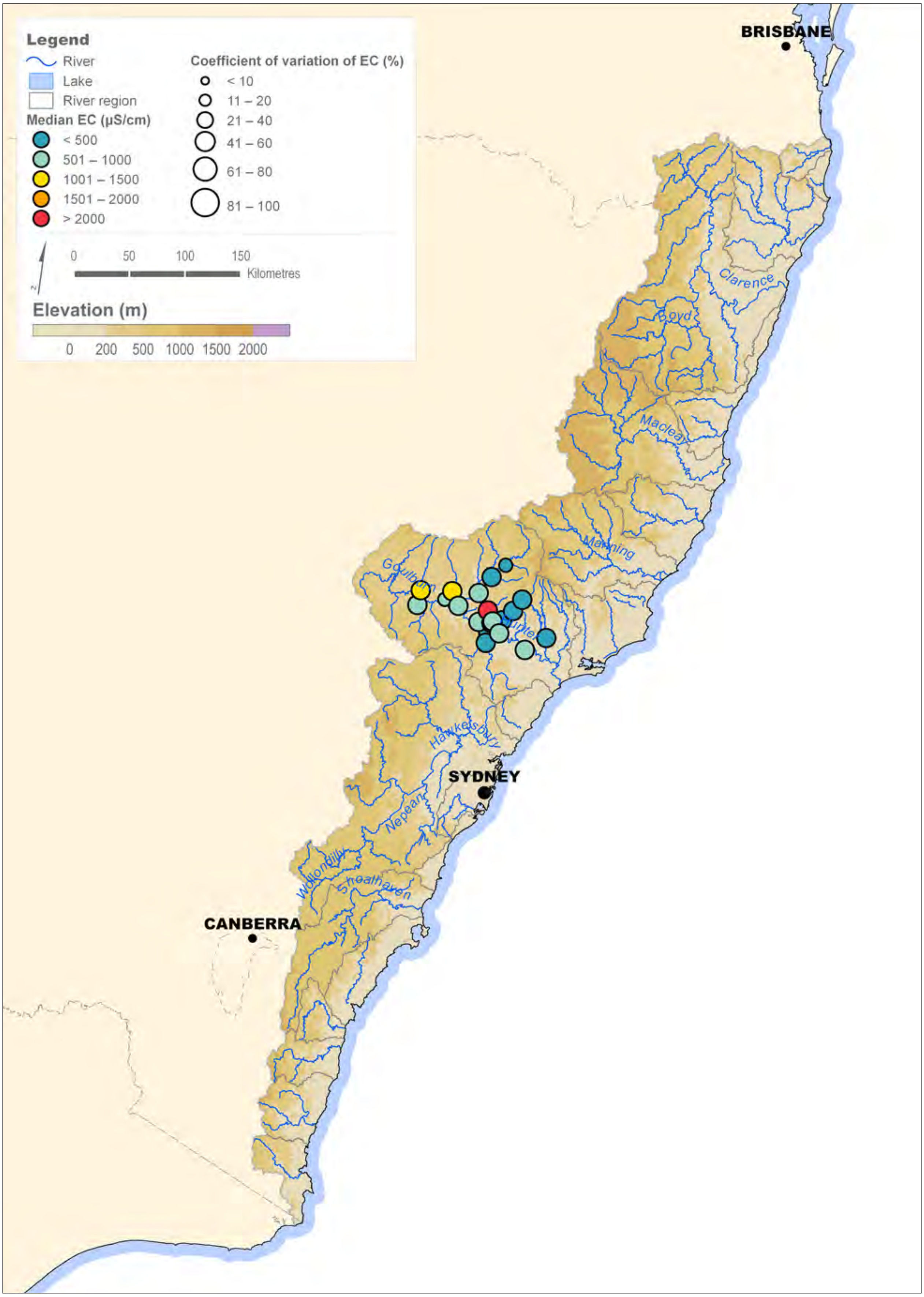



Figure 4.24 Salinity as electrical conductivity and its associated coefficient of variation for 2011–12 in the South East Coast (NSW) region

## 4.5.4 Flooding

Floods can be caused by either localised high intensity rainfall, for example thunderstorms, or prolonged periods of heavy rainfall, for example, during frontal rainfall, monsoon, and tropical storms. While the first rainfall type often results in localised flash flooding, the prolonged rainfall can cause sustained floods spreading over larger areas.

Floods in the region are particularly common in the north of the South East Coast (NSW) region. Most of the region's south has a uniform rainfall pattern while the northern part receives the majority of rainfall during summer. Both types of rainfall can occur across the region, with heavy rainfalls often associated with easterly troughs and frontal systems.

Figure 4.25 shows selected locations where the Bureau is monitoring river levels as part of its flood forecasting service and the highest level reached during the year is expressed in terms of flood classification level. These classification levels are established in consultation with emergency management and local agencies and are further described in the Technical Supplement.

A three-day period of torrential rainfall along the north coast of New South Wales produced totals of about 500 mm of rain from 23–27 January 2012, causing significant flooding in some of the northern rivers. Major flooding occurred along the Tweed River, with approximately 4,200 people evacuated from this area. Rain also led to localised landslides in some areas.

Minor to moderate flooding also occurred along several other rivers, isolating more than 12,000 people in areas including Goodooga, Bellingen, Thora, Darkwood, Upper Macleay, Mullumbimby and the Brunswick and Clarence valleys.
On 1 February 2012, natural disasters were declared in 11 local government areas in the north of the region as a result of the flooding. The damage due to this flooding was assessed to be several million dollars.

Bellingen River Floods | Greg McLagan

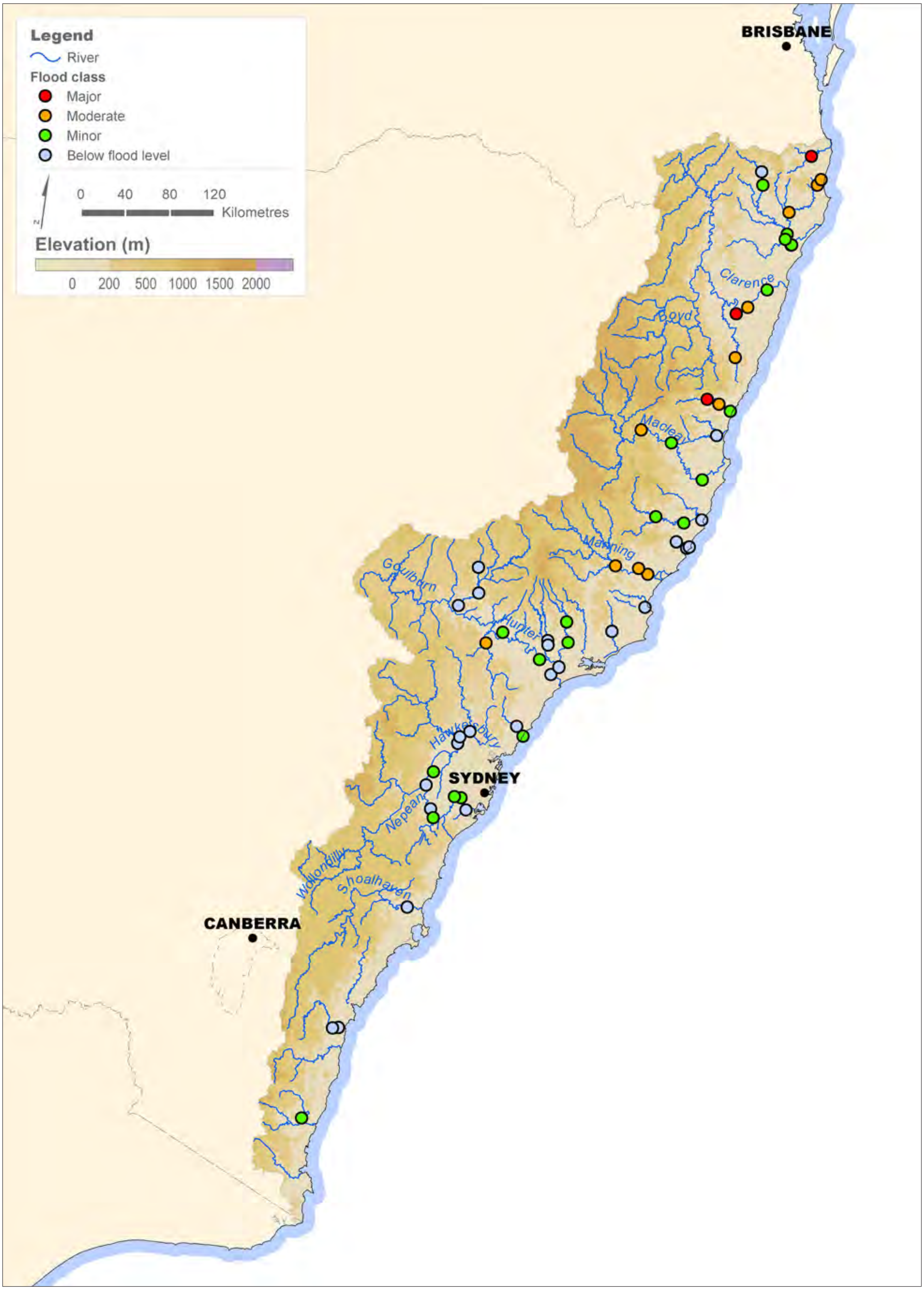



Figure 4.25 Flood occurrence in 2011–12 for the South East Coast (NSW) region, with each dot representing a river level monitoring station and the colour of the dot representing the highest flood class measured

## 4.5.5 Storage systems

There are approximately 50 major publicly owned storages in the South East Coast (NSW) region with a total capacity in excess of 4,600 GL. The Bureau's water storage information includes approximately 83% of the region's publicly owned storage capacity.

Storages in the region supply the irrigation areas in the Hunter Valley as well as the city of Sydney. Table 4.3 gives a summary of the region's major storage systems together with an overview of the storage levels at the end of 2010–11 and 2011-12. The location of all the systems and associated storages are shown in Figure 4.26.

Table 4.3 indicates that the above average rainfall upstream of most storages has resulted in a substantial increase in the accessible volumes region-wide. The Sydney supply storages, especially, have received large amounts of water, with Sydney's largest storage, Warragamba, spilling in March, April and June. The Hunter storages reached full supply level in November 2011 and have been full since. More details on the Sydney and Hunter systems is provided in subsections 4.6–4.7.

Further information on the past and present volumes of the storage systems and the individual storages can be found on the Bureau's water storage website: water.bom.gov.au/waterstorage/awris/

## 4.5.6 Wetlands

### Important wetlands

There are a large number of wetlands of national and international importance in the South East Coast (NSW) region (Figure 4.27). Most of these are coastal wetlands of various types, including salt and freshwater marshes, mangrove forests, reed beds, lakes and lagoons.

The region is the most densely populated region in Australia. As a consequence, most wetlands are impacted by human activities upstream of the wetland or in the wetland area itself. The coastal estuaries and lakes are important refuges for many migrating and threatened bird species as well as many types of fish and amphibians, including several threatened species of frogs.

### Inflows to selected wetlands

The state of the biodiversity in a wetland is linked to the way water is stored within the area and the temporal variability of inflows. An analysis of historic and recent inflows into wetlands forms an informative picture of potential changes.

One internationally recognised Ramsar wetland site (Hunter Estuary wetlands) was selected for hydrological analysis of major inflows.

More information about the region's wetlands is available from the *Australian Directory of Important Wetlands* (www.environment.gov.au/water/topics/wetlands/database/diwa.html).

Two upstream stream monitoring gauges were selected to enable the analyses and interpretation of inflows to these wetlands. The gauges used in the analyses are the closest upstream gauges that have largely continuous discharge records since 1980. Although the analyses do not capture the total inflows, they are indicative of the temporal patterns of freshwater surface flows to these wetlands.

Table 4.3 Major public storage systems in the region as identified in the Bureau's water storage information (August 2012), with 'non-allocated' accounting for the storages not allocated to a particular system

| System name | System type | System capacity | Accessible volume at 30 June 2011 | Accessible volume at 30 June 2012 |
|---|---|---|---|---|
| Sydney | urban | 2, 582 GL | 1,973 GL—76% | 2,496 GL—97% |
| Hunter | rural | 1,031 GL | 965 GL—94% | 1,026 GL—100% |
| Non-allocated | — | 240 GL | 111 GL—46% | 137 GL—57% |
| **Total** | | **3,853 GL** | **3,049 GL—79%** | **3,658 GL—95%** |

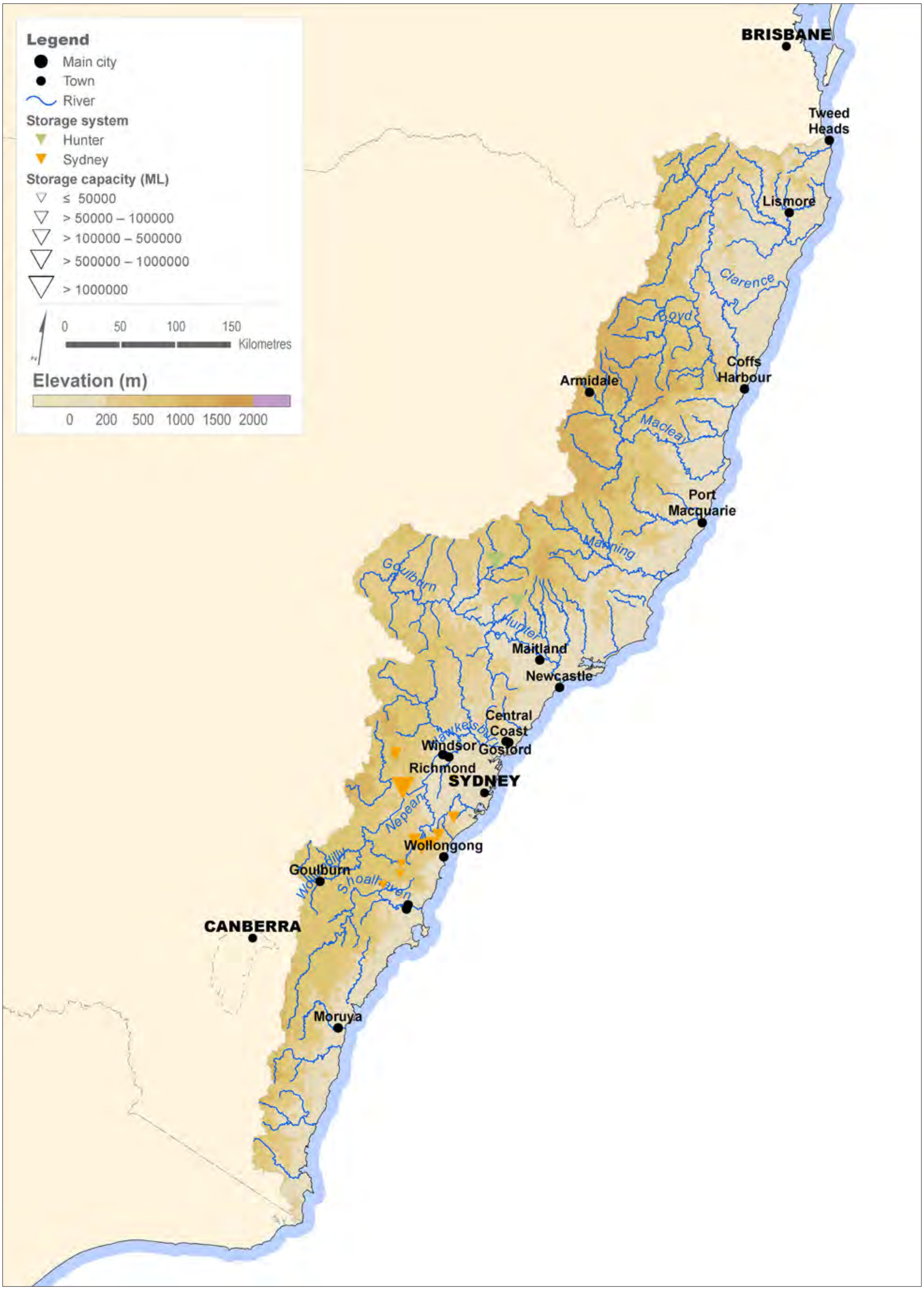



Figure 4.26 Storage systems in the South East Coast (NSW) region; information extracted from the Bureau's water storage information website in August 2012


Figure 4.27 Location of important wetlands in the South East Coast (NSW) region

## Hunter Estuary wetlands

The Hunter Estuary wetlands are downstream of one of the most intensely irrigated areas of the region. The Hunter River and its tributaries contain a number of dams that catch much of the streamflow. Also, the wetlands themselves are impacted by human activities as the surrounding river branches are frequently dredged and are progressively controlled by flood mitigation structures.

Daily discharge data for the monitoring gauges on the Hunter River at Greta and on the Patterson River at Gostwyck have been combined to provide a temporal pattern of freshwater inflows into Hunter Estuary wetlands (Figure 4.28).

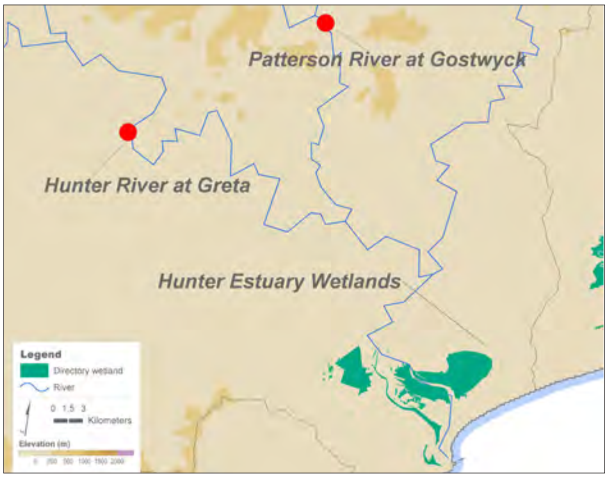



Figure 4.28 Location of the monitoring site in relation to the Hunter Estuary wetlands

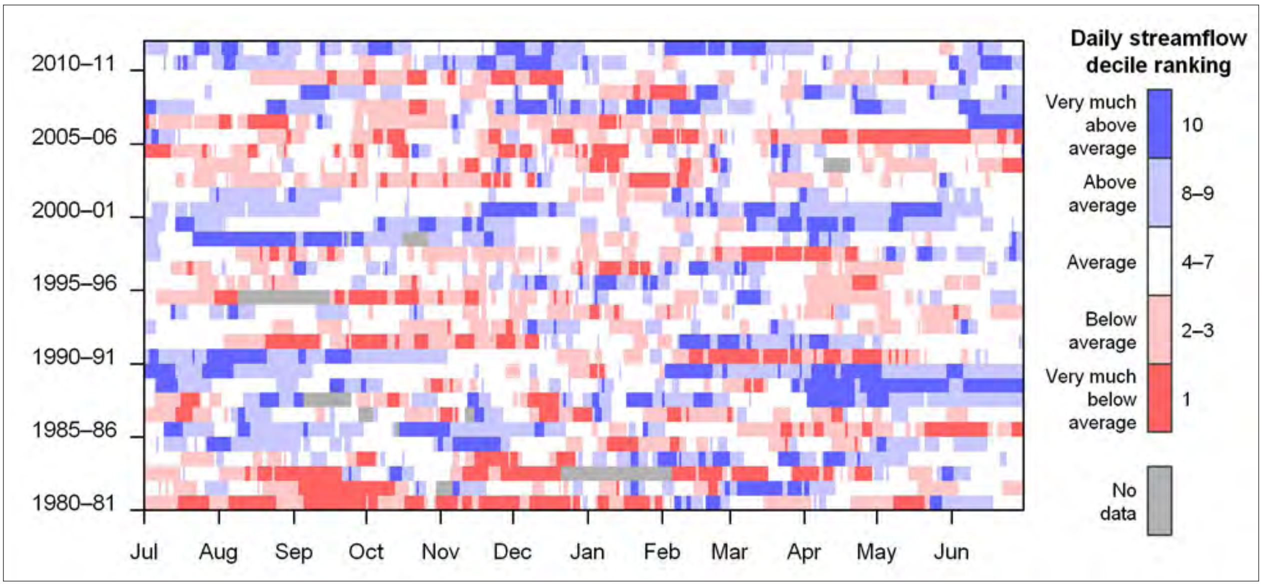



Figure 4.29 Combined daily flows of the Hunter and Patterson rivers between 1980–81 and 2011–12, ranked in decile classes

Figure 4.29 presents an overview of the distribution of daily streamflow decile rankings. With the absence of a distinct rainfall season, the flow pattern is qutie heterogeneous. Some years appear to have less flow than others, but no clear indication can be found that points towards a change in flow regime for the Hunter Estuary wetlands.

Figure 4.30 compares monthly discharges from 2011–12 with the statistics of flows from July 1980 onwards. The November, February and March flows exceeded the ninth decile of the 32-year record and contributed a substantial amount of freshwater to the Hunter Estuary wetlands.

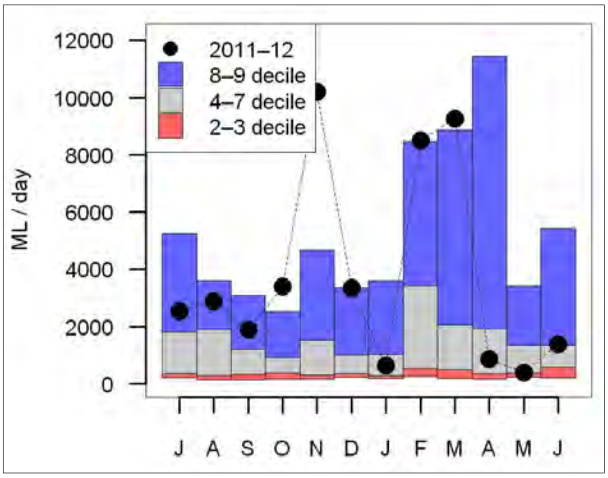



Figure 4.30 Combined monthly flows of the Hunter and Patterson rivers from 2011–12 compared with the July 1980—June 2012 decile rankings

## 4.5.7 Hydrogeology

The hydrogeology of the South East Coast (NSW) region is dominated by a large area of outcropping fractured basement rock. Aquifer systems in fractured rock typically offer restricted low-volume groundwater resources. Productive groundwater resources are localised in alluvial valley and coastal sand aquifers.

The watertable aquifers present in the region are shown in Figure 4.31. Groundwater systems in the region that generally provide more potential for extraction include:

- Surficial sediment aquifer (porous media —unconsolidated); and
- Tertiary basalt aquifer (fractured rock).

## 4.5.8 Watertable salinity

Figure 4.32 shows a classification of the watertable aquifer as either fresh (total dissolved solids [TDS] < 3,000 mg/L) or saline (TDS ≥ 3,000 mg/L) according to salinity levels.

As shown in the figure, quality-assured salinity data are not available for most of the region. Where data are available, as in the central part of the region southwest, west and northwest of Sydney, groundwater is generally fresh. Areas with known high salinity values in the region are relatively small in area.

## 4.5.9 Groundwater management units

Groundwater management units within the region are key features that control the extraction of groundwater through planning mechanisms. Figure 4.33 shows large groundwater management units located within the fractured and consolidated sedimentary rocks that typically provide low-volume groundwater resources. In contrast, the smaller units represent local coastal sand, alluvial valley or tertiary basal aquifers which are usually better yielding aquifers.

The Tomago Sandbeds unit (no. 5 in Figure 4.33) within coastal sand aquifers in the eastern part of the region is important as it provides 20% of the drinking water supply to the Hunter area.

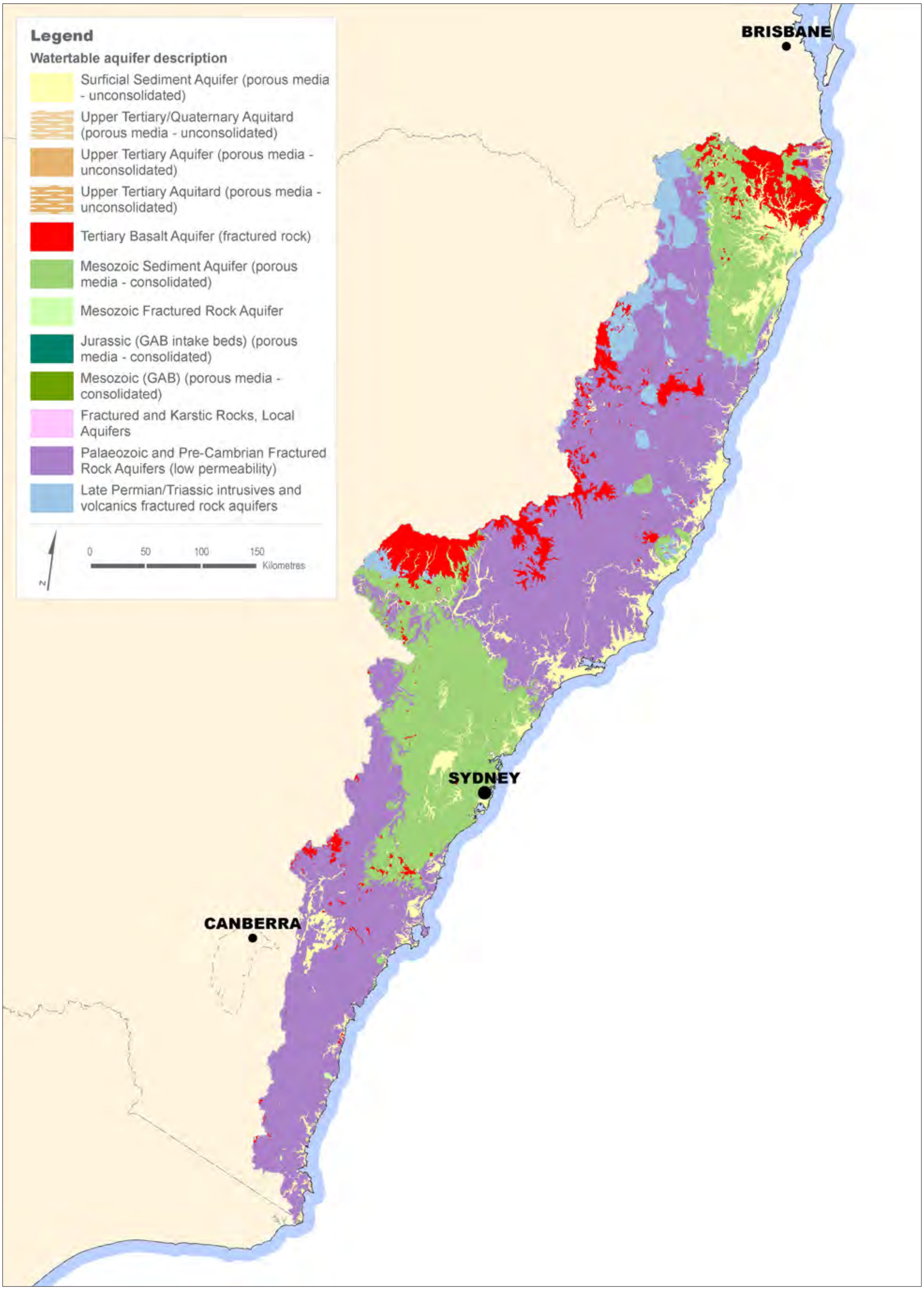



Figure 4.31 Water table aquifers of the South East Coast (NSW) region; data extracted from the Groundwater Cartography of the Australian Hydrological Geospatial Fabric (Bureau of Meteorology 2012)

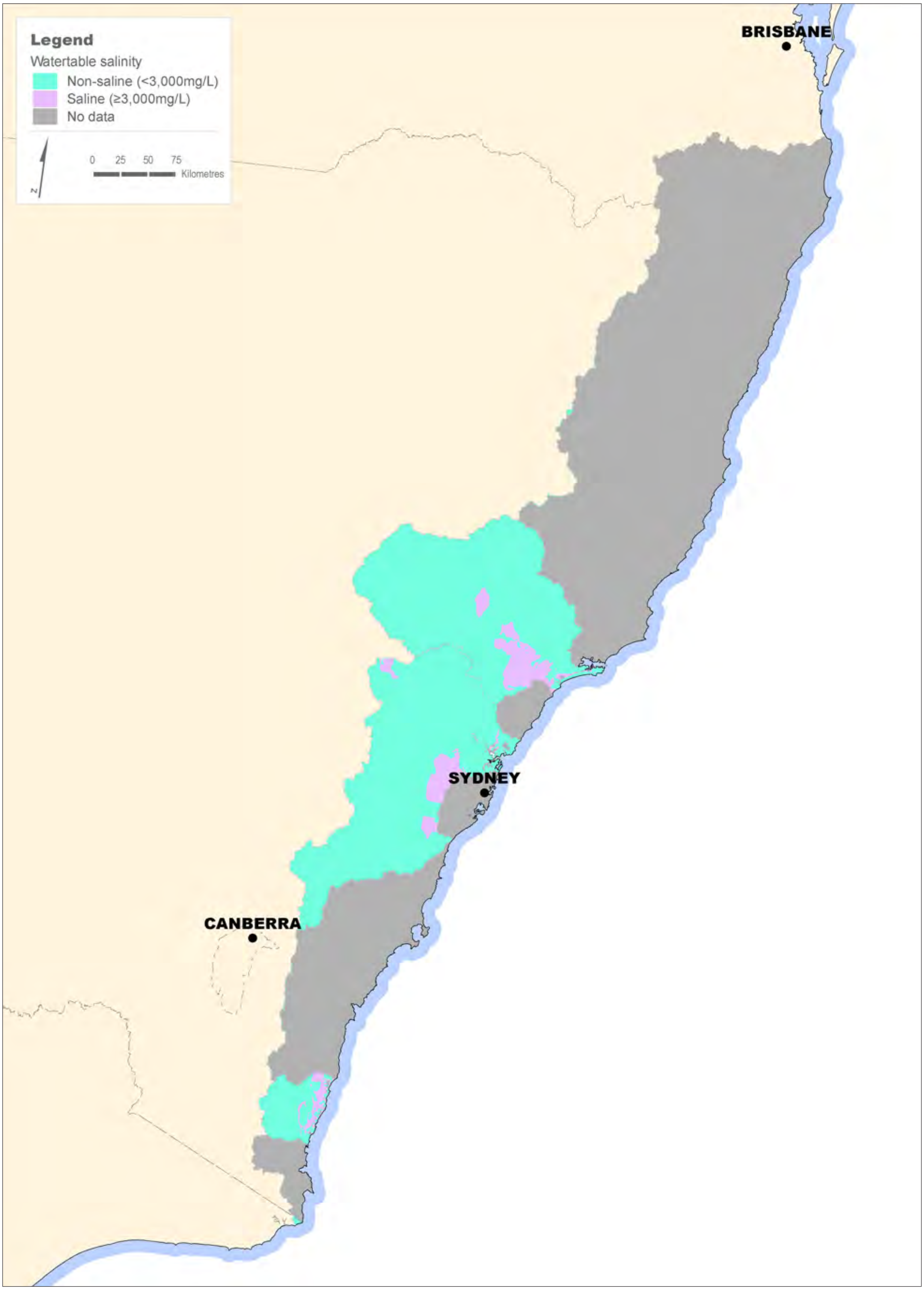



Figure 4.32 Water table salinity classes in the South East Coast (NSW) region; data extracted from the Groundwater Cartography of the Australian Hydrological Geospatial Fabric (Bureau of Meteorology 2012)

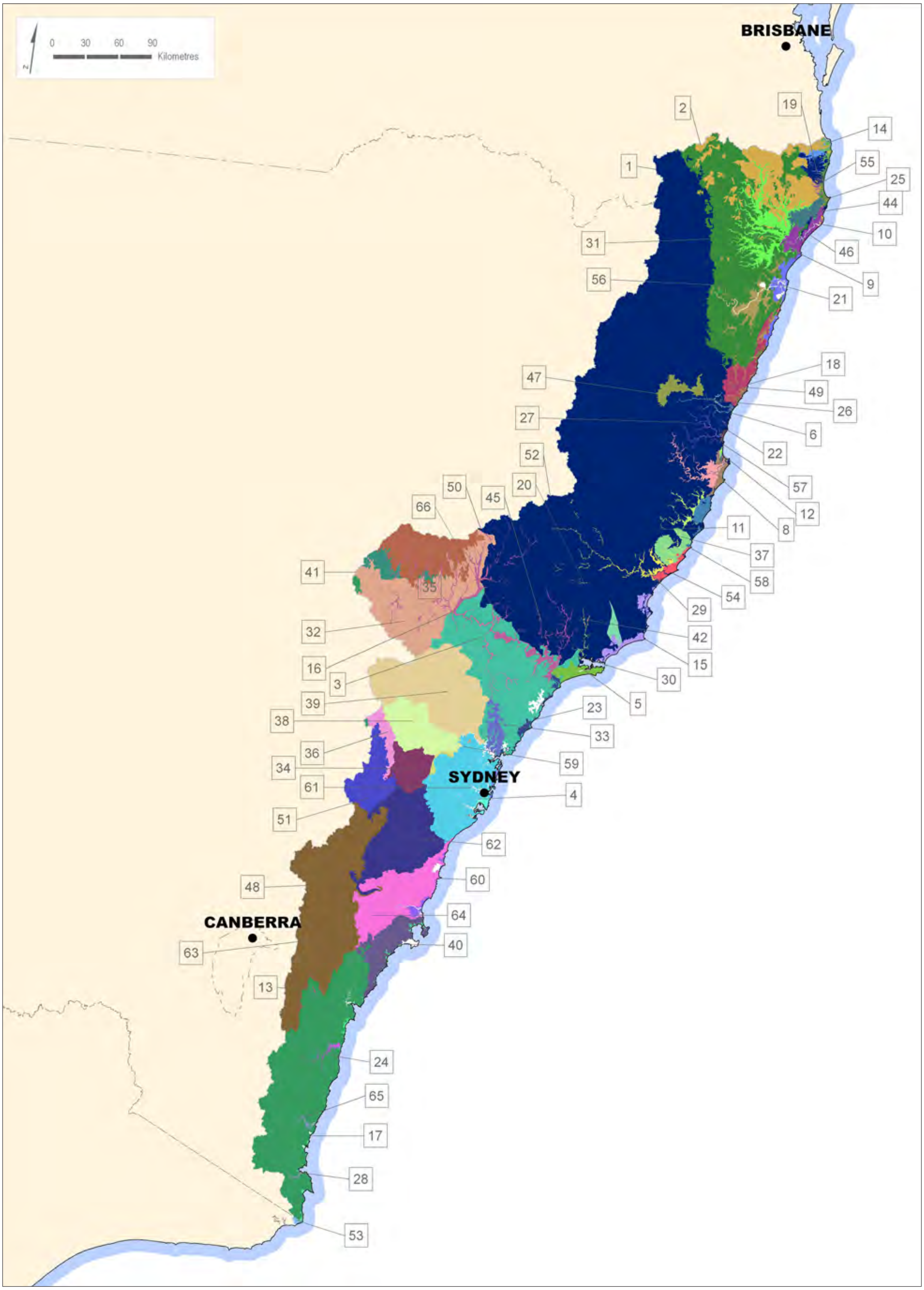



Figure 4.33 Groundwater management units in the South East Coast (NSW) region; data extracted from the National Groundwater Information System (Bureau of Meteorology 2013)

**Legend**

**Groundwater management unit**

01 Unincorporated Area
02 Eastern Downs
03 Hunter River Alluvium
04 Botany Sandbeds
05 Tomago-Tomaree-Stockton Sandbeds
06 Bellinger Coastal Sands
07 Maroota Tertiary Sands
08 Macleay River Alluvium
09 Richmond River Alluvium
10 Richmond Coastal Sands
11 Hastings River Alluvium
12 Stuarts Point Sandbeds
13 Araluen Alluvium
14 Tweed Coastal Sands
15 Great Lakes Coastal Sands
16 Goulburn River Alluvium
17 South East Coastal Sands
18 Coffs Harbour Coastal Sands
19 Tweed River Alluvium
20 Manning Alluvium
21 Clarence Coastal Sands
22 Nambucca Coastal Sands
23 Hawkesbury to Hunter Coastal Sands
24 Tuross Alluvium
25 Brunswick Alluvium
26 Bellinger Alluvium
27 Nambucca Alluvium
28 Towamba Alluvium
29 Manning Coastal Sands
30 Karuah Alluvium
31 Clarence-Moreton Basin
32 Sydney Basin - Upper Hunter
33 Sydney Basin - Mangrove Mountain Sandstone
34 Sydney Basin - Blue Mountains Sandstone
35 Oxley Basin
36 Sydney Basin - Coxs River Sandstone
37 Lorne Basin
38 Sydney Basin - Richmond Sandstone
39 Sydney Basin - North
40 Sydney Sandstone South Coast
41 Sydney Basin - Macquarie Bogan
42 Gloucester Basin
43 Bulahdelah Sandstone
44 Alstonville Basalt
46 North Coast Fractured Rock
47 Dorrigo Basalt
48 Lachlan Fold Belt
49 Coffs Harbour Metasediments
50 Liverpool Ranges Basalt
51 Coxs River Fractured Rock
52 Peel Valley Fractured Rock
53 Unincorporated Area
54 New England Fold Belt
55 Brunswick Coastal Sands
56 Clarence and Coffs Alluvium
57 Macleay Coastal Sands
58 Hastings Coastal Sands
59 Hawkesbury Alluvium
60 Metropolitan Coastal Sands
61 Sydney Basin Central
62 Sydney Basin - Nepean Sandstone
63 Goulburn Fractured Rock
64 Sydney Basin - South
65 Bega River Alluvium
66 Sydney Sandstone Central Coast

Legend to Figure 4.33 Groundwater management units in the South East Coast (NSW) region; data extracted from the National Groundwater Information System (Bureau of Meteorology 2013)

## 4.6 Water for cities and towns

This section examines the urban water situation in the South East Coast (NSW) region in 2011–12. The large urban centres in the region, their water supply systems and the storage situations are briefly described. The analysis includes the most populous city in Australia, Sydney, and for this centre further details are provided on the water supply system, storage volumes, water sources and water delivered.

### 4.6.1 Urban centres

Sydney is the most populous city in Australia. It is located on Australia's southeast coast. As of June 2012, the metropolitan area had a population of 3.9 million people (ABS 2011b). Sydney's urban area is in a coastal basin, which is bordered by the Pacific Ocean to the east, the Blue Mountains to the west, the Hawkesbury River to the north, and the Royal National Park to the south.

Newcastle, situated 162 km north of Sydney, has a population of just over 300,000 people and is the second most populated city in region.

The Central Coast is a peri-urban area located north of Sydney and south of Lake Macquarie. It has a population of 298,000 and is the third largest urban area in the region. The Central Coast is generally considered to include the area bounded by the Hawkesbury River in the south, the Watagan Mountains in the west and the southern end of Lake Macquarie in the north. It is reported to be growing at 1% per year.

Wollongong, located in the Illawarra district, has a population of 246,000 people. It is a coastal city that lies on the narrow strip between the Illawarra Escarpment and the Tasman Sea. It is situated 80 km south of Sydney.

Outside of its two major cities, the region has a large number of other 'regional' urban centres and towns. These, along with Sydney, Newcastle, the Central Coast and Wollongong, are shown Figure 4.34 in conjunction with their population ranges.


Sydney CBD | Malcolm Watson

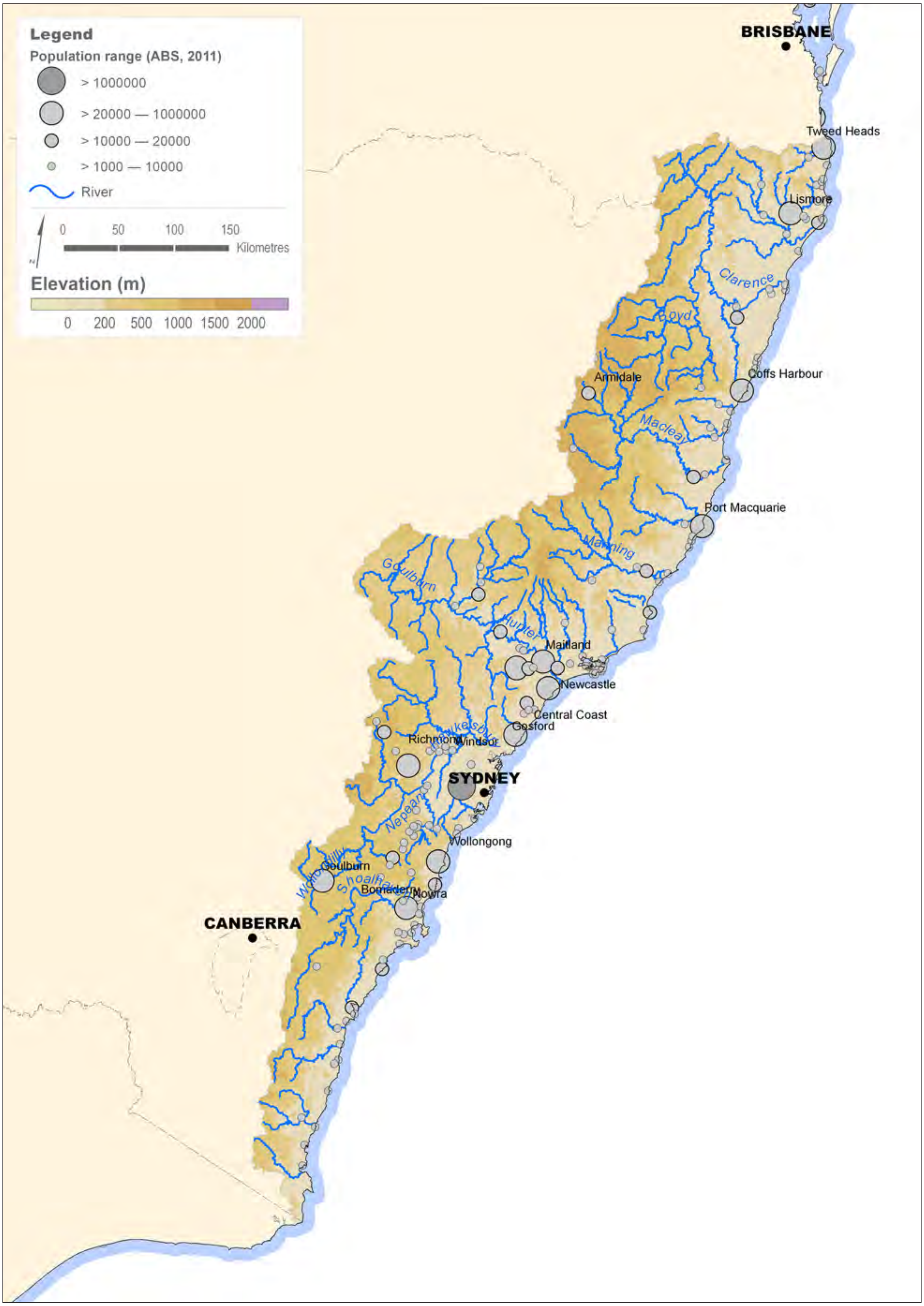



Figure 4.34 Population range of urban centres in the South East Coast (NSW) region

The major urban centres of the region, with populations of over 25,000 people, are summarised in Table 4.4. This table provides information on the population, surrounding river basin and significant water storages for each of the major urban centres.

### 4.6.2 Sources of water supply

All major cities and towns in the region are predominantly supplied with drinking water coming from surface water storages, or in some cases from direct river extractions, partly fed by upstream storage releases.

The region is home to over 20 major surface water storages that supply its many cities and towns. This includes the major Sydney metropolitan storage, Warragamba. With a total accessible storage capacity of over 2,000 GL it provides almost 85% of Sydney's total surface water storage.

Major surface water storages, predominantly used for urban water supply, are shown in Figure 4.35.

In addition to surface water storages, the region utilises direct river extractions, including extractions of upstream storage releases, groundwater, desalination, recycled water, and harvested stormwater and rainwater to supply the urban demands of the region.

Groundwater extractions form a reliable source of supply in the region and are an important source of water for Newcastle and the Port Stephens area.

Recycled water is an important source of water in the region, in particular in Sydney where dedicated recycling schemes such as Rouse Hill operate to provide 'third pipe' recycled water to consumers.

Table 4.4 Major urban centres and their water supply sources in the South East Coast (NSW) region

| City | Population[1] | River basin | Major supply sources |
|---|---|---|---|
| Sydney | 3,908,000 | Hawkesbury River | Warragamba (Lake Burragorang)<br>Upper Nepean storages (Cataract, Avon, Cordeaux and Nepean)<br>Shoalhaven system storages (Wingecarribee, Fitzroy Falls, Tallowa [Lake Yarrunga] and Bendeela Pondage)<br>Woronora storage<br>Blue Mountains storages (Lower Cascade, Middle Cascade, Upper Cascade, Lake Medlow and Lake Greaves)<br>Lake Oberon<br>Prospect Reservoir |
| Newcastle | 308,000 | Hunter River | Grahamstown and Chichester storages, Tomago Sandbeds |
| Central Coast | 298,000 | Macquarie–Tuggerah Lakes | Mangrove Creek, Mardi and Mooney Mooney storages |
| Wollongong | 246,000 | Wollongong Coast | Avon storage |
| Maitland | 67,000 | Hunter River | Grahamstown and Chichester storages, Tomago Sandbeds |
| Coffs Harbour | 45,500 | Clarence River<br>Bellinger River | Karangi storage, Orara River |
| Port Macquarie | 41,500 | Hastings River | Port Macquarie and Cowarra off-creek storages |
| Nowra–Bomaderry | 28,000 | Shoalhaven River | Shoalhaven River with water released from Lake Yarrunga (Tallowa) |
| Lismore | 27,500 | Richmond River | Rocky Creek storage |

[1] Australian Bureau of Statistics (2011b)


Figure 4.35 Urban supply storages in the South East Coast (NSW) region

### 4.6.3 Greater Sydney

Sydney, with a built up area of 4,000 $km^2$, is one of the largest cities in the world. The urban centres of Sydney and Wollongong account for nearly 60% of the population of New South Wales and are part of the Greater Sydney area, which also includes the Blue Mountains. Greater Sydney is the urban water supply reporting area addressed in this subsection.

The State Government-owned Sydney Water Corporation, Sydney Water, is the urban water utility that supplies Greater Sydney. It services a population of 3.9 million people. Sydney Water operates the bulk water supply and distribution systems, wastewater collection system and drainage assets.

Water supplies are mainly sourced from catchment areas occupying approximately 16,000 $km^2$, managed by the Sydney Catchment Authority (SCA).

#### Supply systems

Sydney's water supply catchments include the Warragamba, Upper Nepean, Blue Mountains, Woronora and Shoalhaven river basins, which provide water for Sydney's storages as well as for the Southern Highlands and Shoalhaven areas. Parts of these water supply catchments are protected to help maintain water quality and provide habitat for a variety of rare and endangered flora and fauna.

The Fish River Water Supply Scheme, originating in Oberon, supplements Sydney's water supply by providing water to the Blue Mountains area. Water from Tallowa (Lake Yarrunga), Fitzroy Falls and Wingecarribee storages is used to supply local communities and supplement SCA water storages during drought (NSW Government 2011b).

While water from the storages provide most of Greater Sydney's drinking water needs, the 2006 Metropolitan Water Plan (New South Wales Government 2006) introduced measures to diversify Sydney's water supply through water recycling and desalination. Recycled water has become important in securing supply for the residential, commercial and industrial needs of Sydney.

The major water components of the water supply system for the Greater Sydney area is shown in Figure 4 36. Sydney is known to have one of the highest per capita water storage capacities in the world (NSW Government 2011c). The inter-connected network represents a complex urban water system and includes a total of 21 storages that can hold more than 2,500 GL of water. Water taken from the Hawkesbury River is used to supply Richmond–Windsor. The water supply for Wollongong is sourced from the Avon storage.

Figure 4.36 also shows the water treatment plants and the treated water delivery systems for the Greater Sydney area. Water sourced from the storage network, the Hawkesbury River and the Kurnell desalination plant is treated and delivered to customers by Sydney Water. The water supply system includes ten water treatment plants and a network of about 21,000 km of water mains (National Water Commission 2011a). Most of the water is treated at privately owned water filtration plants operating under contract to Sydney Water.

The major surface water storage in the network, Warragamba, collects water from the Wollondilly and Coxs rivers. Its catchments cover an area of 9,000 $km^2$. It is the largest urban water storage in Australia and accounts for about 80% of water supplies to Greater Sydney (SCA 2011b).

The storages of the Upper Nepean collect water from the catchments of the Cataract, Cordeaux, Avon and Nepean rivers. The catchments of the Upper Nepean lie in one of the highest rainfall areas in New South Wales. Together with the Shoalhaven River basin, they provide more reliable inflows than the Warragamba catchments. The Upper Nepean transfer system can provide the equivalent of 30% of Sydney's water supply (NSW Government 2010b). Upper Canal, a 64-km long combination of open channels, tunnels and aqueducts, transfers water from Upper Nepean storages to the Prospect water filtration plant.

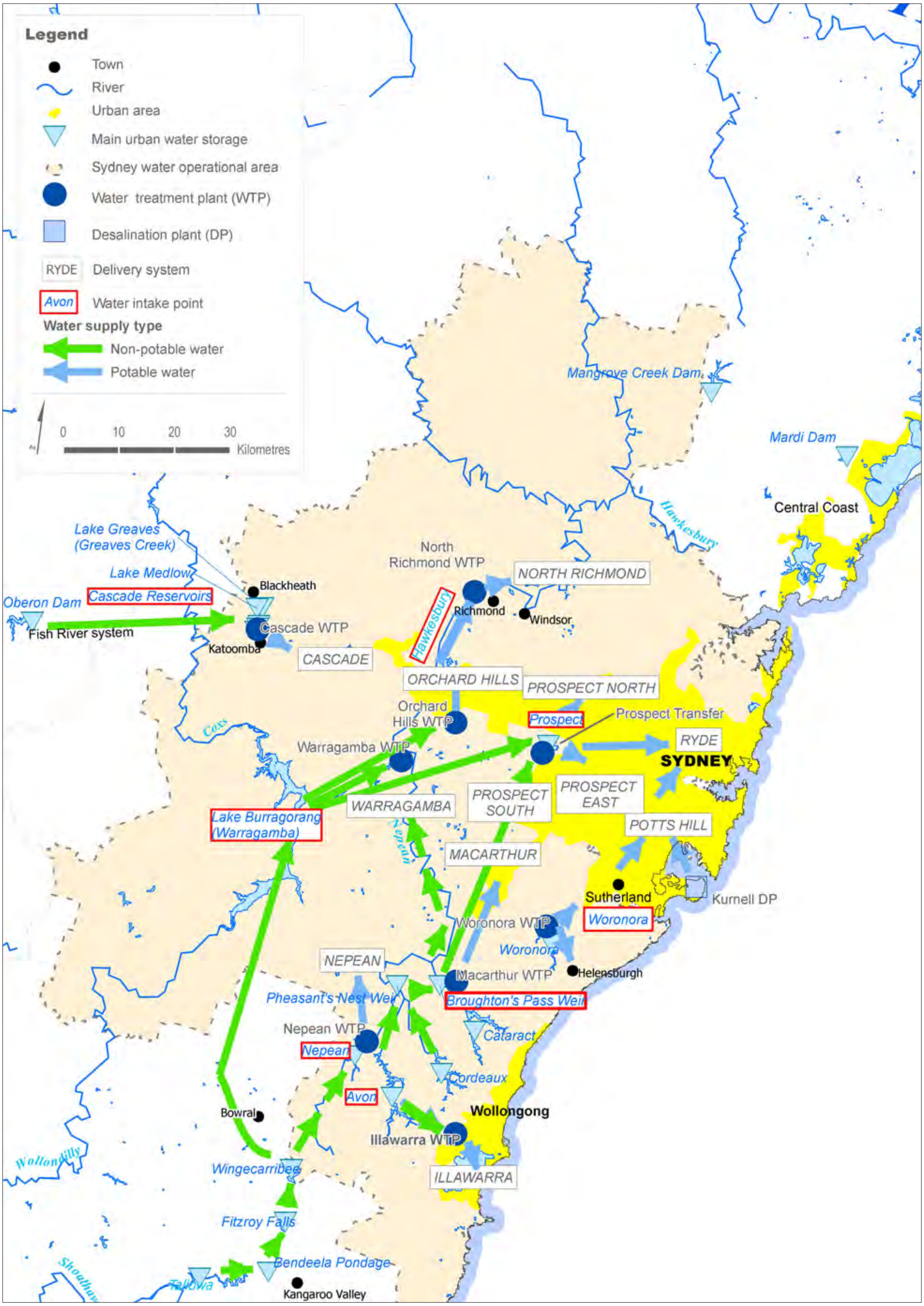



Figure 4.36 Water supply schematic for Greater Sydney

The Blue Mountains storage system comprises three small catchments feeding six storages that provide water for the Blue Mountains region. Water can also be sourced from the Fish River Water Supply Scheme (SCA 2011a). Due to a continuing water shortage in the Oberon and surrounding regions, this scheme has not recently been used to supply the Blue Mountains.

Woronora storage, the water supply source for the Sutherland Shire in Sydney's southeast, collects water from the Woronora River catchment.

The Shoalhaven system in the south, which includes the storages of Wingecarribee, Fitzroy Falls, Bendeela Pondage and Tallowa, is an integral part of Sydney's water supply system. The Shoalhaven system serves as a dual-purpose water supply and hydro-electric power generation scheme. Since the 1970s, Sydney and the Illawarra have relied on water pumped from Tallowa on the Shoalhaven River to supplement water supplies in times of drought. The system can provide around 30% of supply to the Greater Sydney region. Water is transferred using the river system to provide additional water into Warragamba (Lake Burragorang) or the upper Nepean storages (NSW Government 2010b).

The Kurnell desalination plant was constructed in response to low water storage inflows from 2000 onwards and began supplying water to Sydney in January 2010. When operating at full capacity, the desalination plant can produce 90 GL of water per year, enough water to supply up to 15% of Sydney's current water needs. Water from the desalination plant is distributed to approximately 1.5 million people across the Sydney central business district, inner west, eastern suburbs, south Sydney, as well as parts of the Sutherland Shire.

In addition to water sourced from surface water and desalination, water recycling is an important source for securing water for residential, commercial and industrial needs. Sydney Water operates 17 recycled water schemes including Australia's largest recycled water scheme at Rouse Hill. The Wollongong recycled water scheme supplies water for industrial and irrigation use. The remaining recycled water schemes mainly supply agricultural areas and sports fields.

### Storage volumes

Figure 4.37 shows the total accessible storage volumes for Sydney's major storage, Warragamba and three of the four upper Nepean storages over the period 1989–90 to 2011–12. These plots clearly illustrate the significant draw down to critical levels during the latter stages of the Millennium Drought and the dramatic recovery to near full supply levels during the above average rainfall years post 2009–10.

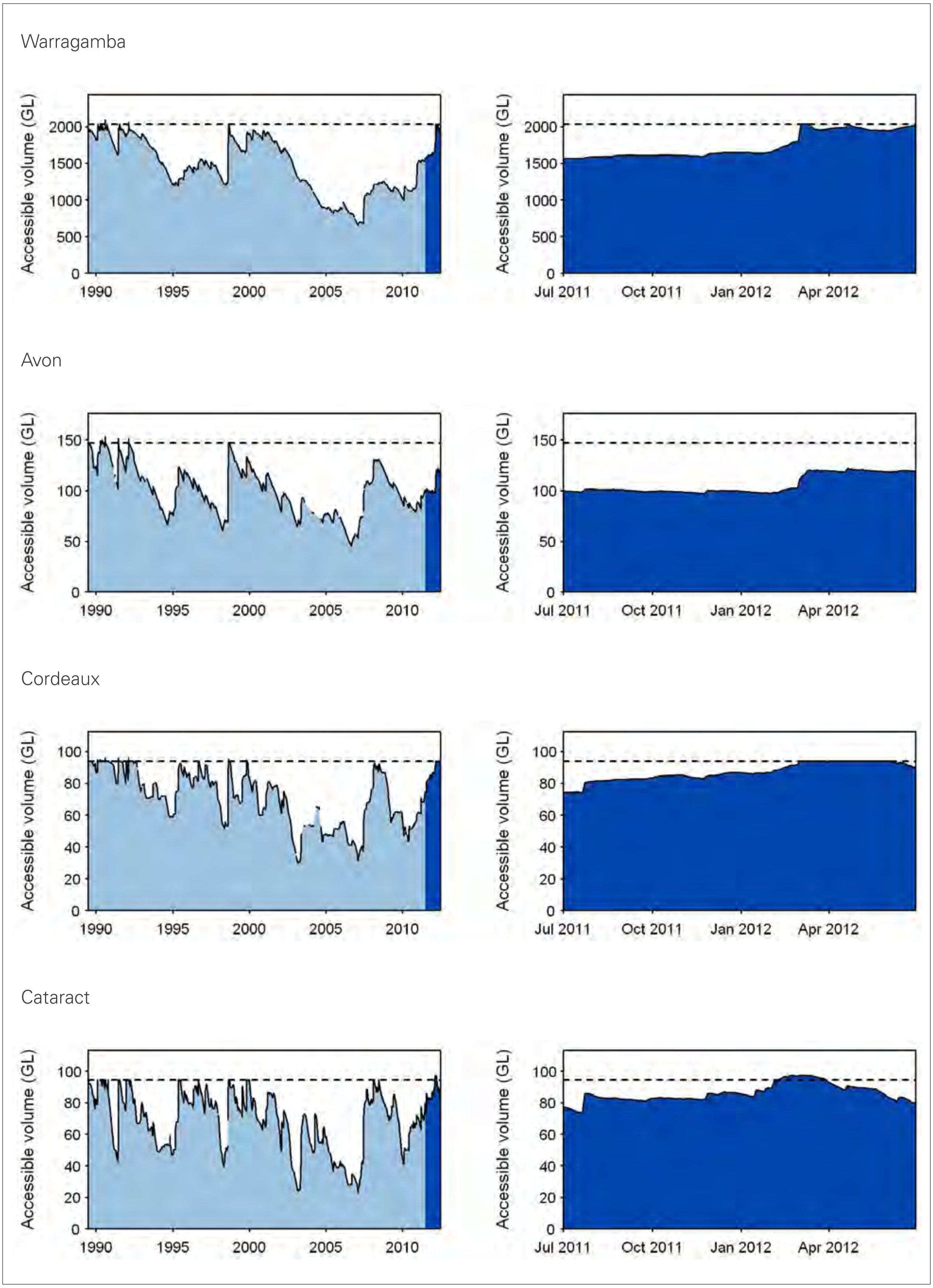



Figure 4.37 Variation in the amount of water held in storage over recent years (light blue) and over 2011–12 (dark blue) for Sydney's major storage, Warragamba, and three of the four upper Nepean storages, as well as total accessible storage capacity (dashed line).

### Water restrictions

Figure 4.38 shows the accessible storage volume and the water restrictions implemented for Sydney in recent years. Water restrictions are used as a measure to reduce the demand on water supplies. On 1 November 1994, mandatory water restrictions were introduced for Sydney in response to a decreasing accessible volume at Warragamba. Above average rainfall during 1995 led to an increase in storage volume, and on 16 October 1996 the restrictions were lifted.

During 2002, Sydney experienced one of the worst periods of drought on record. Surface water storage levels began to decline rapidly and, as a strategy to reduce water consumption, voluntary water restrictions were introduced in Sydney in November 2002 (Sydney Water Corporation 2010). Despite this, the volume of water in Warragamba continued to decrease under the ongoing drought conditions.

With the total combined storage volume of Sydney's supply network falling below 60% of its capacity, Sydney Water introduced mandatory water restrictions level 1 at the beginning of October 2003.

When Sydney's total storage volume dropped below 50% of capacity, mandatory water restrictions were elevated on 1 June 2004 to level 2. Water restrictions were elevated to level 3 on 1 June 2005 when the total storage volume dropped below 40% of capacity.

In May 2007, Warragamba reached the lowest water level in recent years. Above average rainfall increased storage volumes to about 60% of its accessible storage capacity. As a consequence, Level 3 water restrictions were eased out by June 2008.

Combined storage volumes remained at around 60% over the following 12 months and water restrictions were replaced by 'Water Wise Rules' in June 2009 to encourage continued water saving. Water Wise Rules have remained in place since then as storage levels have continued to rise to near full capacity during early 2012.

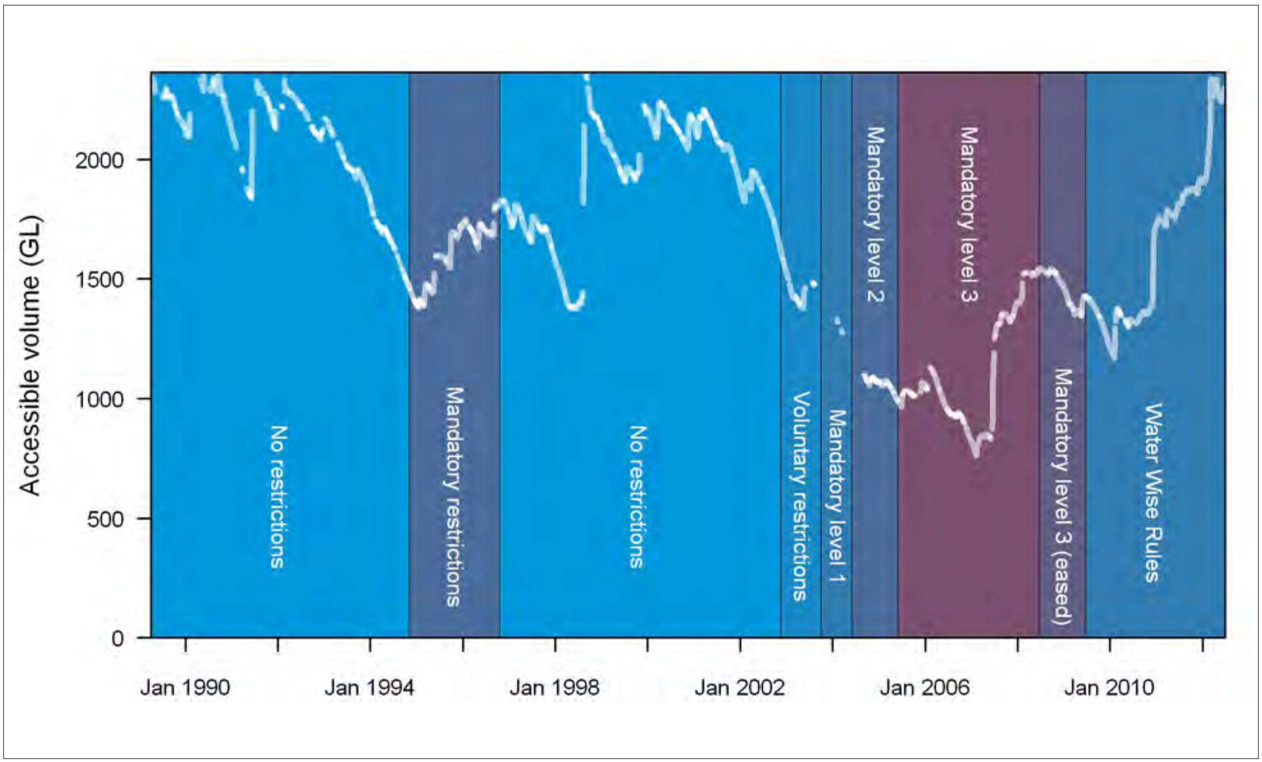



Figure 4.38 Water restrictions in the Greater Sydney area

## Sources of water obtained

Figure 4.39 shows the total volume of water sourced from surface water, recycling, and desalination by Sydney Water from 2006–07 to 2011–12 (National Water Commission 2011a). The volume sourced from surface water includes water received from the bulk supplier (SCA) and surface water taken from the Hawkesbury River for supply to Richmond–Windsor.

The total volume of water sourced in 2011–12 was 495 GL. Over the past five years, the highest volume of water sourced, 517 GL, was in 2006–07. The following year annual volumes decreased to 491 GL in 2007–08 and 506 GL in 2008–09. This decrease can be attributed to, in part, the easing of water restrictions from June 2008.

The main source of water supply for the Greater Sydney region is surface water, which ranged from 97% of the total water sourced in 2006–07 to 81% in 2010–11. The decrease in surface water sourced coincides with an increase in desalination water supplied.

The Kurnell desalination plant was commissioned in January 2010. Water sourced from desalination accounted for 3.9% of total water sourced in 2009–10. The share of desalinated water increased to 15% for the 2010–11 year and 12% for 2011–12 year.

Water from recycling comprises a small yet significant component of water sourced, ranging from 1.5% in 2006–07 to 2.1% in 2010–11. In 2011–12, water sourced from recycling accounted for 2.7%.

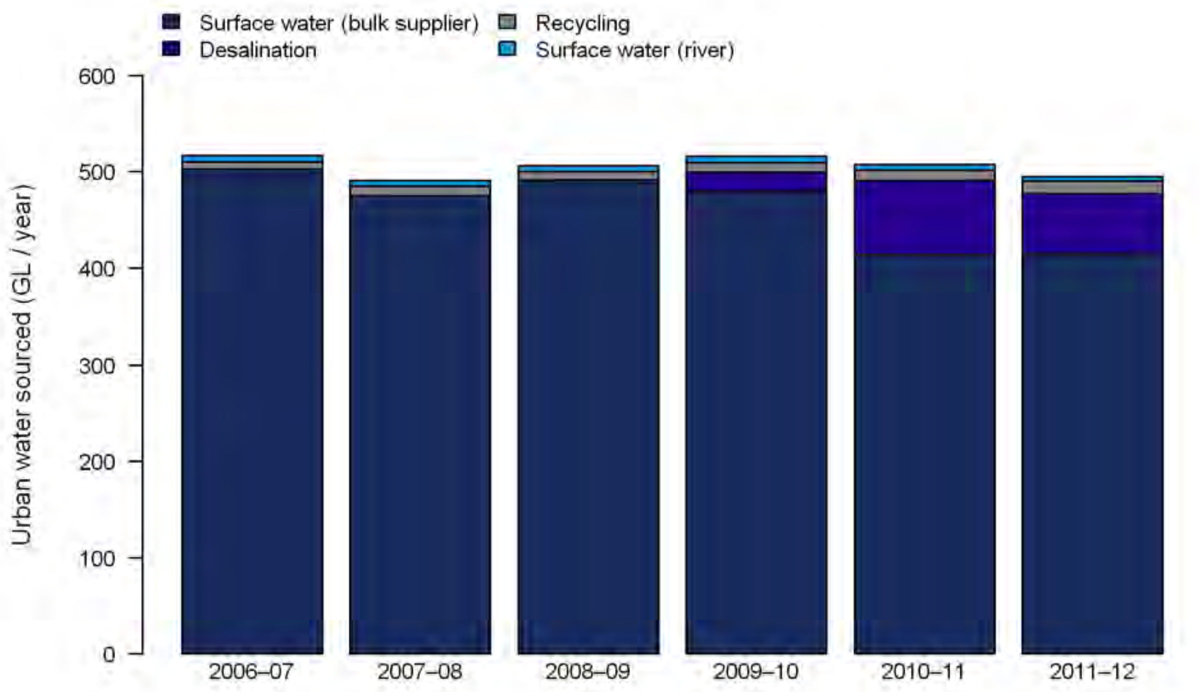



Figure 4.39 Total urban water sourced for the Greater Sydney area from 2006–07 to 2011–12

## Categories of water delivered

Figure 4.40 shows the total volume of water delivered to residential, commercial, municipal and industrial consumers in the Greater Sydney region from 2006–07 to 2011–12 (National Water Commission 2012). The total volume of water delivered to the residential sector in 2011–12 accounted for 61% of total potable water consumption.

Total water supplied has gradually increased since the 2007–08 year and was highest in 2010–11 at 544 GL. While residential and commercial use has remained consistent over the last three years, there has been a significant growth in water supplied for other uses.

Based on the data obtained from the National Performance Reports (National Water Commission 2012), the average water supplied by Sydney Water, per property for residential use was estimated to be 196 kL from 2006–07 to 2011–12. The maximum residential water use per property was 205 kL in 2009–10 and the minimum was 182 kL in 2007–08.

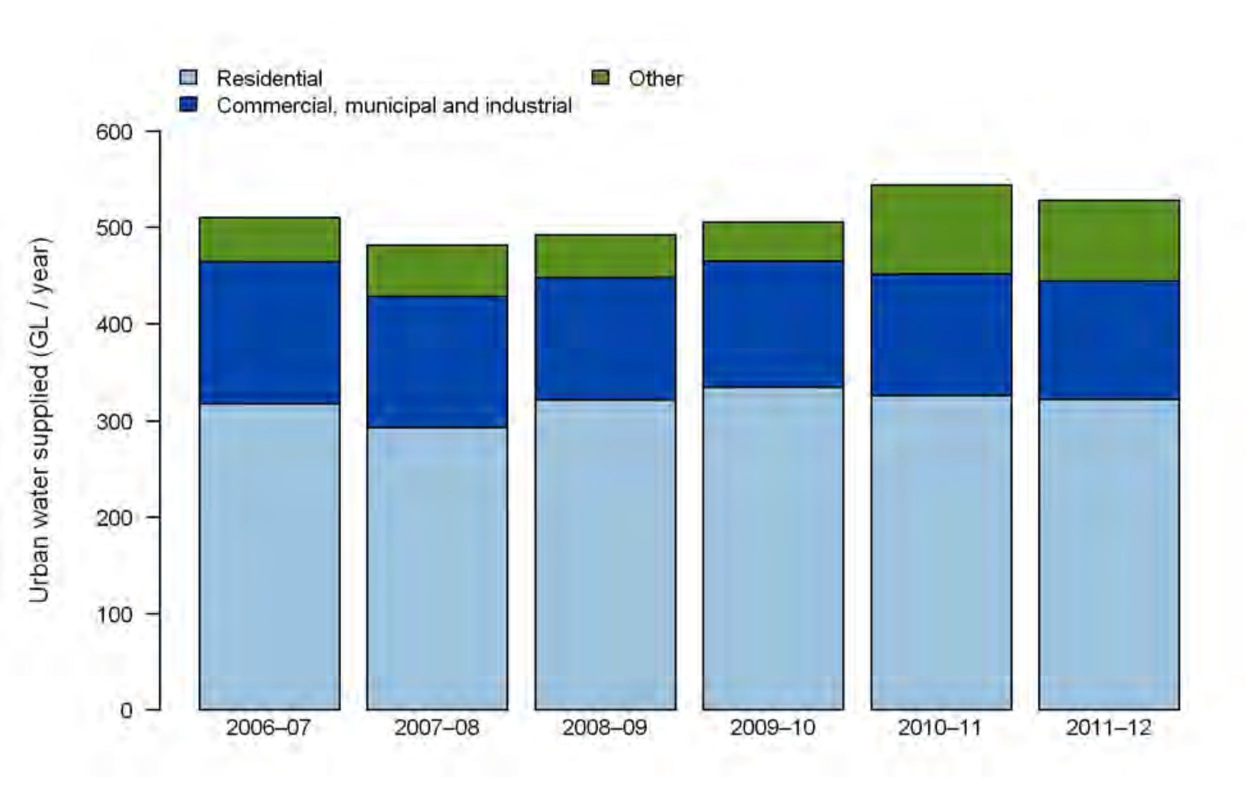



Figure 4.40 Total urban water supplied to the Greater Sydney area from 2006–07 to 2011–12

## 4.7 Water for agriculture

This section describes the water situation for agriculture in the South East Coast (NSW) region in 2011–12. Soil moisture conditions are presented and important irrigation areas are identified. The Hunter River irrigation area is described in more detail and information is provided regarding surface storage.

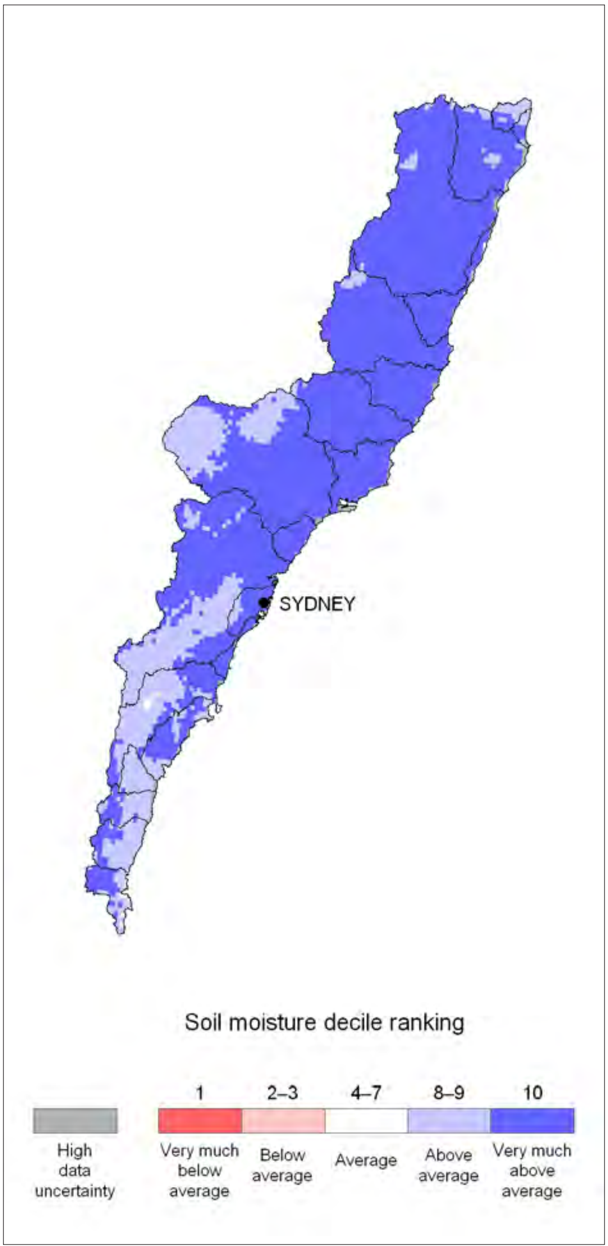



Figure 4.41 Deciles rankings of the soil moisture over the 1911–2012 period in the South East Coast (NSW) region

### 4.7.1 Soil moisture

Since model estimates of soil moisture storage volumes are based on a simple conceptual representation of soil water storage and transfer processes averaged over a 5 km x 5 km grid cell, they are not suitable to compare with locally measured soil moisture volumes. This analysis therefore presents a relative comparison only, identifying how modelled soil moisture volumes of 2011–12 relate to those of the 1911–2012 period, expressed in decile rankings.

The above average rainfall in the region during 2011–12 favoured wet conditions in the soils, which ranked as very much above the long-term average for most areas. In the southern parts, the soils were generally at above average conditions (Figure 4.41).

Temporal variation of the decile rankings show very much above average soil moisture conditions for most of 2011–12 (Figure 4.42). This was a result of the high rainfall in the region, which sustained the wet conditions in the soil.

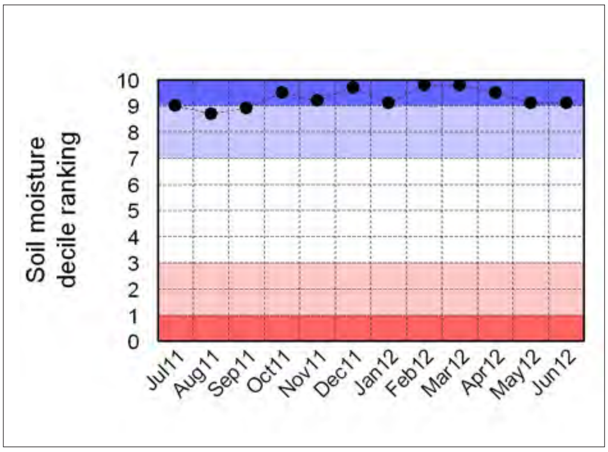



Figure 4.42 Decile ranking of the monthly soil moisture conditions during the 2011–12 period in the South East Coast (NSW) region

### 4.7.2 Irrigation water

Irrigation water use in the region between 2005–06 and 2010–11 is shown in Figure 4.43 and Figure 4.44 by natural resource management (NRM) region. Data for the 2011–12 year was not available at the time of preparing this report.

The data show that the highest irrigation water use occurs in the regulated Hunter River basin, followed by the Hawkesbury–Nepean river basin.

Figure 4.44 shows the variation in the irrigation water use during the 2010–11 year. The Hunter River basin with 86 GL was the major consumer of irrigation water.

In the next section, the Hunter River basin is used as an example for water resource conditions and irrigated agriculture in 2011–12.

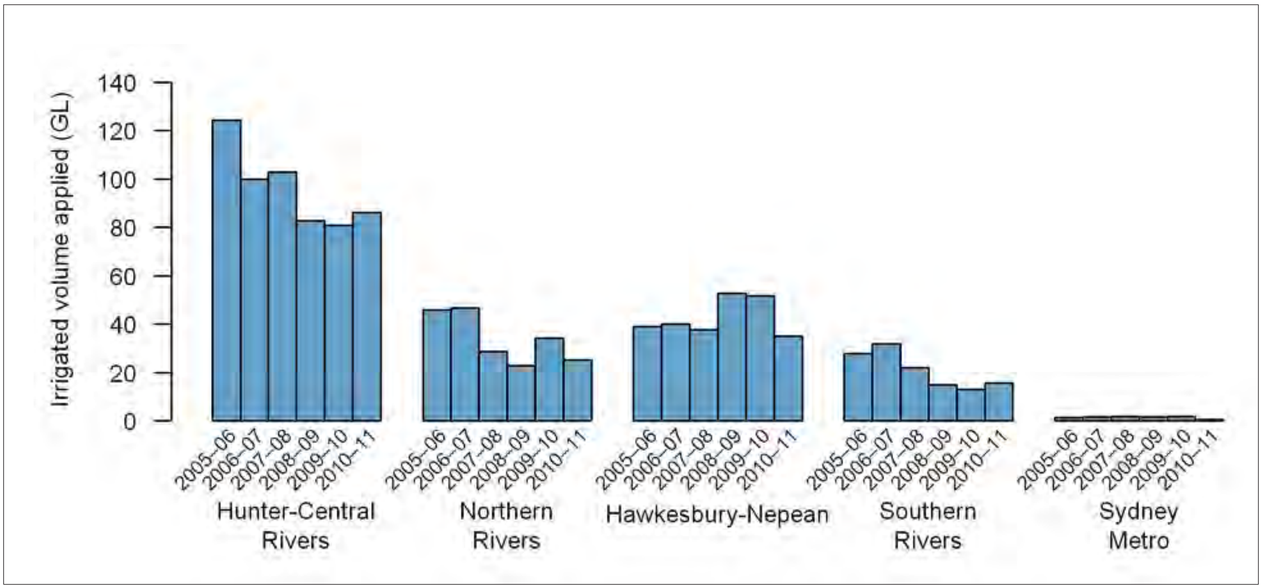



Figure 4.43 Total annual irrigation water use for 2005–06 to 2010–11 for natural resource management regions in the South East Coast (NSW) region (ABS 2006–10; 2011a)

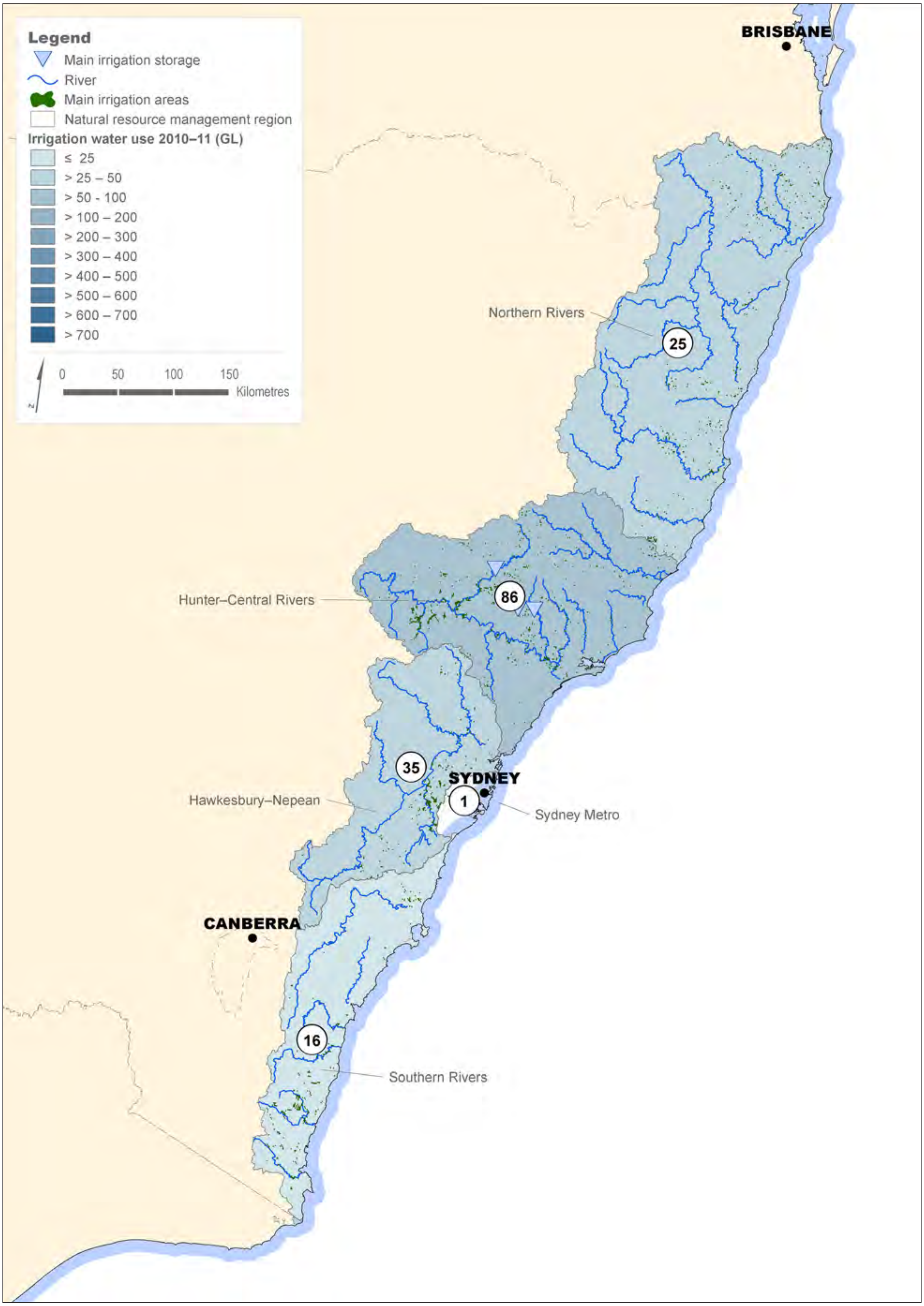



Figure 4.44 Annual irrigation water use per natural resource management region for 2010–11 (ABS 2011a)

### 4.7.3 Irrigation areas

In the subtropical north, where dairy is the largest industry, irrigation is necessary during spring and early summer. Mild winters and warm hot summers in the north are conducive also to avocado, banana, citrus and other fruit production.

In the mid-coast catchments, wine grapes and dairy pasture are the two most important irrigated industries. In these areas, most of the licences for irrigation are located in the Hunter catchment (Figure 4.45) along the Williams and Goulburn rivers and Wollombi Brook (Hope 2003b).

The southern coast has extensive forested headwaters, wetlands, river estuaries and freshwater swamps. Irrigated agriculture occurs mainly in the Hawkesbury–Nepean and Bega river basins (Hope 2003c). Dairy production is the main industry followed by vegetables and floriculture.

Unregulated rivers are the major source of water for the irrigation industry in most parts of the region. Irrigation from farm storages is widespread and provides a level of security during droughts. Irrigation from groundwater is very limited (Hope 2003a).

The Hunter River basin irrigation areas are described in more detail in subsection 4.7.4.

Hunter Valley vineyards, New South Wales | Christopher Howey (Dreamstime)

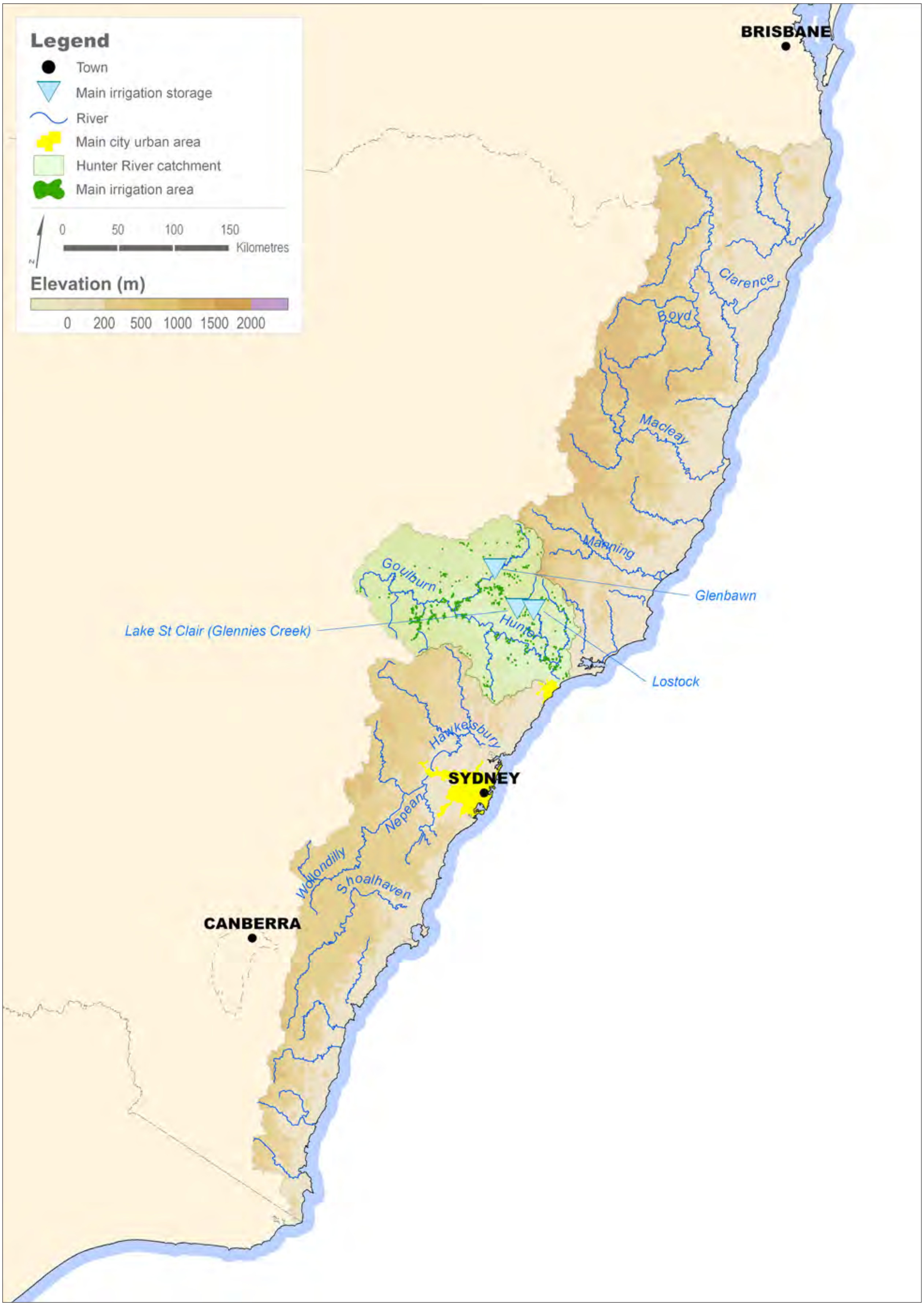



Figure 4.45 The Hunter River basin in the South East Coast (NSW) region

### 4.7.4 Hunter River basin

The Hunter River drains the largest coastal catchment in New South Wales (22,000 km$^2$) and provides the only regulated water supplies in the mid-coast part of the South East Coast (NSW) region (Figure 4.46).

The Hunter River basin contains approximately 80% of the irrigated area in the mid-coast. Irrigation is used to grow pasture and lucerne for dairy farms. Vineyards are the second most important irrigated enterprise in the river basin and are located along the Goulburn River and Wollombi Brook. The river basin also supports a diversity of other agricultural activities, such as beef cattle, dairy, poultry, wool and sheep, cereal crops and horse and cattle studs.

Most of the water in the Hunter Valley irrigation area comes from the north-eastern part of the catchment. Water is controlled by three storages: Glenbawn, Lake St Clair, behind Glennies Creek dam, and Lostock.

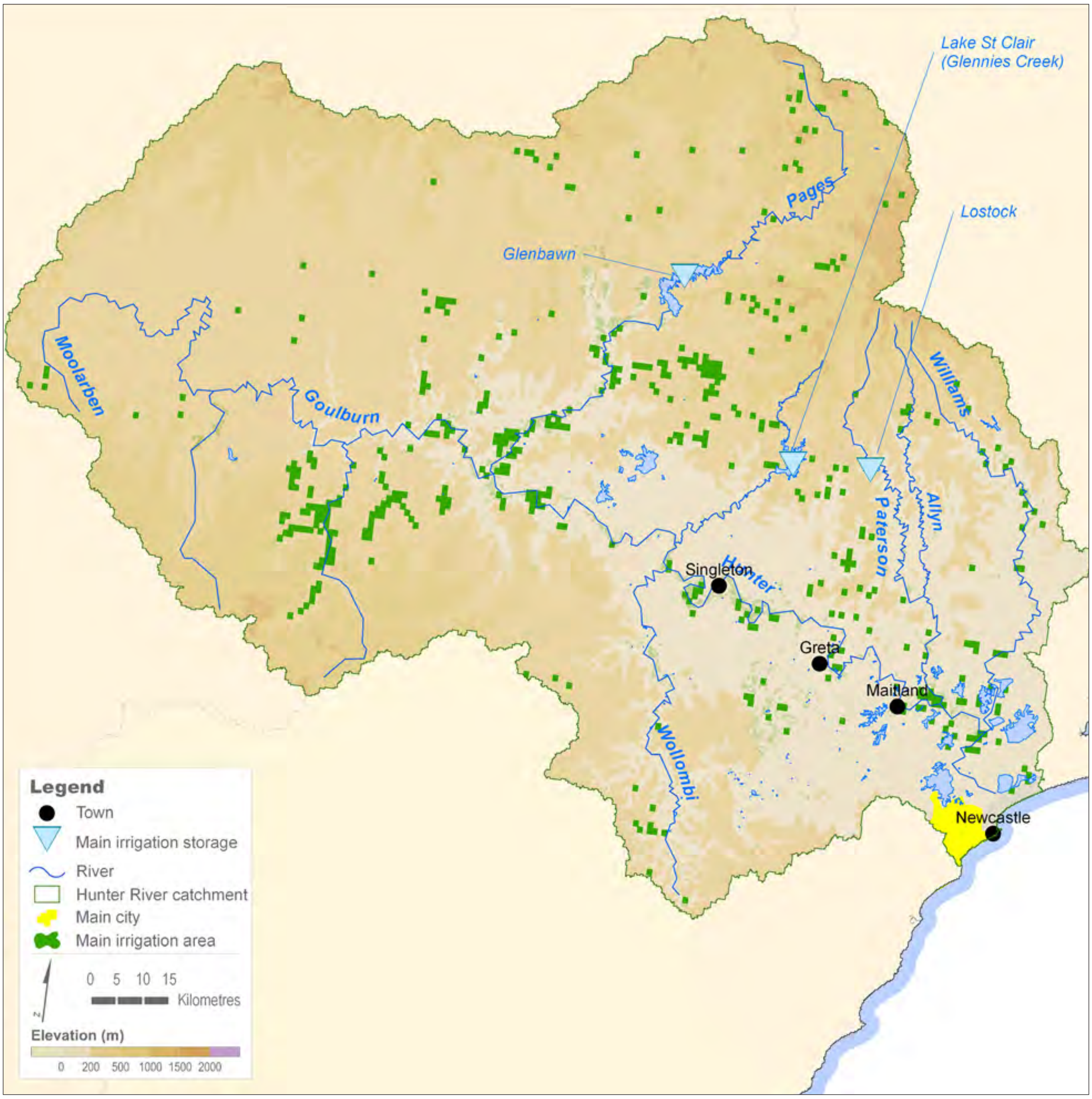



Figure 4.46 Irrigated areas in the Hunter River basin

Glenbawn storage, with an accessible capacity of 750 GL plus 120 GL for flood control, is located behind the largest earth-filled dam in Australia. It regulates flows in the Hunter River downstream of Maitland. The storage has an area of 26 $km^2$ with a maximum depth of 85 m. It provides water for towns, stock, irrigation, industry and environmental flows.

Glenbawn is operated in conjunction with Glennies Creek storage. The latter has an accessible storage capacity of 283 GL with surface and catchment areas of 15 $km^2$ and 233 $km^2$, respectively. It supplies water for the town of Singleton as well as for irrigation, stock and industries such as coal mining (State Water Corporation 2011).

The Hunter Regulated River Water Sharing Plan contains rules for how water is shared between the environment and water users with different categories of licences. The plan establishes a long-term average annual extraction limit estimated as 217 GL per year, out of an annual natural average flow estimated at 1,042 GL (New South Wales Department of Water and Energy 2009). This ensures a minimum level of flow in the Hunter River at Liddell, just upstream of the Glennies Creek junction, and Greta (near the end of the regulated river system).

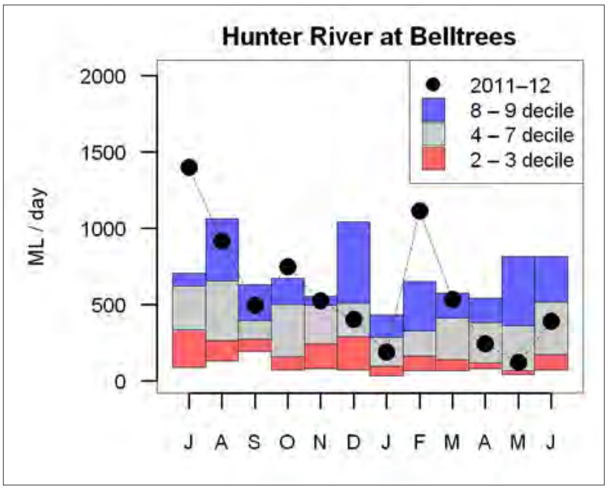



Figure 4.47 Monthly discharge hydrographs compared to discharge deciles of Hunter River at Belltrees, representing inflows into Glenbawn

The plan also establishes water reserves (or environmental contingency allowances) of 20 GL per year in both Glenbawn and Glennies Creek. The rules for how water is shared between extractive users are set by the plan.

The Hunter regulated river water source is divided into three management zones and five supplementary water reaches for the management of extractions by supplementary water access licences. An actual volumetric allocation scheme was introduced in 1981 which is based on 6 ML/ha. In most years, water allocation for general security use was 100% or more.

### Surface water storage inflows

In 2011–12, the flows in the catchments upstream of the Glenbawn storage were at medium to high levels compared with their historic record. The maximum flows at the Hunter River occurred in February that coincided with the high incidents of rainfall in the region (Figure 4.47). The flows gradually declined during spring and early summer, with a sudden rise during February following the rainfall pattern in the region.

### Surface water storage volumes

Combined inflows to the Glenbawn and Glennies Creek storages and total regulated water use in the Hunter region since 1985 are shown in Figure 4.48. The inverse relationship between the two indicates diversions increased in drought years in response to greater irrigation water demand. The combined inflows to Glenbawn and Glennies Creek in 2011–12 were much above the average (184 GL).

The storage volume for both the Glenbawn and Glennies Creek storages remained at 100% of their accessible capacity for most parts of the year (Figure 4.49).

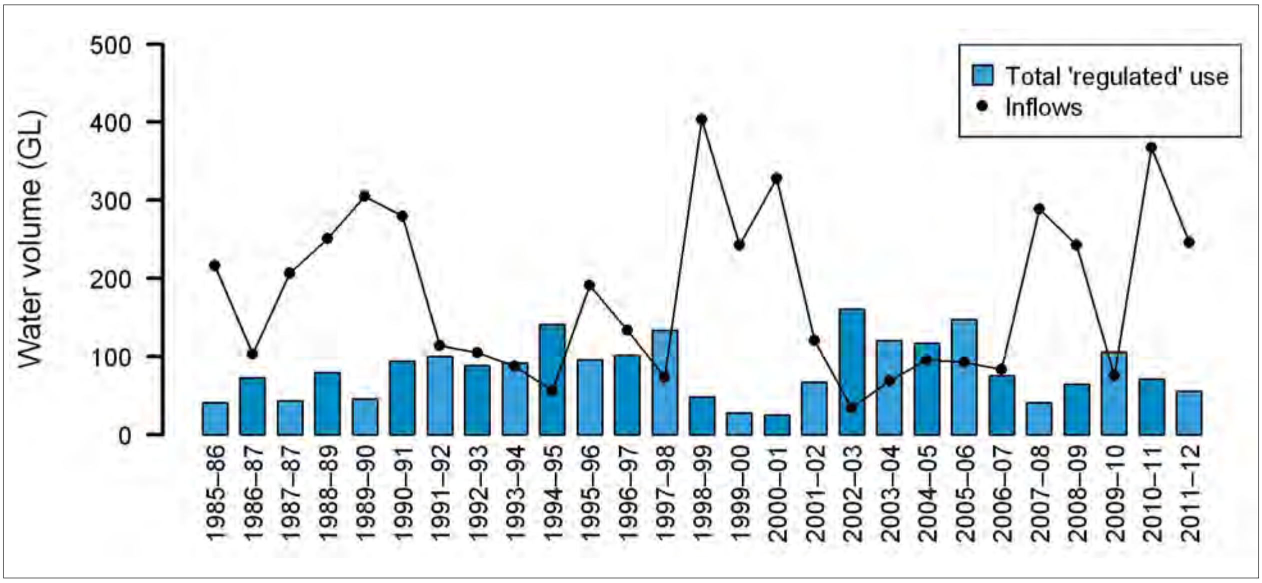



Figure 4.48 Combined inflows to the Glenbawn and Glennies Creek storages and total regulated water use in the Hunter region between 1985–86 and 2011–2012

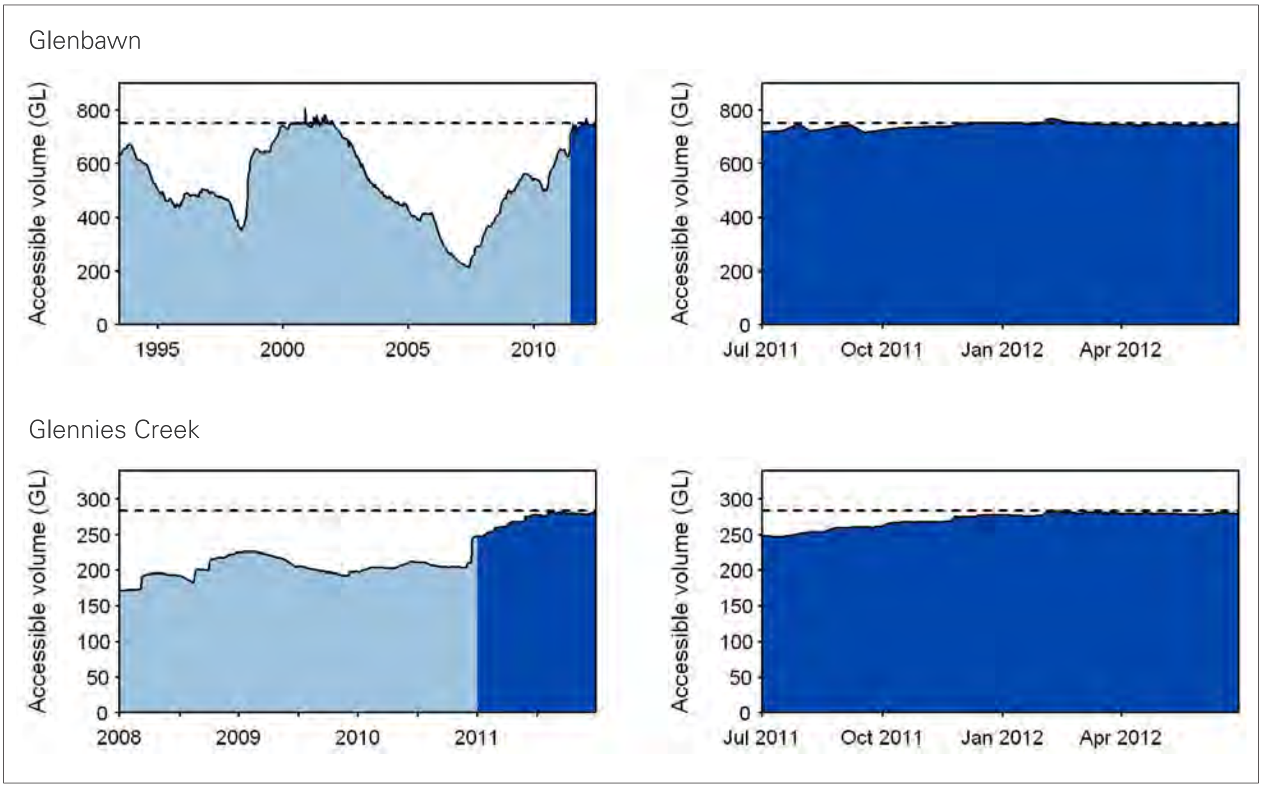



Figure 4.49 Variation in the amount of water held in storage over recent years (light blue) and over 2011–12 (dark blue) for Glenbawn and Glennies Creek storages, as well as total accessible storage capacity (dashed line)