South West Coast

10 South West Coast

10.1 Introduction

This chapter examines water resources in the South West Coast 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.

10.2 Key information

Table 10.1 gives an overview of the key components of the data and information in this chapter.

Table 10.1 Key information on water flows, stores and use in the South West Coast region

Landscape water flows

	Region average	Difference from 1911–2012 long-term annual mean	Decile ranking with respect to the 1911–2012 record
Rainfall	499 mm	+14%	8th—above average
Evapo-transpiration	455 mm	+15%	10th—very much above average
Landscape water yield	28 mm	-24%	4th—average

Streamflow (at selected gauges)

Annual total flow:	Between average and very much below average flow throughout the region
Salinity:	Annual median electrical conductivity predominantly above 2,000 µS/cm inland and less saline in the coastal rivers in the west
Flooding:	Sporadic minor and moderate flooding in the southwest river basins

Surface water storage (comprising about 92% 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
951 GL	309 GL	32%	210 GL	22%	+99 GL	+10%

Groundwater (in selected aquifers)

Salinity:	Non-saline groundwater (<3000 mg/L) only along the southwest coastline and in scattered areas in the north

Urban water use (Perth)

Total sourced in 2011–12	Total sourced in 2010–11	Change	Restrictions
248 GL	247 GL	+1 GL	Eased to Stage 5 in September, back to Stage 7 in June

Annual mean soil moisture (model estimates)

Spatial patterns:	Predominantly average to below average annual mean soil moisture with large areas of very much below average soil moisture to the east and in the southwest
Temporal patterns in regional average:	Below average soil moisture throughout the year, only reaching average levels in summer

10.3 Description of the region

The South West Coast region covers approximately 326,000 km^2 of land. It is bounded to the west by the Indian Ocean and to the south by the Great Australian Bight. The northern boundary is the Pilbara–Gascoyne region and the eastern boundary is the South Western Plateau region.

The landscape of the region is generally flat and sandy in inland areas. Higher altitude topographic features include the Darling Scarp that forms an ancient geological boundary to the 30-km wide Swan Coastal Plain along the west coast and the Stirling Range near Albany. The Swan Coastal Plain consists of relatively infertile sandy soils and coastal dunes; a number of estuaries and wetlands are separated from the sea by these dunes. Subsections 10.3.1–10.3.4 give more detail on physical characteristics of the region.

The region has a population just over 2 million people, which accounts for just over 9% of the nation's total population (Australian Bureau of Statistics [ABS] 2011b). Figure 10.1 highlights the major population centres in the region that includes Perth, Mandurah, Bunbury and Albany. Further discussion of the region's population distribution and urban centres can be found in subsection 10.3.6 and section 10.6 respectively.

The north of the region is dominated by pasture, becoming a more complex pattern of pasture and dryland crops towards the central and southern parts of the region. Forestry is important in the wetter higher altitude western slopes, with extensive conservation reserve areas in this part of the region. Conservation shrubland and heathland reserves are well represented in the more arid east (Figure 10.1).

Dryland and irrigated agriculture account for a very small proportion of the land use in the area. Intensive land uses such as urban areas also account for small proportions of the region. The largest areas of irrigated agriculture are located in the Peel–Harvey irrigation district, with a considerable proportion of the water used to irrigate pasture for dairy and for vegetable and fruit crops. Section 10.7 has more information on agricultural activities in the region.

The region has a temperate climate with warm dry summers and cool winters. Most rainfall occurs in the west with reduced rainfall further inland. The Stirling Range receives occasional snowfall. Subsections 10.3.7 and 10.3.8 provide more information on the rainfall types and deficits across the region.

The longest rivers are located in the southwest, with the Avon and Blackwood rivers having the largest catchment areas. Due to the raised topography and orientation of the Darling Scarp, most of the major rivers drain towards the Indian Ocean but the high soil permeability results in generally low surface flows.

The hydrogeology of the region is dominated by a large area of outcropping fractured basement rock. The groundwater systems in fractured rock typically offer a restricted low volume groundwater resource. Significant groundwater resources are, however, available on parts of the coastal plain. Approximately 35–50% of the water supplied to the city of Perth is sourced from groundwater. A more detailed description of the rivers and groundwater status in the region is given in section 10.5.

Figure 10.1 Major rivers and urban centres in the South West Coast region

10.3.1 Physiographic characteristics

The physiographic map in Figure 10.2 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 West Coast region has two physiographic provinces, namely the Western Coastlands and Yilgarn Plateau provinces.

The Western Coastlands province stretches along the western side of the region, occupying 9% of the area. In the north it has dissected ferruginous plateaus and hills on sedimentary rocks with areas of extensive coastal dune systems. The central portion of the region has dune ridges (on limestone along the coast) and inner alluvial plains. In the southeast there are low moderately dissected ferruginous plateaus on down faulted sedimentary rocks and a swampy south coastal plain. In the southwest there is a narrow granitic ridge with calcareous dunes and dissected ferruginous plateaus.

The Yilgarn Plateau province covers 91% of the area and is largely flat to undulating, with salt lakes and occasional low hills of igneous and metamorphic rock. Some areas have ferruginous breakaways and dunes.

Figure 10.2 Physiographic provinces of the South West Coast region

10.3.2 Elevation

Figure 10.3 presents ground surface elevations in the South West Coast region. Information was obtained from the Geoscience Australia website (www.ga.gov.au/topographic-mapping/digital-elevation-data.html). The landscape of the region is generally flat in inland areas. Higher altitude topographic features include the Darling Range, reaching altitudes exceeding 400 m above sea level, and the Stirling Range, with its highest peaks reaching just over 1,000 m above sea level (Figure 10.3).

The Darling Range forms an ancient geological boundary to the 30-km wide Swan Coastal Plain along the west coast.

The Swan Coastal Plain consists of relatively infertile sandy soils and coastal dunes. A number of estuaries and wetlands are separated from the sea by these dunes.

Moving from the west to the east into the vast inland area, altitudes gradually rise from around 200 m above sea level in the west to altitudes exceeding 400 m above sea level at the eastern border of the region.

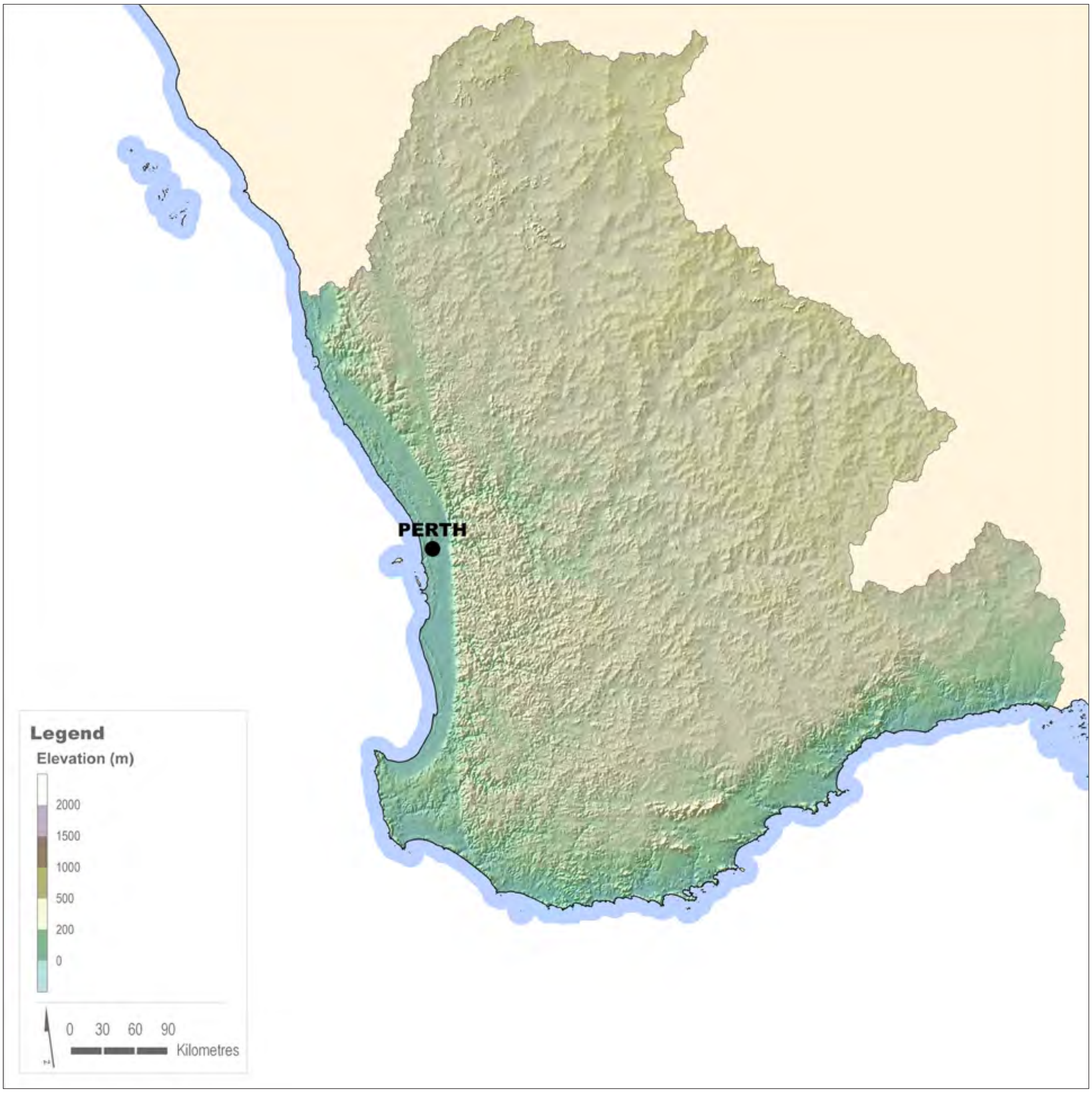


Figure 10.3 Ground surface elevations in the South West Coast region

10.3.3 Slopes

Areas with steep slopes provide higher run-off generating potential than flat areas. The South Australian Gulf region has hardly any areas with steep slopes. Most of the area is rather flat (Table 10.2 and Figure 10.4).The slopes were derived from the elevation information used in the previous section.

Table 10.2 Proportions of slope classes for the region

Slope class (%)	0–0.5	0.5–1	1–5	> 5
Proportion of region (%)	20.6	28.0	48.0	3.4

The steep slopes in Figure 10.4 in particular highlight the Stirling Range in the south and some deeper valleys in the Darling Range which have been cut out by rivers. The western coastal plains run along the coast for about 400 km, although the northern part is separated from the sea by a high and wide ridge of sand dunes.

The inland of the region is not as flat as other inland parts of Australia. The gentle slopes there do not interfere with advanced commercial use of land, such as dryland agriculture. On the steeper slopes of the Darling Range, however, forestry is a dominant land use.

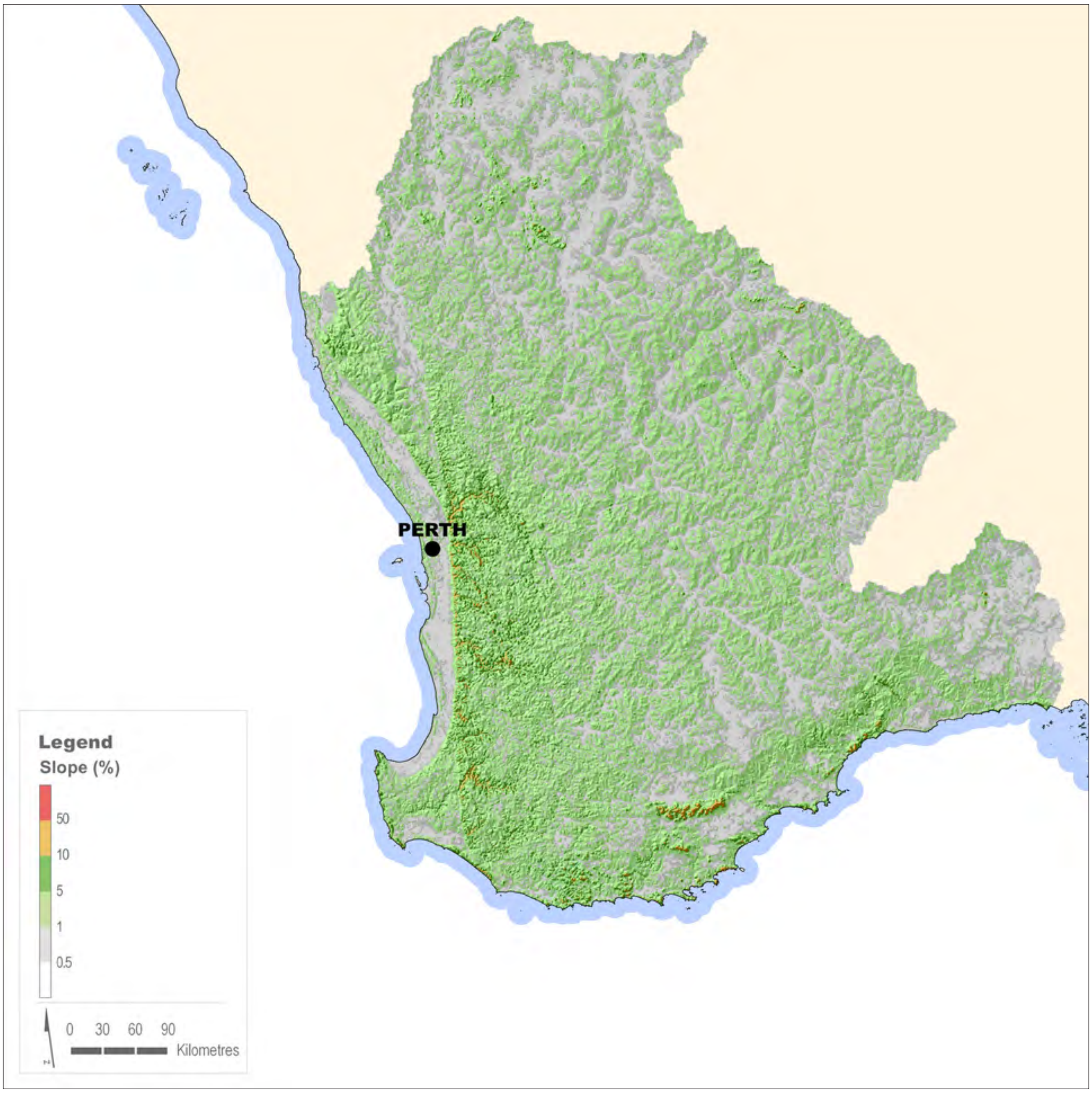


Figure 10.4 Surface slopes in the South West Coast region

10.3.4 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 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 86% of the South West Coast region is covered by four soil types, namely sodosols, tenosols, kandosols and chromosols (Figure 10.5 and Figure 10.6).

Sodosols are the most common soils in this region. They are dominant in the central-south to southeast of the region. These soils have a strongly contrasting texture, with impermeable sodic subsoils arising from elevated sodium concentrations and clay. They are susceptible to dryland salinity as well as erosion, if vegetation is removed. Sodosols are usually low in nutrient status but, in this region, are present in areas used for dryland crops and pastures.

Similarly chromosols have a strongly contrasting texture, but have permeable subsoils which are not high in sodium. They have moderate chemical fertility, water-holding capacity and agricultural potential. Soil acidification and soil structural decline may also occur. They are common in the western part of the region and are mostly present in pastures and areas used for forestry or nature conservation (Figure 10.6).

Tenosols and kandosols are soils with weak and minimal development throughout the profile (tenosols) and are less structured (kandosols). These soils are low in fertility and water-holding capacity, having a weak profile development. They are often shallow or stony. Tenosols are common in the northern as well as in the western part of the region and are scattered in the western part. Kandosols are scattered all over the region. These soils are used for forestry, pastures and nature conservation.

The other soil types that have minimal representation in the South West Coast region are hydrosols, calcarosols, podosols, kurosols and rudosols (1–5% of the total area).

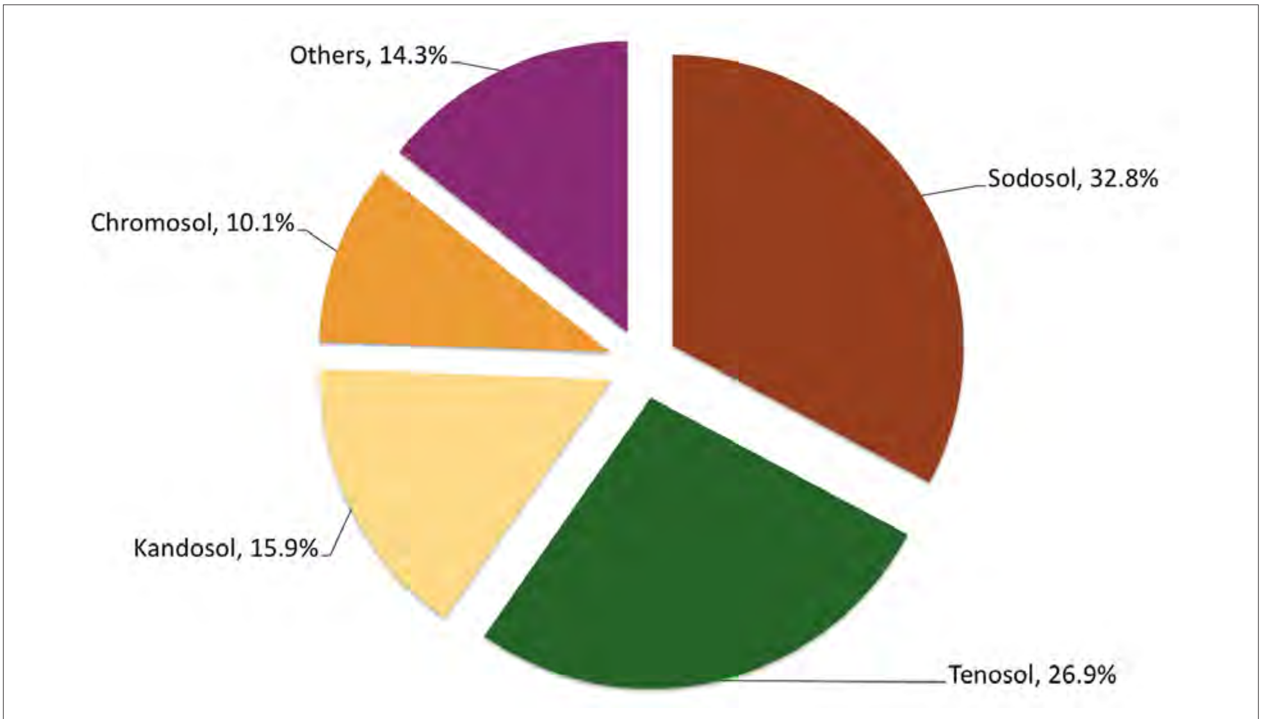


Figure 10.5 Soil types in the South West Coast region

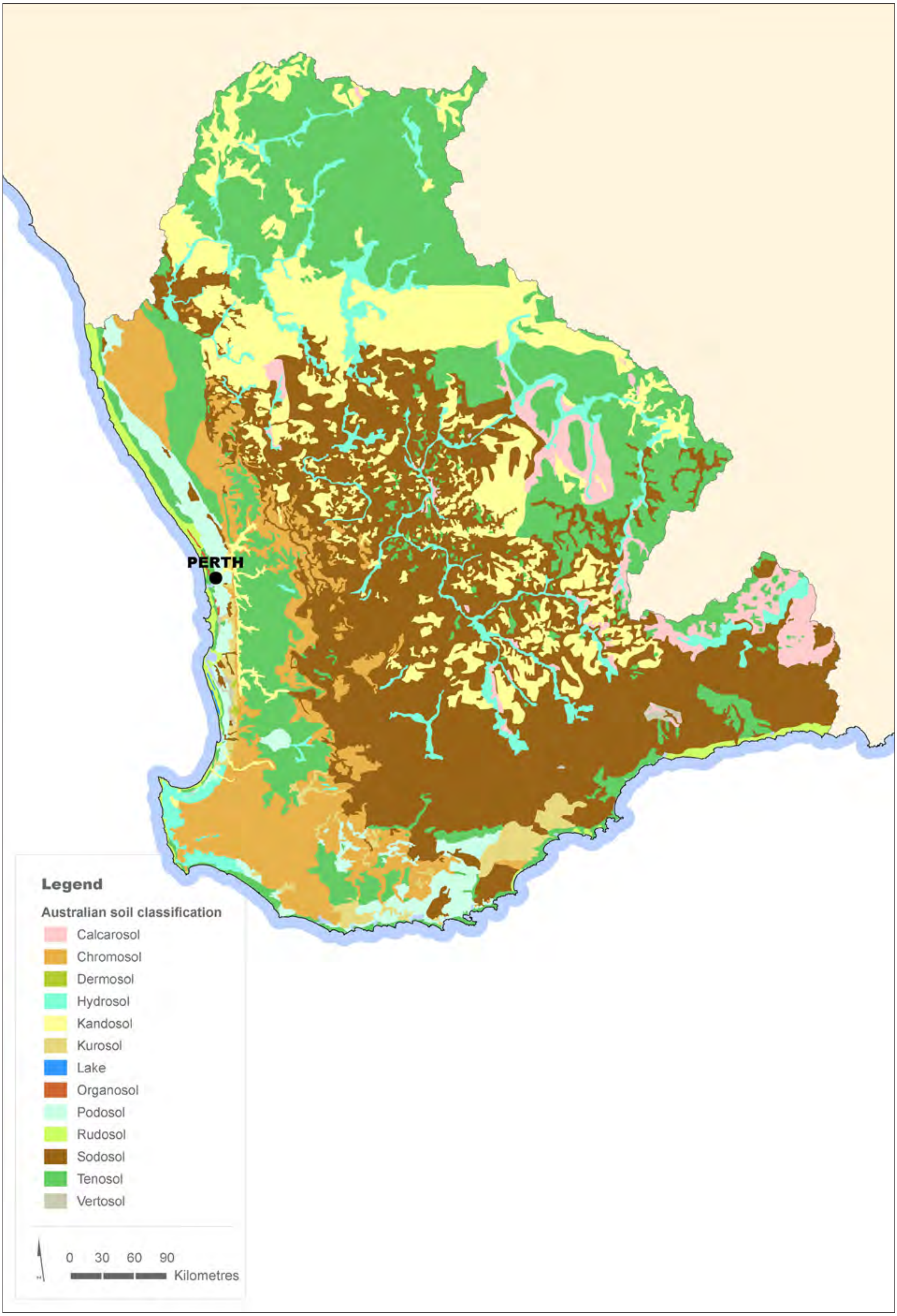


Figure 10.6 Soil type distribution in the South West Coast region

10.3.5 Land use

Figure 10.7 presents land use in the South West Coast region (data from data.daff.gov.au/anrdl/metadata_files/pa_luav4g9abl07811a00.xml). Much of the region's north is dominated by pasture, becoming a mix of pasture and dryland crops towards the central and southern parts of the region (Figure 10.8).

Forestry is a major land cover in the wetter, higher altitude southwestern slopes, with extensive conservation reserve areas in this part of the region.

Conservation shrublands and heathland reserves occupy most of the arid east of the region. Irrigated agriculture accounts for a very small proportion of the land use of the area. Intensive land uses such as urban areas also account for small proportions of the region.

The largest areas of irrigated agriculture in the region are located in the Peel–Harvey irrigation district, with a considerable proportion of the water used to irrigate pasture for dairy and for vegetable and fruit crops.

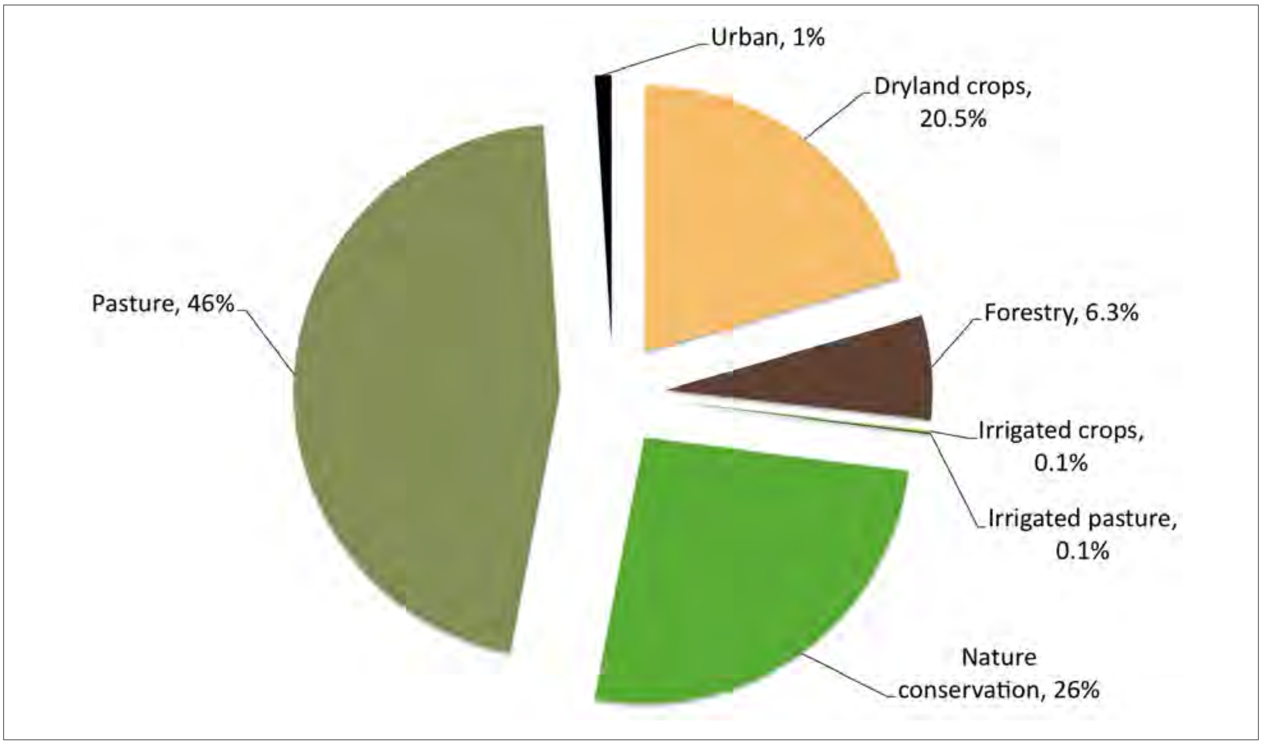


Figure 10.7 Land use in the South West Coast region

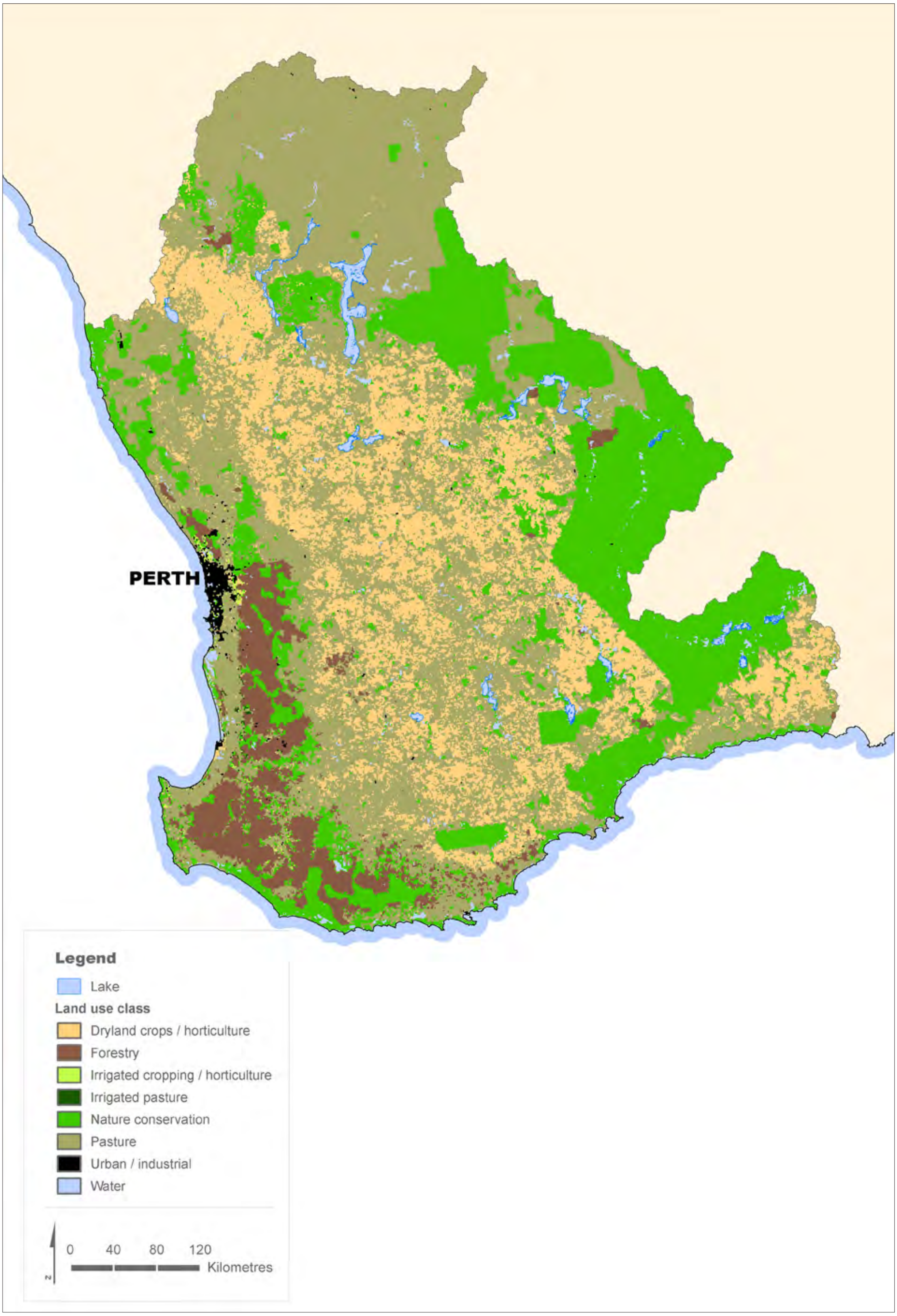


Figure 10.8 Land use distribution in the South West Coast region

10.3.6 Population distribution

While the South West Coast region occupies the more populous southwestern corner of Western Australia, its population density, in contrast to the North East Coast and South East Coast regions, is relatively low.

With the majority of the population residing in Perth, the region's population centre is located on its western coastal fringe. The populations of Perth and surrounding districts have been bolstered in recent years while providing supporting services to the renewed and increased mining activities in the State.

Outside of Perth, agriculture, mining and forestry have played important roles in the distribution of the region's remaining major population centres. Many of these centres are located in the southwestern coastal districts of the region and include the urban centres of Bunbury and Albany. The eastern extents of the region encompass much of the wheatbelt district, where farming activities play a major role in the existence of many towns.

Figure 10.9 shows the spatial distribution of population density for the region and is based on data from the ABS (2011b).

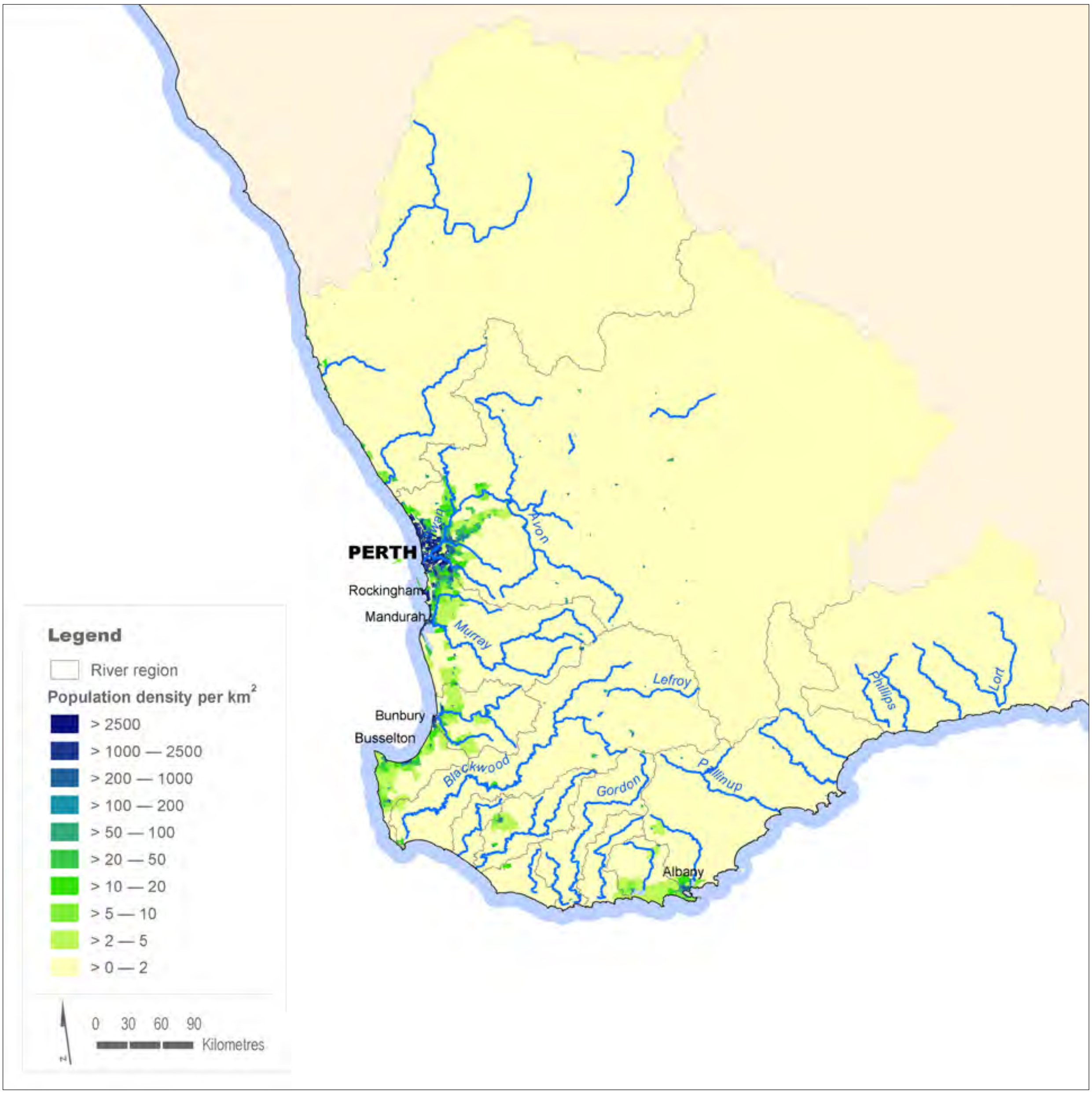


Figure 10.9 Population density and distribution of the South West Coast region

10.3.7 Rainfall zones

The South West Coast region has a temperate climate. Most rainfall occurs in the southwest during winter with reduced rainfall further inland. Median rainfall is rather variable throughout the region.

Figure 10.10 shows that the northeastern inland part of the region is semi-arid to arid and median annual rainfall totals do not exceed 500 mm.

Moving to the southwest, the rainfall becomes more winter dominant and median annual totals increase to levels exceeding 800 mm. Especially in the most southern areas, annual rainfall totals often exceed 1,200 mm.

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

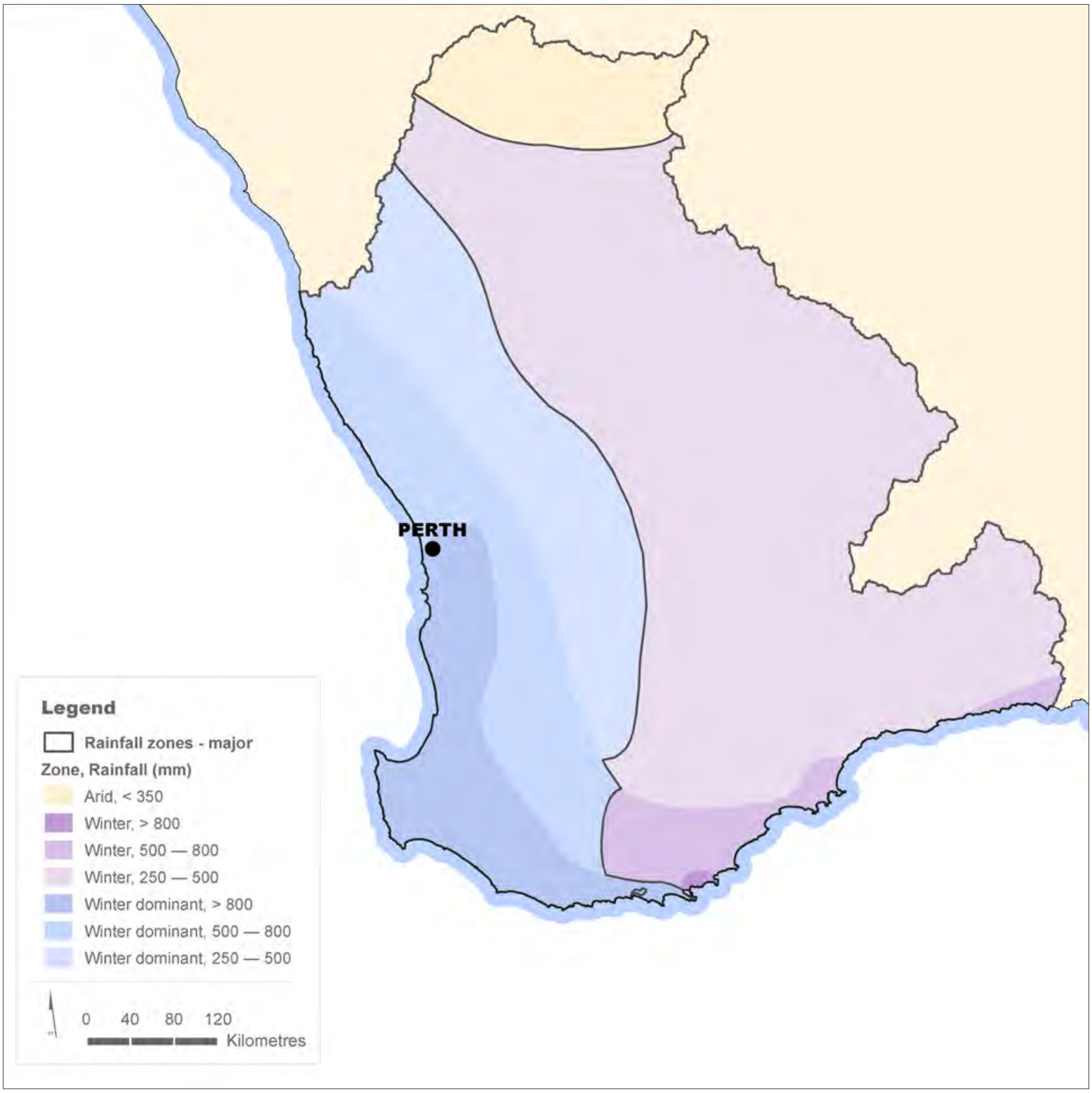


Figure 10.10 Rainfall zones in the South West Coast region

10.3.8 Rainfall deficit

The rainfall minus potential evapotranspiration indicator gives a general impression about where in the region moisture deficits are likely to occur over the period of a year. The South West Coast region has a rather uniform pattern of substantial potential deficits over the entire region (Figure 10.11).

Serious deficits can be expected in inland areas. Due to the seasonality of the rainfall, this area is still well suited for dryland agriculture, which occurs at an extensive scale.

Along the southwest coast, where the deficit is marginal, forestry is a major land use component. The far southwest has some areas of moisture abundance which are predominantly in use for nature conservation, containing some of the tallest trees in Australia, including the Karri forests.

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

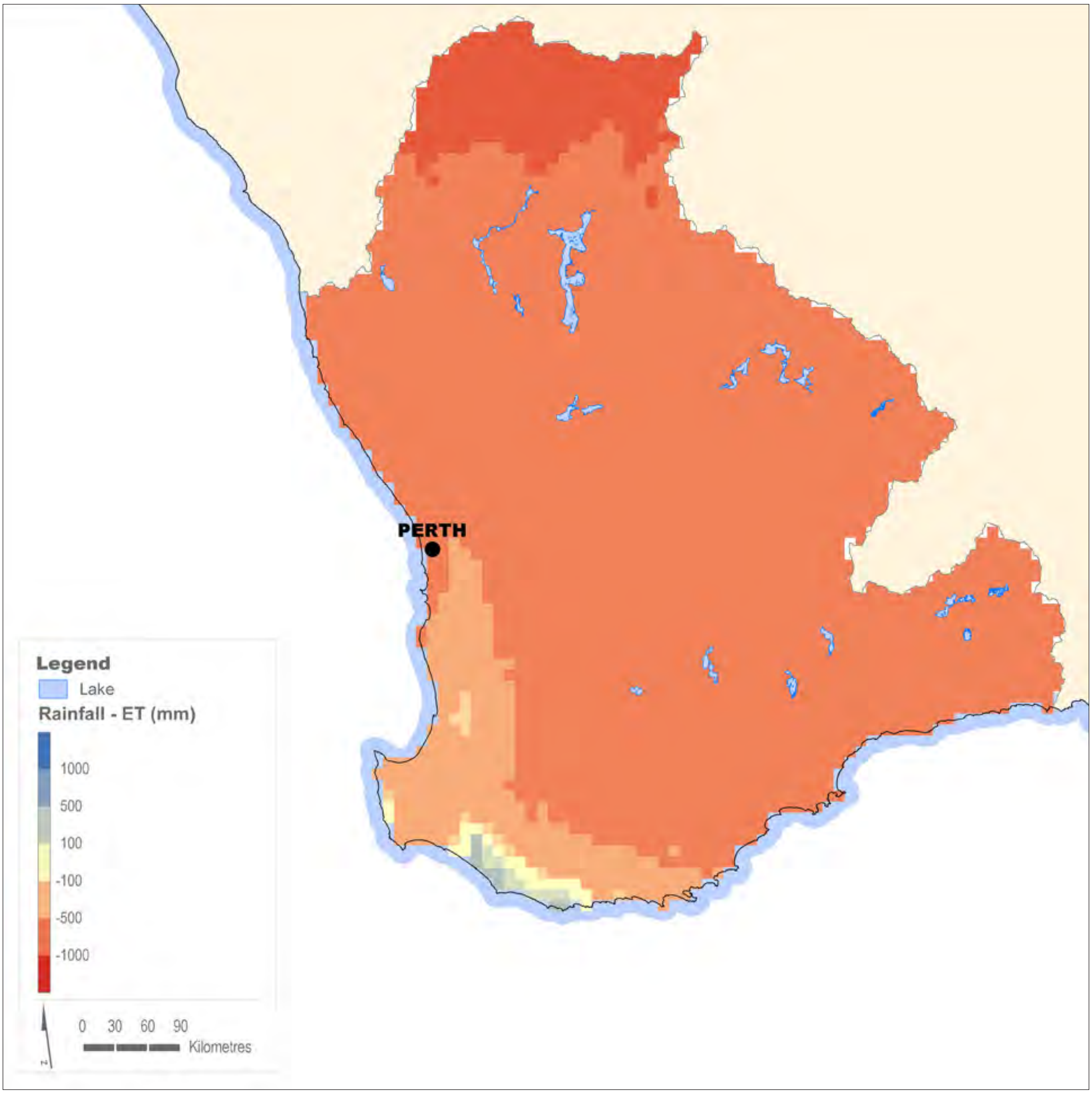


Figure 10.11 Rainfall deficits in the South West Coast region

10.4 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 West Coast 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 the Introduction and addressed in more detail in the Technical Supplement.

Figure 10.12 shows that the region has a highly seasonal rainfall pattern with a wet winter and a dry summer period. Evapotranspiration follows this pattern, albeit with about a month delay, thereby generally exceeding rainfall during spring and summer. The monthly landscape water yield history for the region shows a stable pattern of very low yield in the dry period. It marginally increases during winter months.

The 2011–12 year was a relatively wet year, with some high rainfall between October and December. The December rainfall was the highest on record over the 1911–2012 period. On the other hand, some below average rainfall occurred during April and May 2012.

With above average soil moisture conditions, due to above average rainfall during the October–December period, evapotranspiration was also relatively high for this period. December 2011 had the highest evapotranspiration on record, whereas November had the second highest evapotranspiration on record.

The landscape water yield for 2011–12 showed some distinct patterns, with December having the second highest landscape water yield on record. On the other hand, the April–May period had the fifth lowest landscape water yield on record; however, with very low absolute landscape water yield occurring in these periods, the absolute difference from the mean is not high.

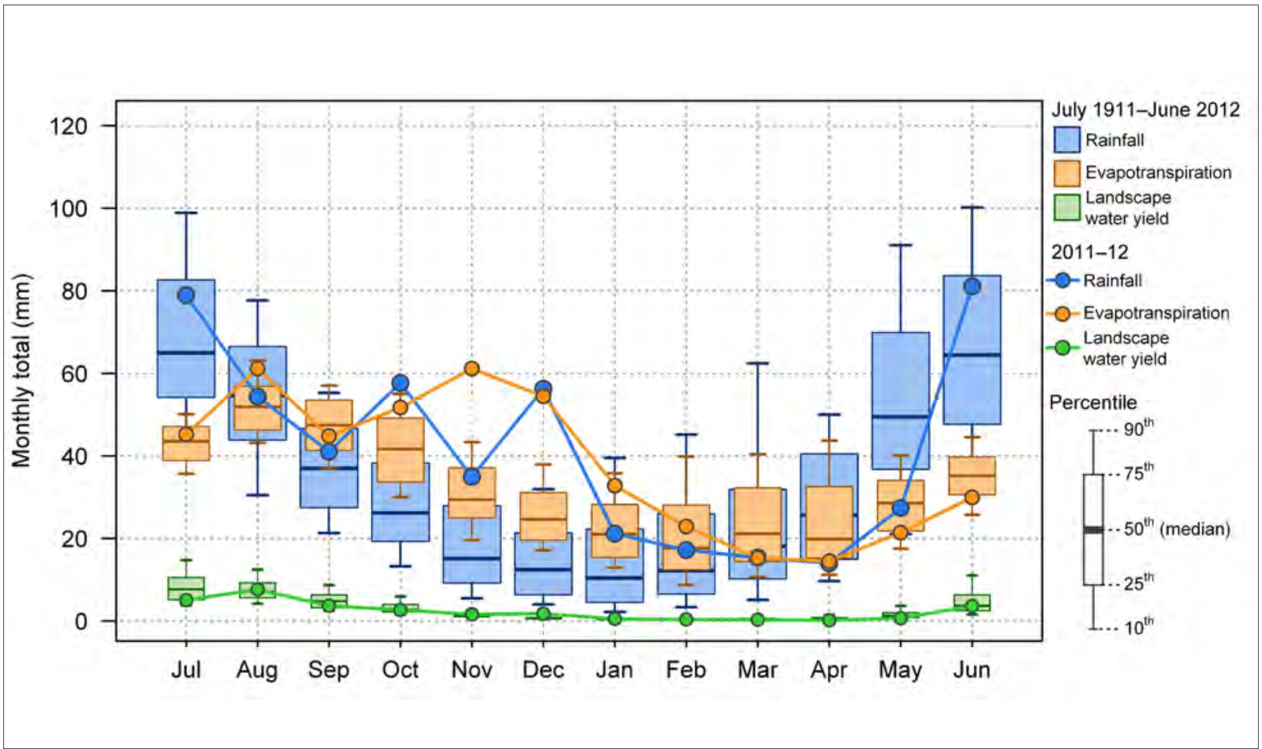


Figure 10.12 Landscape water flows in 2011–12 compared with the long-term record (July 1911–June 2012) for the South West Coast region

10.4.1 Rainfall

Rainfall for the South West Coast region for 2011–12 is estimated to be 499 mm. This is 14% above the region's long-term average (July 1911–June 2012) of 438 mm. Figure 10.13a shows that the highest rainfall occurred along the southern coastal areas with annual totals locally exceeding 900 mm. The rest of the region mostly had rainfall ranging between 300 and 600 mm for 2011–12.

Rainfall deciles for 2011–12 indicate above average rainfall for most of the region over the course of the year (Figure 10.13b). Most of the inland parts of the region received above average rainfall with some parts in the east receiving very much above average rainfall. The western coastal area south of Perth locally had below average rainfall.

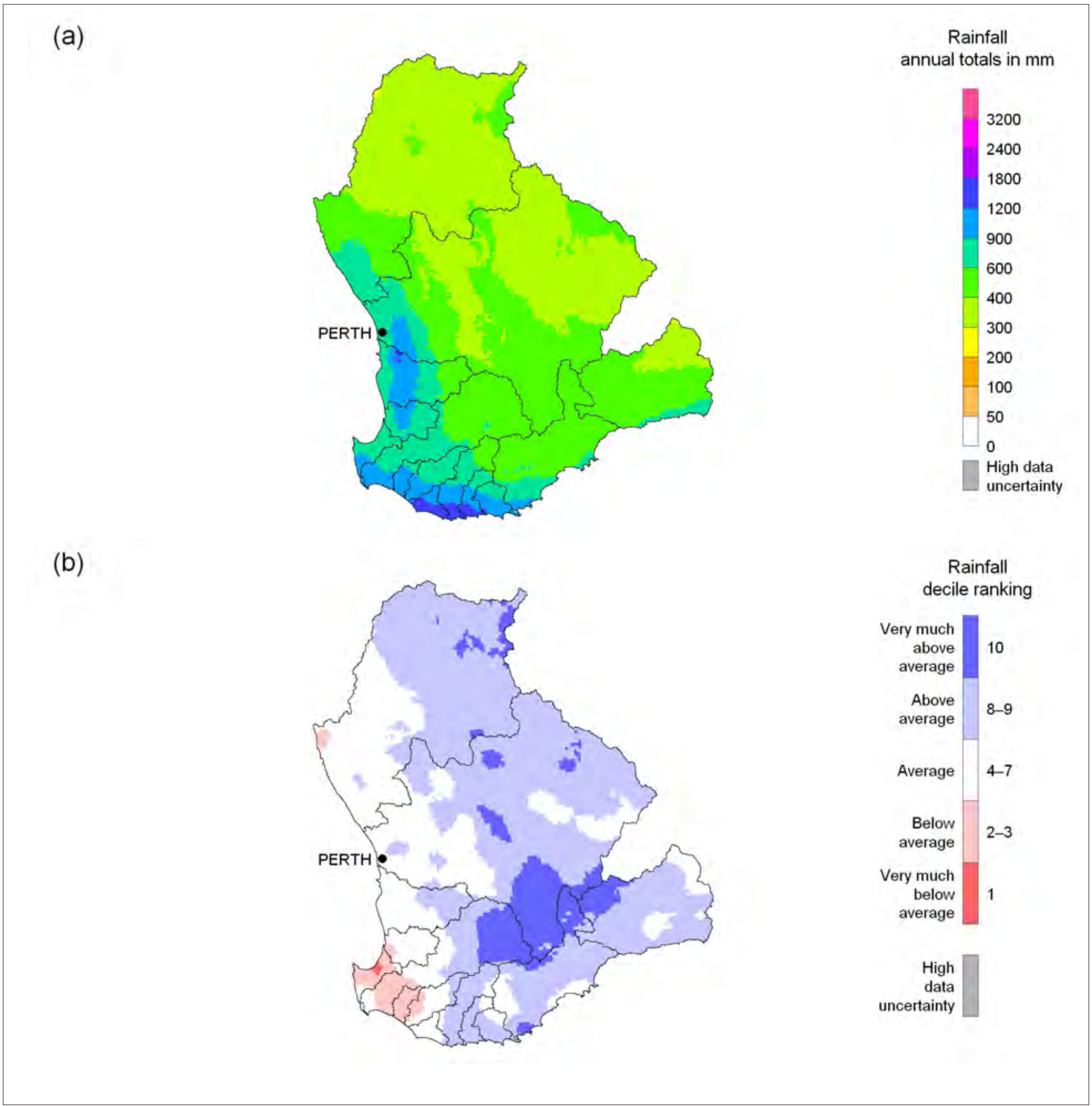


Figure 10.13 Spatial distribution of (a) annual rainfall in 2011–12 and (b) their decile rankings over the 1911–2012 period for the South West Coast region

Rainfall variability in the recent past

Figure 10.14a shows annual rainfall for the region from July 1980 onwards. Over this 32-year period the annual average was 430 mm, varying from 340 mm (2006–07) to 563 mm (1998–99). Temporal variability and seasonal patterns (over the summer and winter periods) since 1980 are presented in Figure 10.14b.

The graphs show a particularly stable pattern of annual rainfall in comparison to other regions. Rainfall in the winter period is consistently higher than in the summer period, although a decrease in winter period rainfall has occurred after 2001. Since then, only the last year of this period reached an annual rainfall total that was substantially higher than the 32-year period average.

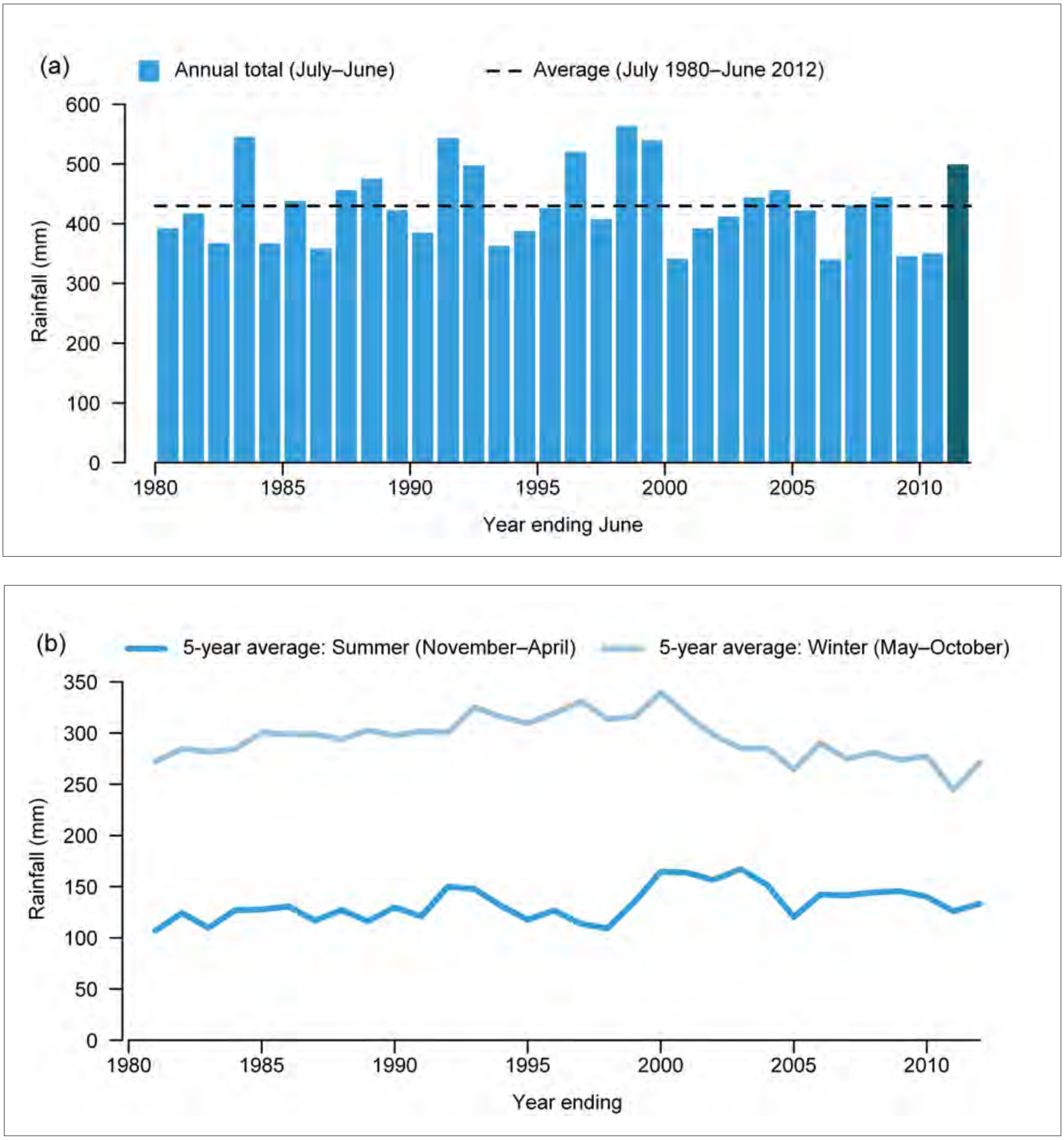


Figure 10.14 Time-series of (a) annual rainfall, and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South West Coast region

Recent trends in rainfall

Figure 10.15a 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 10.15b.

Figure 10.15a shows that since 1980 a strong decrease in rainfall has occurred generally over the whole of the western coastal zone.

The falling trends are strongly significant in large parts of this area (Figure 10.15b), with the peak decrease around Perth. This has seriously impacted the surface water supply for Perth and surroundings (see section 10.6 for more information on urban water supply in the region).

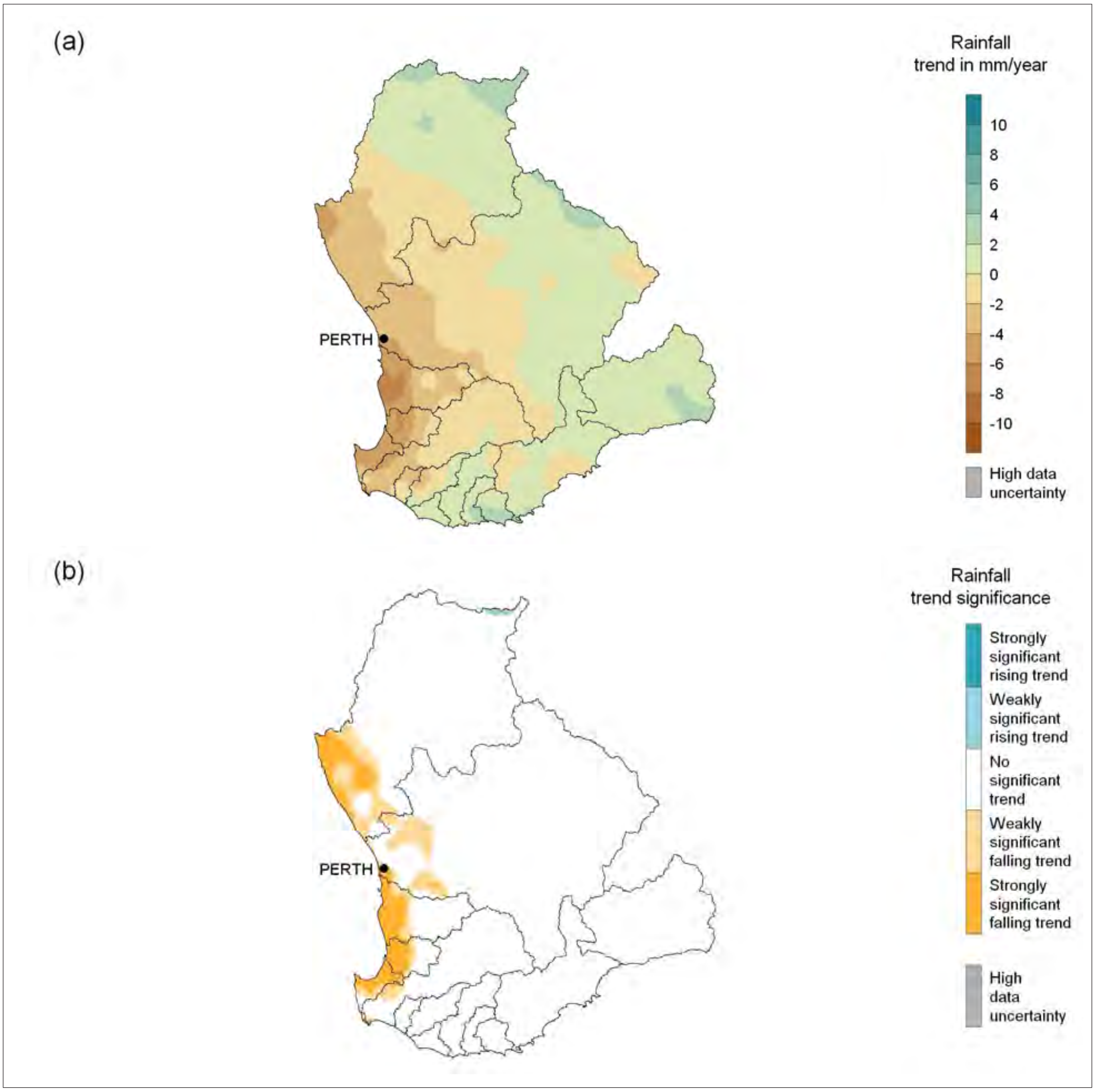


Figure 10.15 Spatial distribution of (a) trends in annual rainfall from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South West Coast region

10.4.2 Evapotranspiration

Modelled annual evapotranspiration for the South West Coast region for 2011–12 is estimated to be 455 mm. This is 15% above the region's long-term (July 1911–June 2012) average of 397 mm.
The spatial distribution of annual evapotranspiration in 2011–12 (Figure 10.16a) is similar to that of rainfall (Figure 10.13a). In absolute terms, evapotranspiration was practically equal to rainfall in the major inland part of the region.

Evapotranspiration deciles for 2011–12 indicate above average or very much above average totals across most of the region (Figure 10.16b). This coincides with the spatial pattern of rainfall deciles in Figure 10.13b. With limited water availability in the southwest, due to below average rainfall, evapotranspiration also remained below average in this area.

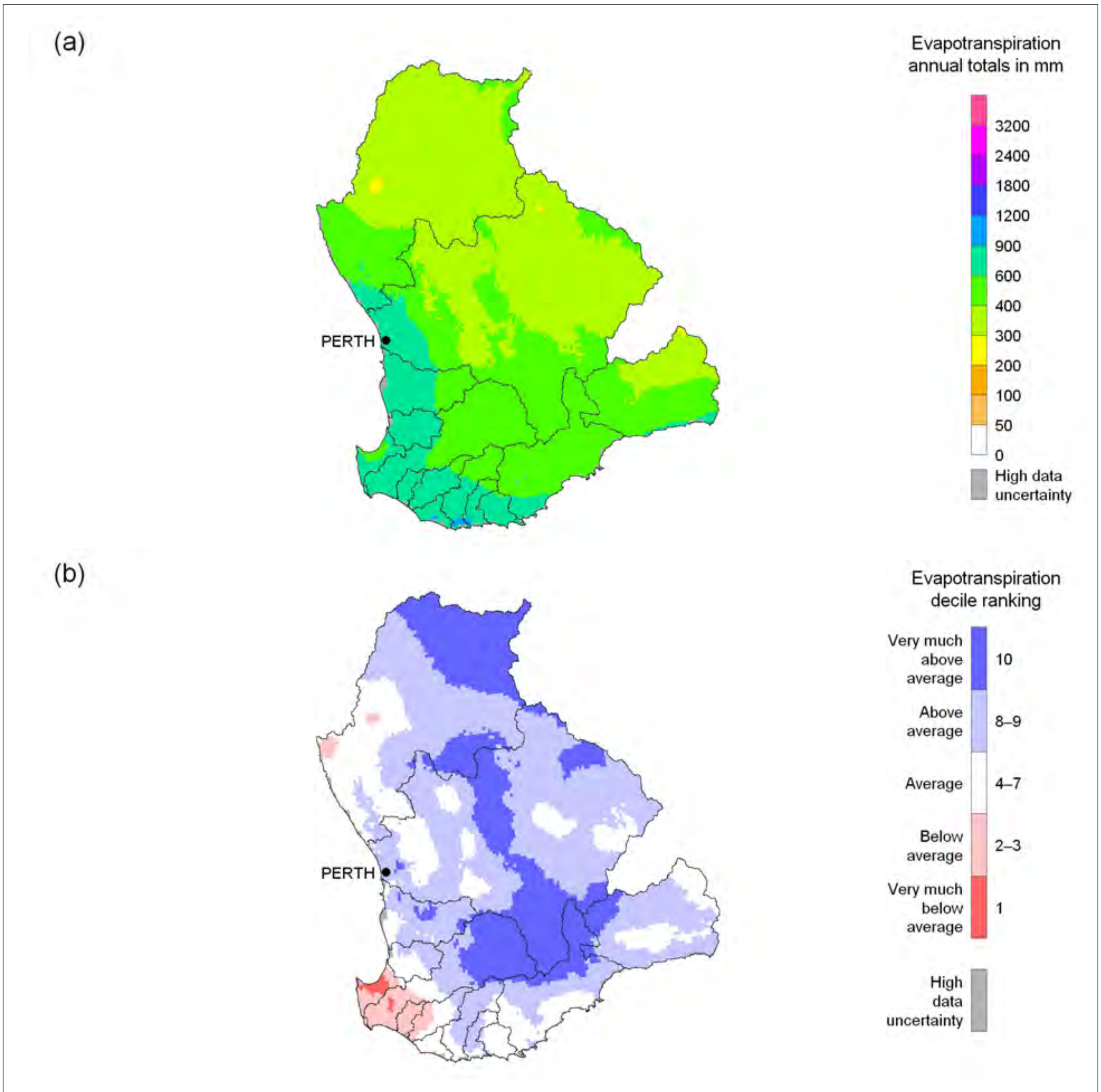
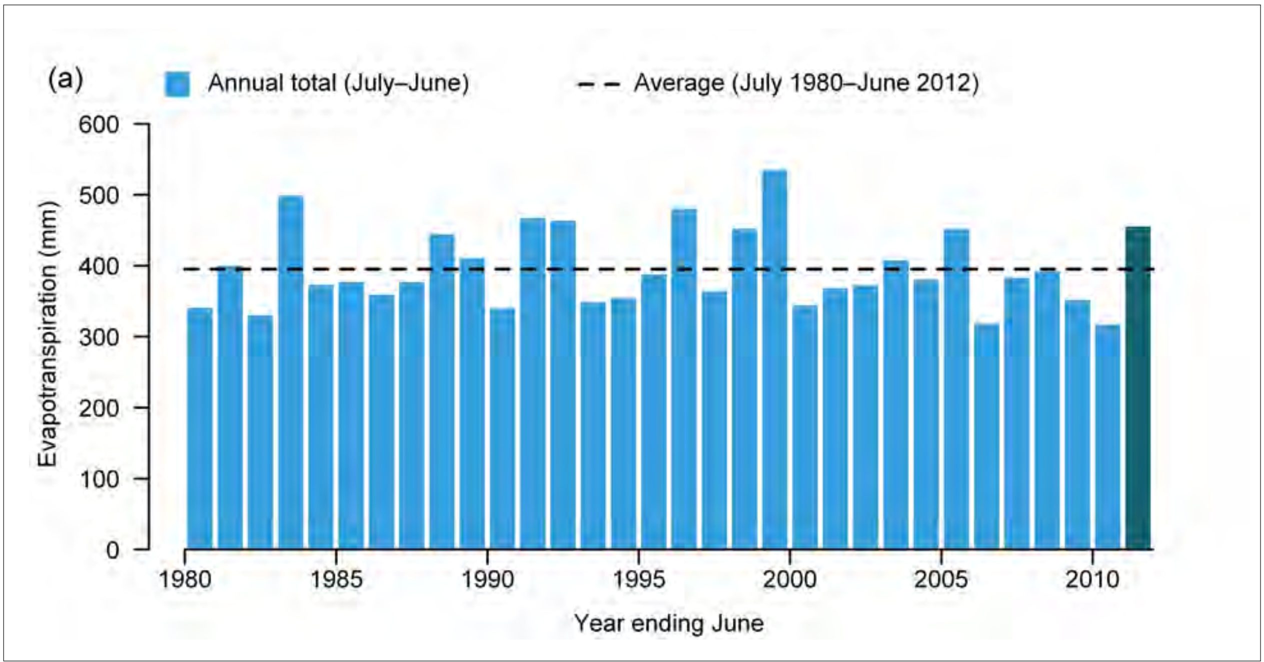


Figure 10.16 Spatial distribution of (a) modelled annual evapotranspiration in 2011–12, and (b) their decile rankings over the 1911–2012 period for the South West Coast region

Evapotranspiration variability in the recent past

Figure 10.17a shows annual evapotranspiration for the region from July 1980 onwards. Over this 32-year period the annual evapotranspiration average was 395 mm, varying from 317 mm (2010–11) to 535 mm (1999–2000). Temporal variability and seasonal patterns (over the summer and winter periods) since 1980 are presented in Figure 10.17b.

Despite the lower temperatures in the winter period, evapotranspiration is consistently higher than in the summer period, due to lower water availability during the summer period. Compared with the seasonal rainfall (Figure 10.14b), the temporal patterns of evapotranspiration are highly similar and also display the minor decrease in evapotranspiration in the winter period since 2001 (Figure 10.17b).



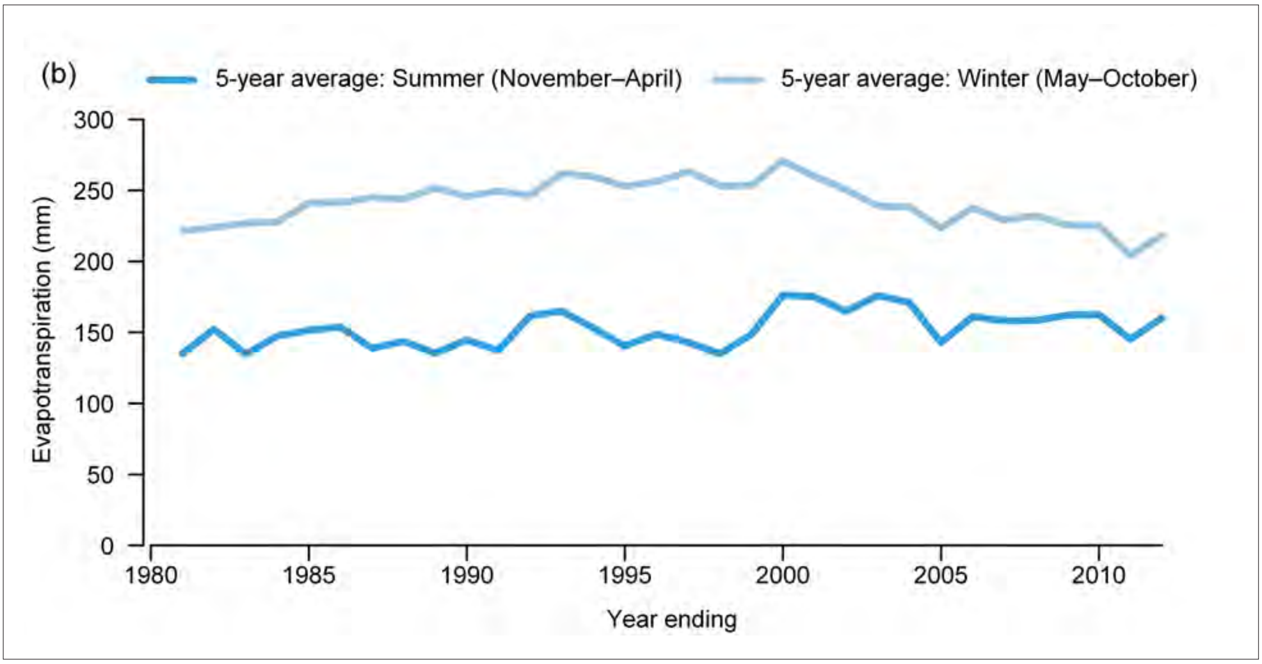


Figure 10.17 Time-series of (a) annual evapotranspiration, and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South West Coast region

Recent trends in evapotranspiration

Figure 10.18a 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 10.18b.

Figure 10.18a shows that, since 1980, falling trends are identified in the western coastal zone. In the east, largely marginally rising trends are calculated.

As shown in Figure 10.18b, the trends are generally only statistically significant in those coastal areas where the trend exceeds –2 mm/year. The spatial distribution of the trends is similar to that of rainfall. As evapotranspiration is driven by the availability of moisture coming from rainfall, the spatial distribution of the trends and the trend significance are similar to rainfall, as shown in Figure 10.15.

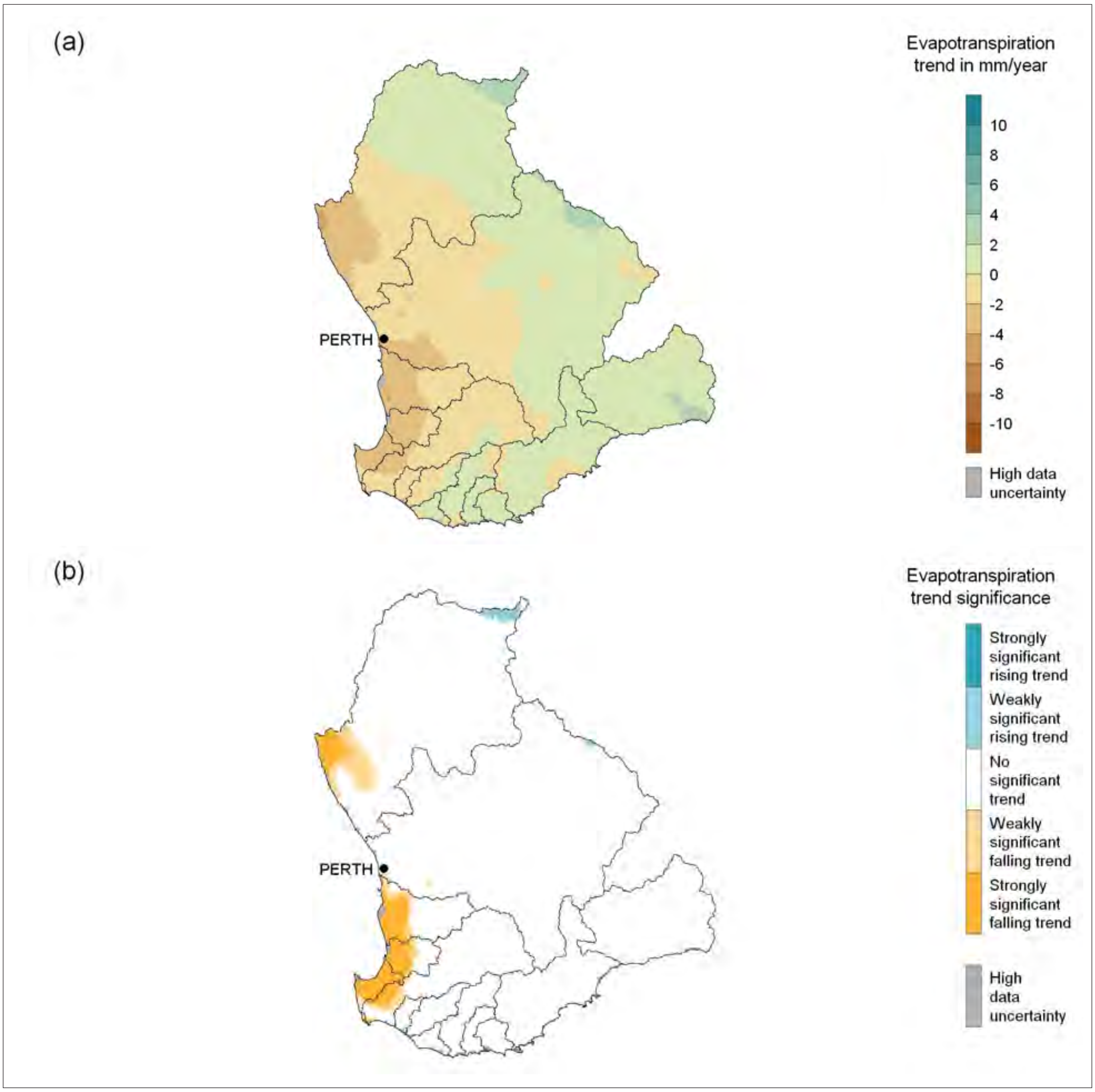


Figure 10.18 Spatial distribution of (a) trends in annual evapotranspiration from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South West Coast region

10.4.3 Landscape water yield

Modelled landscape water yield for the South West Coast region for 2011–12 is estimated to be 28 mm. This is 24% below the region's long-term (July 1911–June 2012) average of 37 mm. Figure 10.19a shows the spatial distribution of landscape water yield for 2011–12, which is similar to the annual rainfall distribution (Figure 10.13a; note the difference in the scales between the two figures).

The decile-ranking map of Figure 10.19b, however, shows a spatial pattern that is dissimilar to those patterns in rainfall of Figure 10.13b. The map shows mostly average to below average landscape water yields for much larger areas along the coast as well as further inland. It has to be acknowledged that model verification assessments for this region identified more questionable performances than in other regions and results should be interpreted with care.

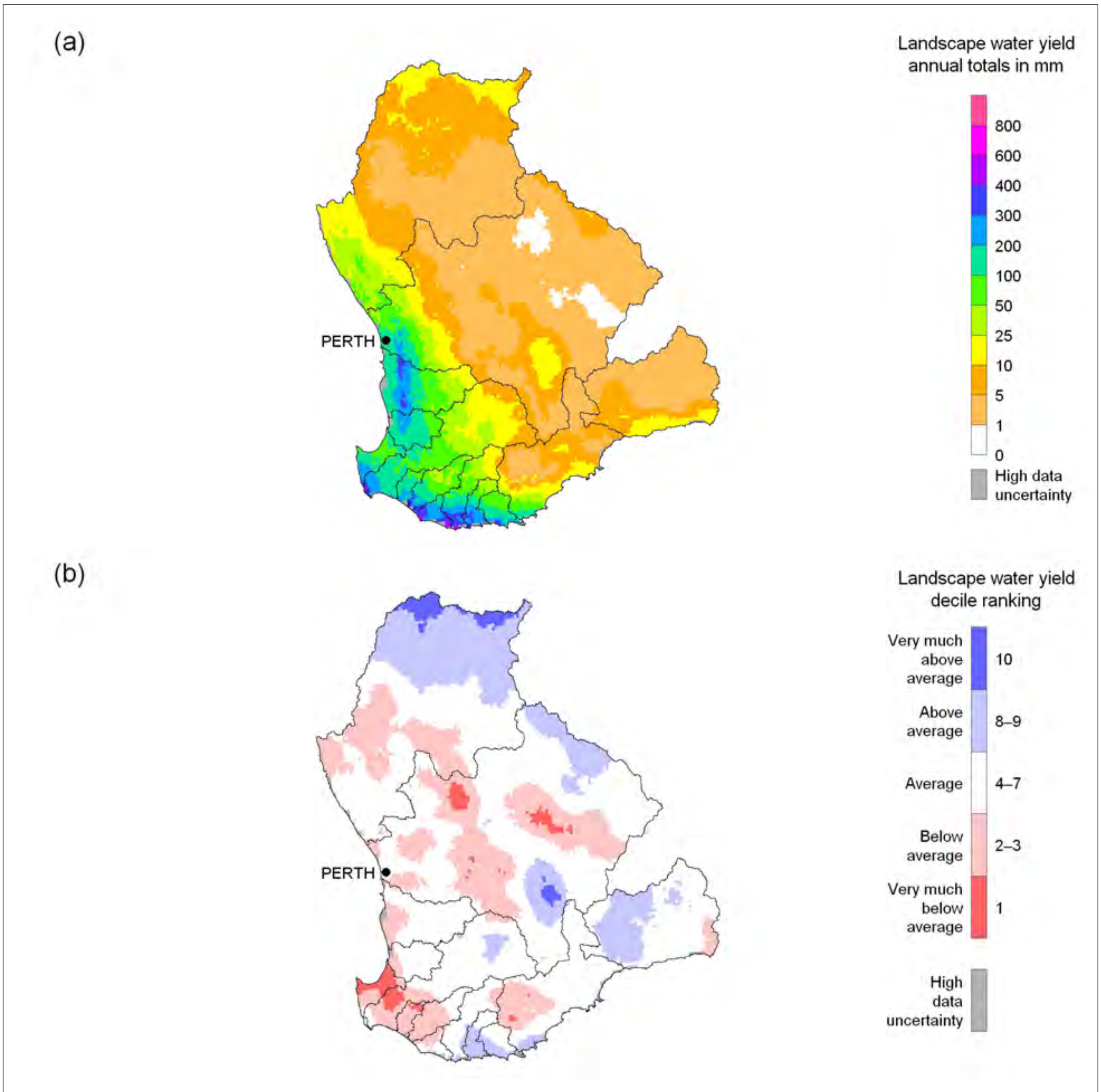


Figure 10.19 Spatial distribution of (a) modelled annual landscape water yield in 2011–12, and (b) their decile rankings over the 1911–2012 period for the South West Coast region

Landscape water yield variability in the recent past

Figure 10.20a shows annual landscape water yield for the South West Coast region from July 1980 onwards. Over this 32-year period, annual landscape water yield was 30 mm, varying from 11 mm (2010–11) to 52 mm (1999–2000). Temporal variability and seasonal patterns (over the summer and winter periods) since 1980 are presented in Figure 10.20b.

Landscape water yield is consistently higher during the winter period and particularly low during the summer period. The falling trend in landscape water yield since 2001 for the winter period is consistent with that of rainfall and evapotranspiration.

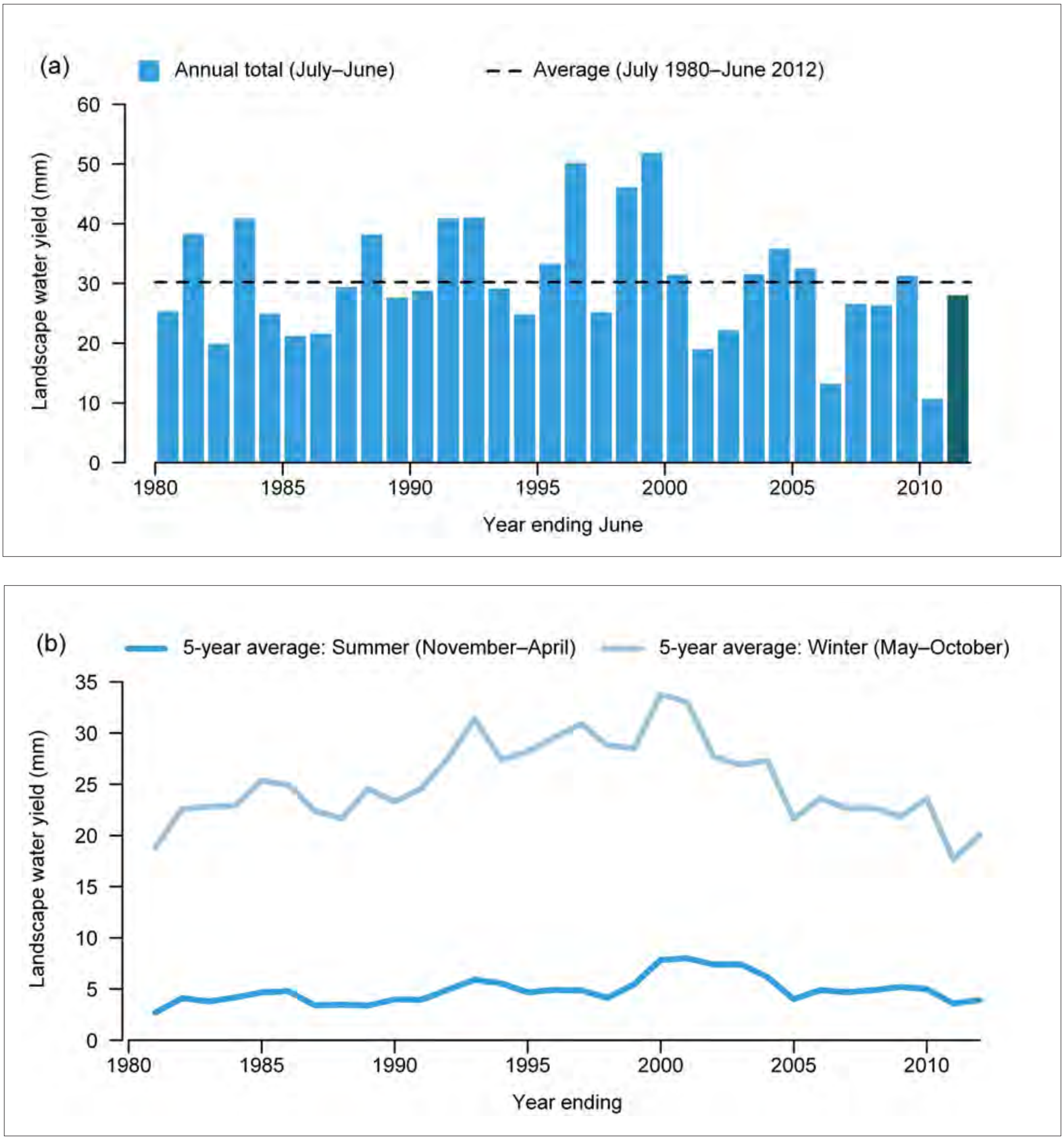


Figure 10.20 Time-series of (a) annual landscape water yield, and (b) five-year retrospective moving averages for the summer (November–April) and winter (May–October) periods for the South West Coast region

Recent trends in landscape water yield

Figure 10.21a 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 10.21b.

As shown in Figure 10.21a, trends are negative in the coastal zone and over a band covering a large part of the south of the region. In this band, trends are locally statistically significant, reaching values of –0.5 mm/year. The far north and far west have some areas of significant rising trends, with trend line slopes up to 0.5 mm/year.

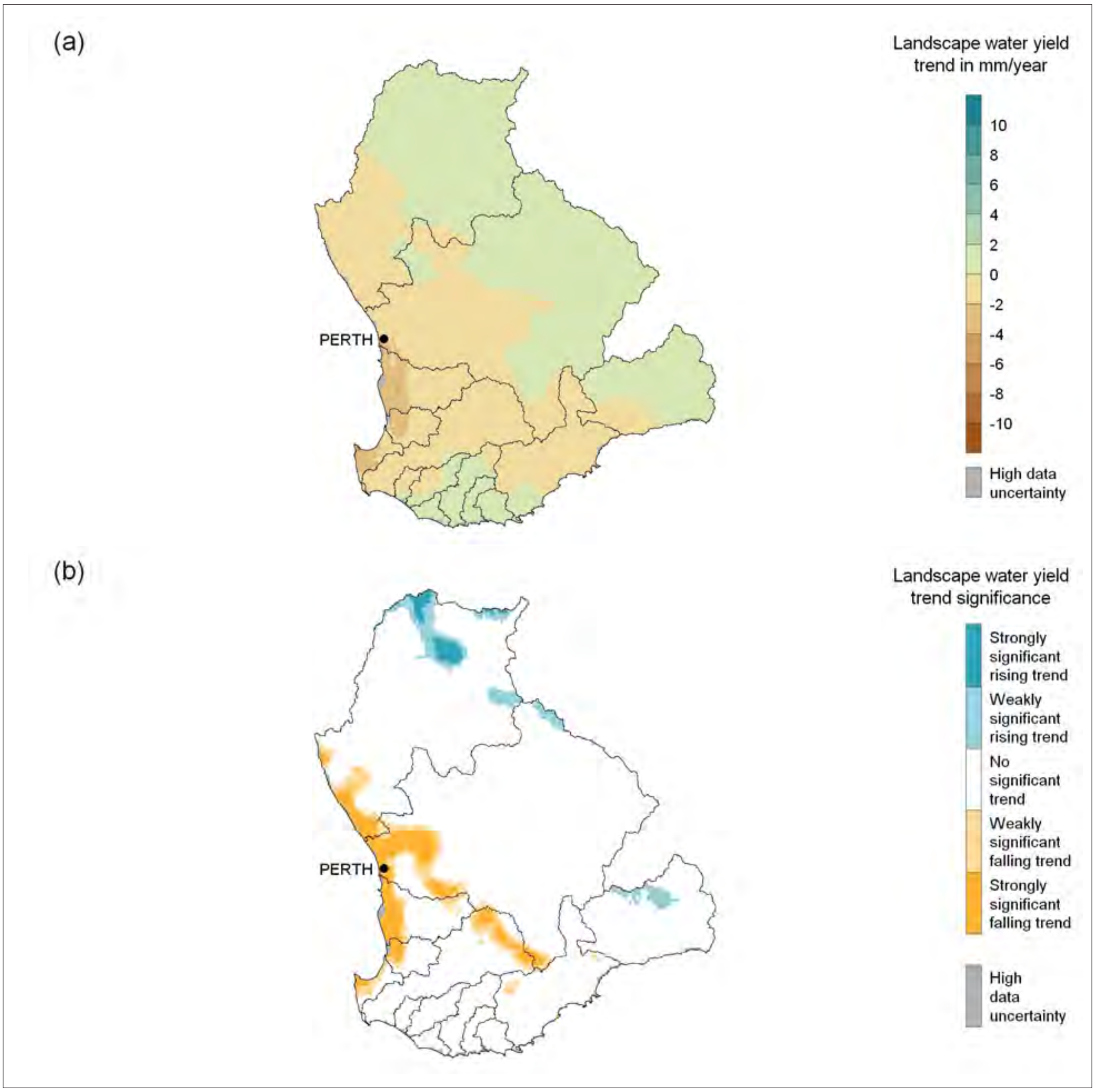


Figure 10.21 Spatial distribution of (a) trends in annual landscape water yield from 1980–2012, and (b) their statistical significance at 90% (weak) and 95% (strong) confidence levels for the South West Coast region

10.5 Surface water and groundwater

This section examines surface water and groundwater resources in the South West Coast 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 on individual aquifers.

10.5.1 Rivers

There are 14 river basins in the South West Coast region, varying in size from about 1,700–121,000 km^2 (Figure 10.22).

Due to the elevated topography and orientation of the Darling Scarp, most of the major rivers drain towards the Indian Ocean; however, the high soil permeability in the Swan Coastal Plain results in substantial losses of surface water to groundwater. The north–south coastal dune pattern causes many watercourses to turn abruptly and flow either in a south or a north direction along the extensive dune swales, often joining with other watercourses before discharging to the sea. There are also inland endorheic river basins to the east of the Darling Scarp.

The longest rivers are located in the southwest, with the Avon and Blackwood rivers having the largest catchments areas. The Swan River becomes the Avon River at the Darling Scarp. Most of the rivers are perennial, but in the north and west many are ephemeral.

Swan River bank, Perth | BockyTandiono (iStockphoto)

Figure 10.22 Rivers and catchments in the South West Coast region

10.5.2 Streamflow volumes

Figure 10.23 presents an analysis of flows at 30 monitoring sites during 2011–12 relative to annual flows for the period from July 1980–July 2012. Monitoring sites with relatively long records across 16 geographically representative rivers 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 generally reflect the mostly average to below average modelled landscape water yield results shown in Figure 10.19b. Above average annual flows were observed at two sites located on the Arthur and Blackwood rivers in the central southwest of the South West Coast region. Average total annual flows were observed at 12 monitoring sites, mainly located on the rivers in the central south, central west, the Lockhart River in the centre and the Moore River in the north of Perth.

Below average flows occurred at 11 sites in the region which were located on the rivers in the west of the region, especially surrounding Perth, and in the Deep and Kalgan rivers in the central south of the region. Of the 30 monitoring sites, there were only five sites across the region which recorded very much below average flows recorded across the in 2011–12. These five monitoring sites were mainly located on the rivers in the far southwest and in the Harvey River in the central west.

Flow deciles for the summer period (November 2011–April 2012) are different to those for total annual flows as shown in Figure 10.23. The difference is that relatively higher flows occurred throughout the region in the summer period.

10.5.3 Streamflow salinity

Figure 10.24 presents an analysis of streamflow salinity for 2011–12 at 28 monitoring sites throughout the South West Coast region. Monitoring 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.

The median EC values for five of the monitoring sites in the main rivers fall in the range 0–1,000 µS/cm, suitable for most irrigation uses. Most of the selected monitoring sites in the rivers and creeks of the region have median EC values outside this range (see Figure 10.24). This is unsuitable for most irrigation uses and for many aquatic ecosystems. Of the 28 monitoring sites, 14% had median EC values below 500 µS/cm and at one site (4%) the median fell in the range 500–1,000 µS/cm. For the remainder of the sites (82%), EC values were above 1,500 µS/cm. Median salinities values are generally higher to the west of the region.

Streamflow salinity was above 2,000 µS/cm at 21 of the 28 monitoring sites. These are located on the rivers in the southwest, centre and some sites in the central west of the region. High salinity in the monitoring sites in this area may be influenced by extensive land clearing, large natural stores of salt in the landscape, poor irrigation practices, saline base flow and evaporation during low flow. Naturally occurring saline soils are also a key factor influencing in-stream salinity in the region and are associated with lacustrine sediments of salt lake systems (McArthur 1991).

The CV is the expected variability of a measurement of EC value, relative to the annual mean of EC. The CV is high at some sites in the central west of the region whereas variability is relatively low for the rivers in the southwest of the region. The CV in EC is highly related to the variability in annual flow at the monitoring sites. Of the 28 monitoring sites, 7% of them had a CV below 20%; 57% of the sites had a CV between 20% and 60%; and 36% were above 60%. These were mainly located on the rivers in the central west and southwest of the region. The CV was above 80% at five of the 28 monitoring sites. These were located on the rivers in the central west and at Mobrup Creek in the central southwest of the region.

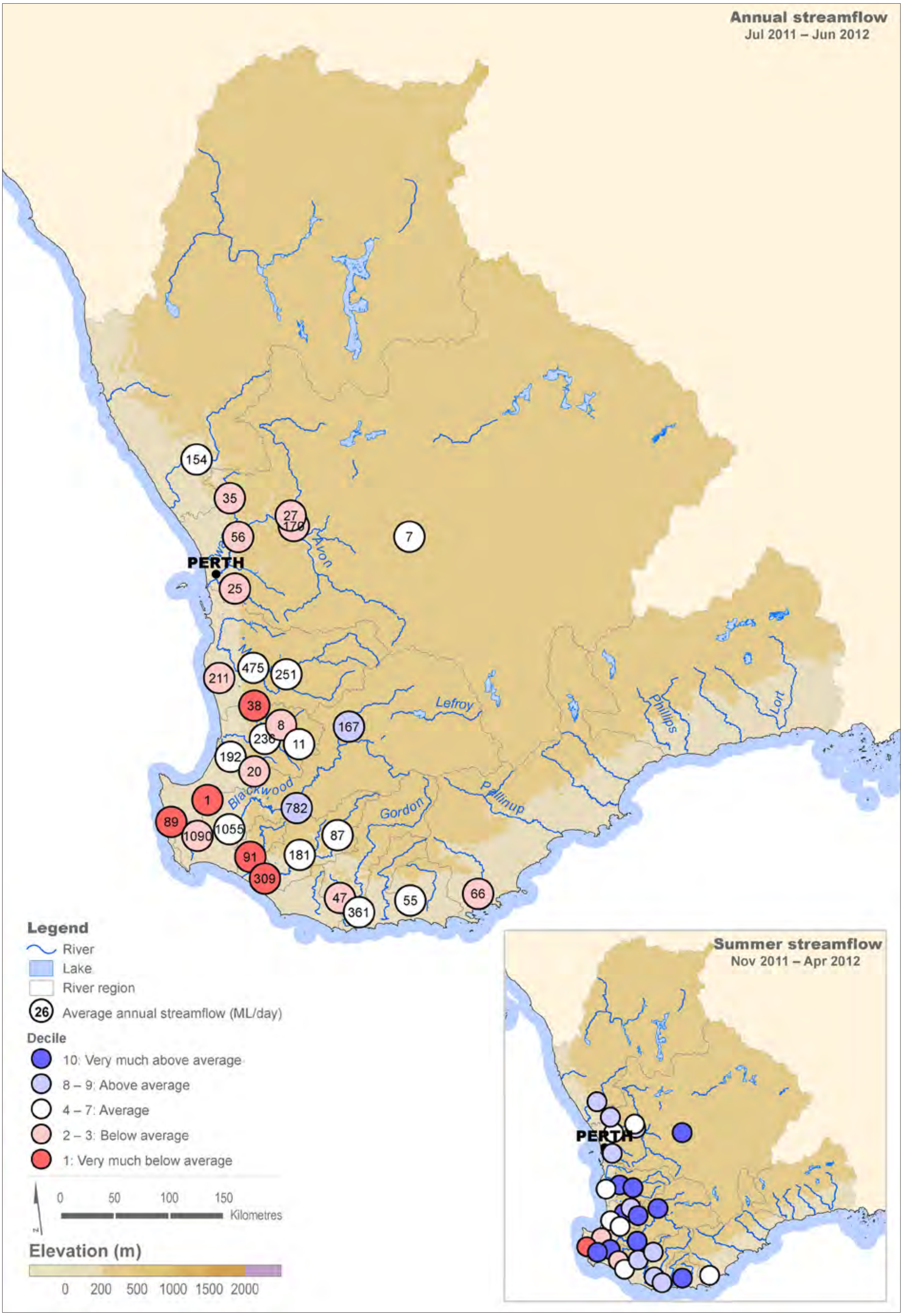


Figure 10.23 Average annual and summer period flow volumes of selected sites for 2011–12 and their decile rankings over the 1980–2012 period in the South West Coast region

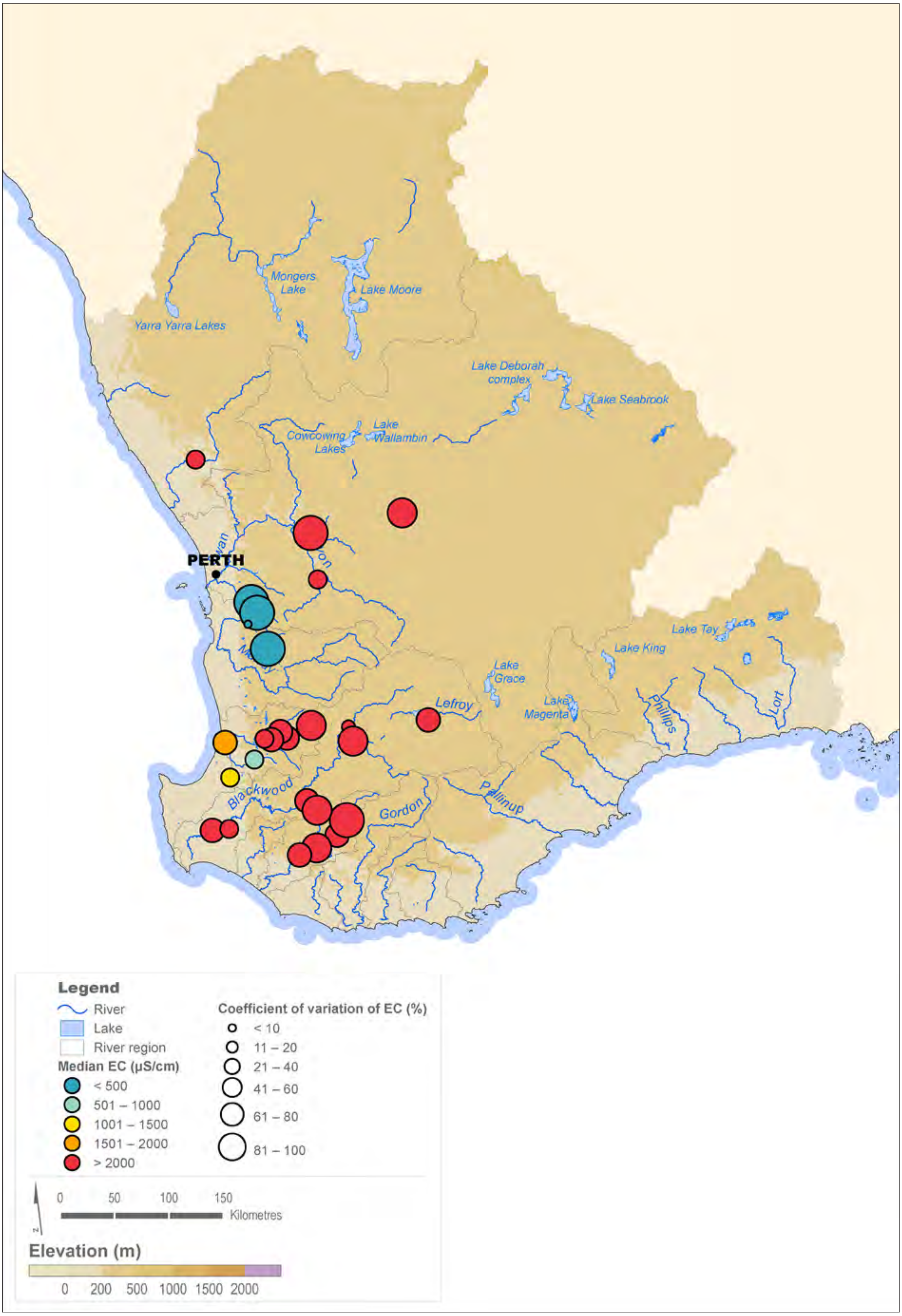


Figure 10.24 Salinity as electrical conductivity (µS/cm) and its associated coefficient of variation for 2011–12 in the South West Coast region

10.5.4 Flooding

There were no major floods in the South West Coast region during the 2011–12 year. The locations of minor and moderate floods are shown in Figure 10.25.

10.5.5 Storage systems

There are 21 major publicly owned storages in the South West Coast region, with a total storage capacity in excess of 1,000 GL. The Bureau's water storage website includes information on approximately 95% of the region's publicly owned storage capacities (as at August 2012). Most storages in the region supply two major systems; the Harvey Irrigation Area and the Integrated Water Supply Scheme which supplies water to the Perth urban area.

Table 10.3 gives a summary of the major storage systems in the region 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 10.26.

The storages in the region currently have particularly low volumes, especially in relation to the storages in the eastern part of Australia. The lower rainfall totals during the winter period (as found in Figure 10.14b) have resulted in the catchment upstream of the dams to be in a very dry state. New rainfall coming in has to partly fill up these soils first before run-off is generated. With the average to above average rainfall of 2011–12 in the rivers upstream of the storages, this has partly been achieved. Together with the commissioning of a second desalination plant, which reduced the demands on the storage supply, water levels were able to rise by 10% of accessible capacity.

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

10.5.6 Wetlands

There are a number of Ramsar-listed, internationally important wetlands in the South West Coast region as well as a number of wetlands of national importance mentioned in the *Australian Directory of Important Wetlands* (www.environment.gov.au/water/topics/wetlands/database/diwa.html). The wetlands vary from coastal tidal flats to inland ephemeral lakes and large salt lakes (Figure 10.27).

No detailed assessment on the inflows of selected wetlands has been performed for this region.

Table 10.3 Major public storage systems in the region as identified in the Bureau's water storage website (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
Perth	urban	593 GL	107 GL—18%	139 GL—23%
Harvey	rural	279 GL	72 GL—26%	135 GL—48%
Non-allocated	—	79 GL	30 GL—38%	35 GL—44%
Total		951 GL	210 GL—22%	309 GL—32%

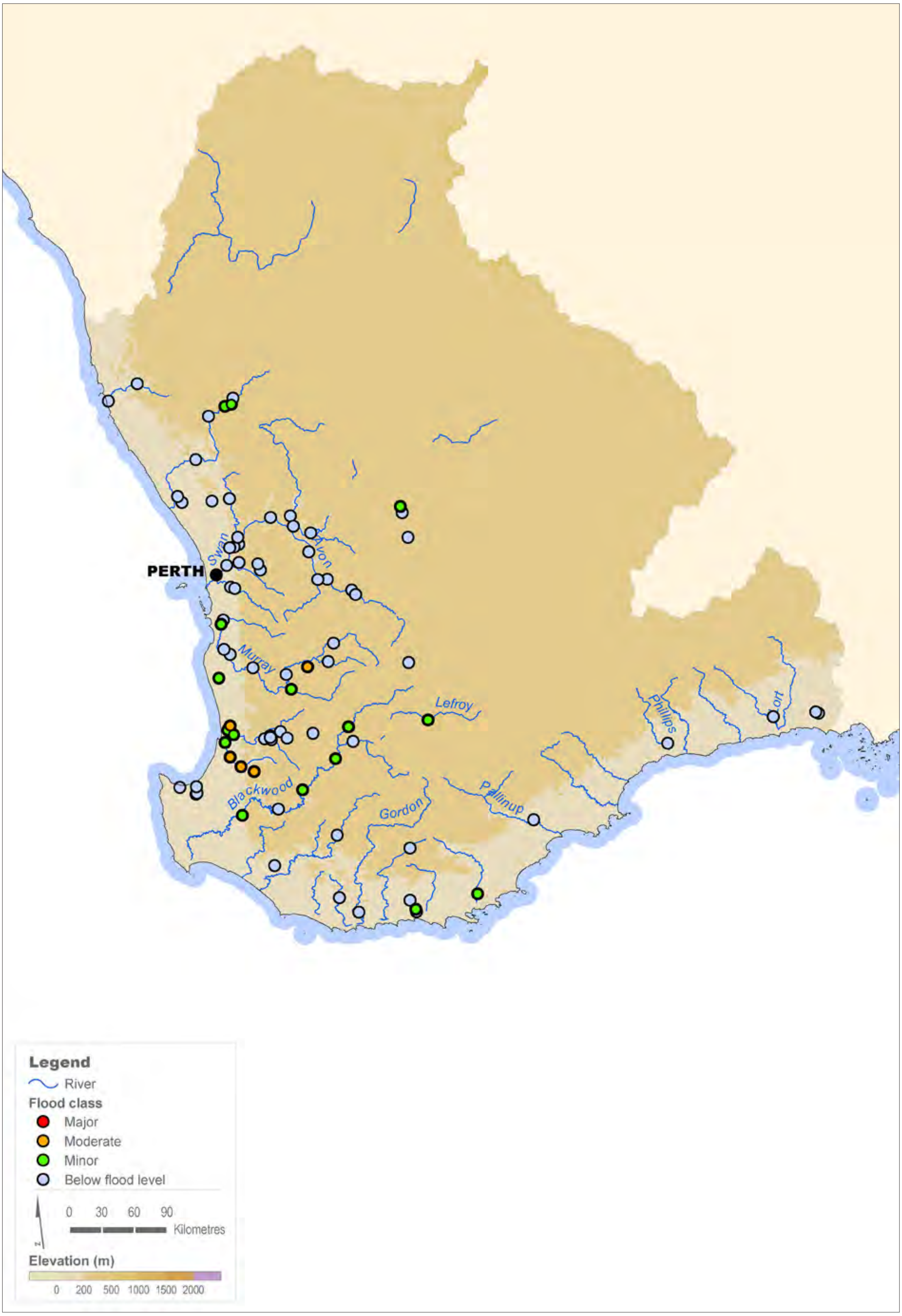


Figure 10.25 Flood occurrence in 2011–12 for the South West Coast region, with each dot representing one gauging station and the colour of the dot representing the highest flood class measured

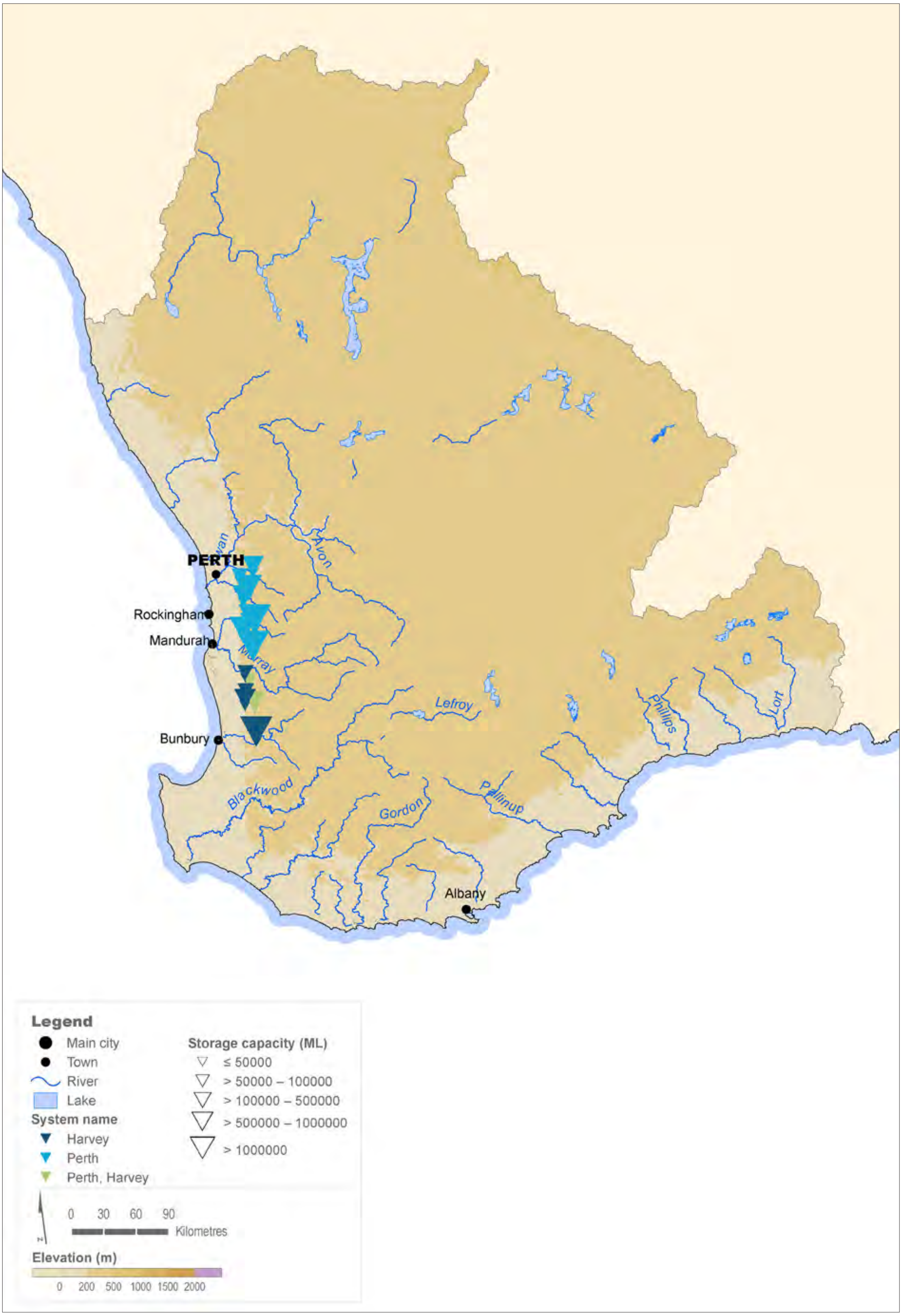


Figure 10.26 Storage systems in the South West Coast region (information extracted from the Bureau's water information website in August 2012)

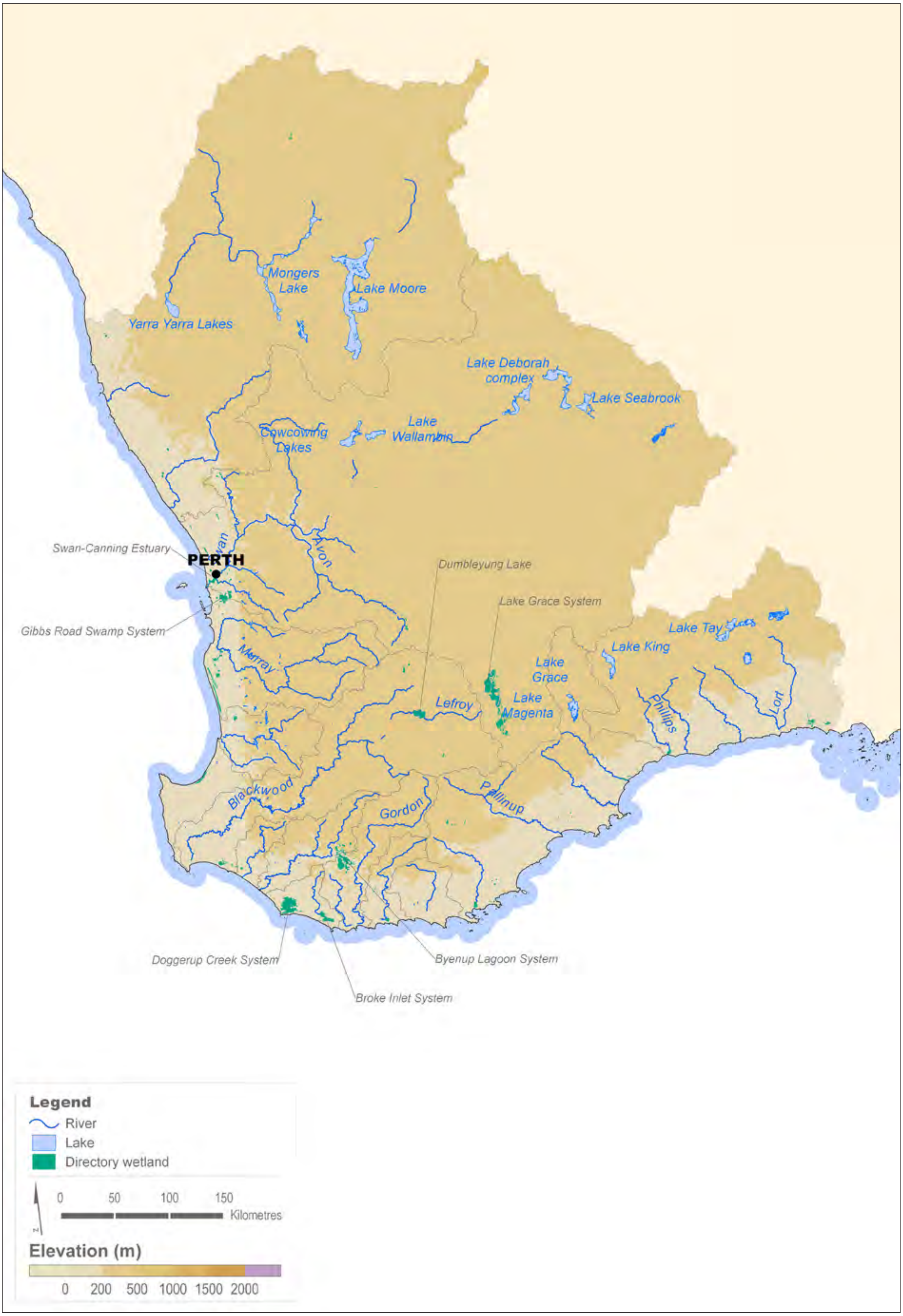


Figure 10.27 Location of important wetlands in the South West Coast region

10.5.7 Hydrogeology

Figure 10.28 shows the major aquifer groups present at the watertable. The region is dominated by fractured rock groundwater systems that may provide a low volume groundwater resource. Groundwater systems that provide more potential for extraction are labelled as:

- Surficial sediment aquifer (porous media—unconsolidated);
- Mesozoic sediment aquifer (porous media — consolidated); and
- Upper tertiary/quaternary aquifer (porous media—unconsolidated).

Confined aquifer systems, underlying some of the watertable aquifers shown in the figure, provide an important resource for the region. Most notable are the Leederville and Yarragadee aquifers beneath the Swan Coastal Plain.

10.5.8 Watertable salinity

Figure 10.29 shows the classification of watertable aquifers as fresh (total dissolved solids [TDS] < 3,000 mg/L) or saline (TDS ≥ 3,000 mg/L) water according to watertable salinity. Most parts of the region are considered to have saline groundwater. The coastal regions with usable groundwater resources are those identified as non-saline.

10.5.9 Groundwater management units

The hydrogeology of the region is dominated by a large area of outcropping fractured basement rock which typically offers a restricted low volume groundwater resource. Significant groundwater resources are, however, available on parts of the coastal plain. Approximately 35% to 50% of the water supplied to the city of Perth is sourced from groundwater.

The groundwater management units within the region are presented in Figure 10.30. Most of the smaller units are located near the western boundary of the region, while the larger units are located in the east and south. The size is inversely correlated to the yield and quality of groundwater resources, that is, large units typically have low volume and low quality. In fact, the major aquifers within the region include surficial aquifers of the Gnangara Mound and the underlying confined Leederville and Yarragadee aquifers.

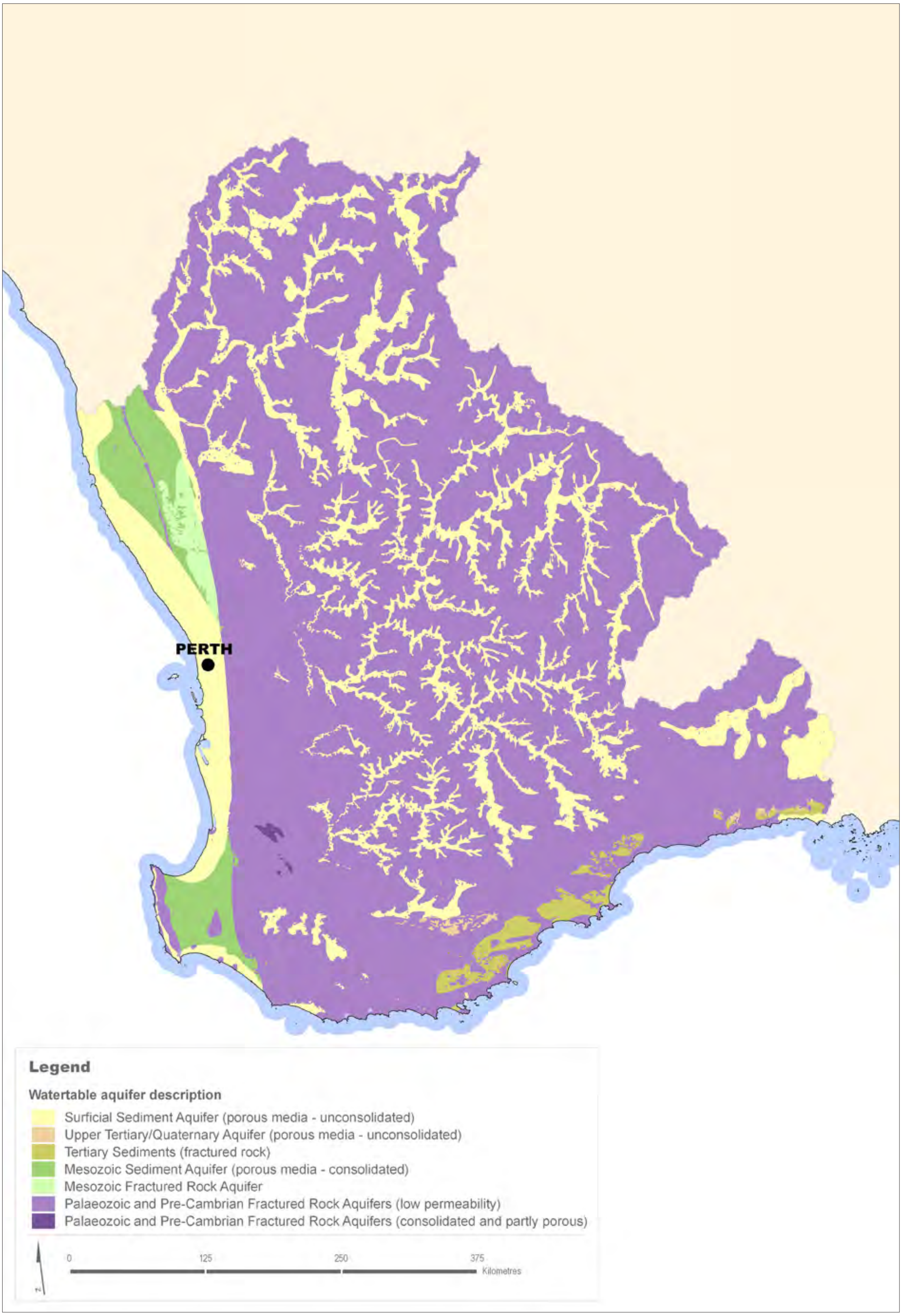


Figure 10.28 Watertable aquifers of the South West Coast region; data extracted from the Groundwater Cartography of the Australian Hydrological Geospatial Fabric (Bureau of Meteorology 2012)

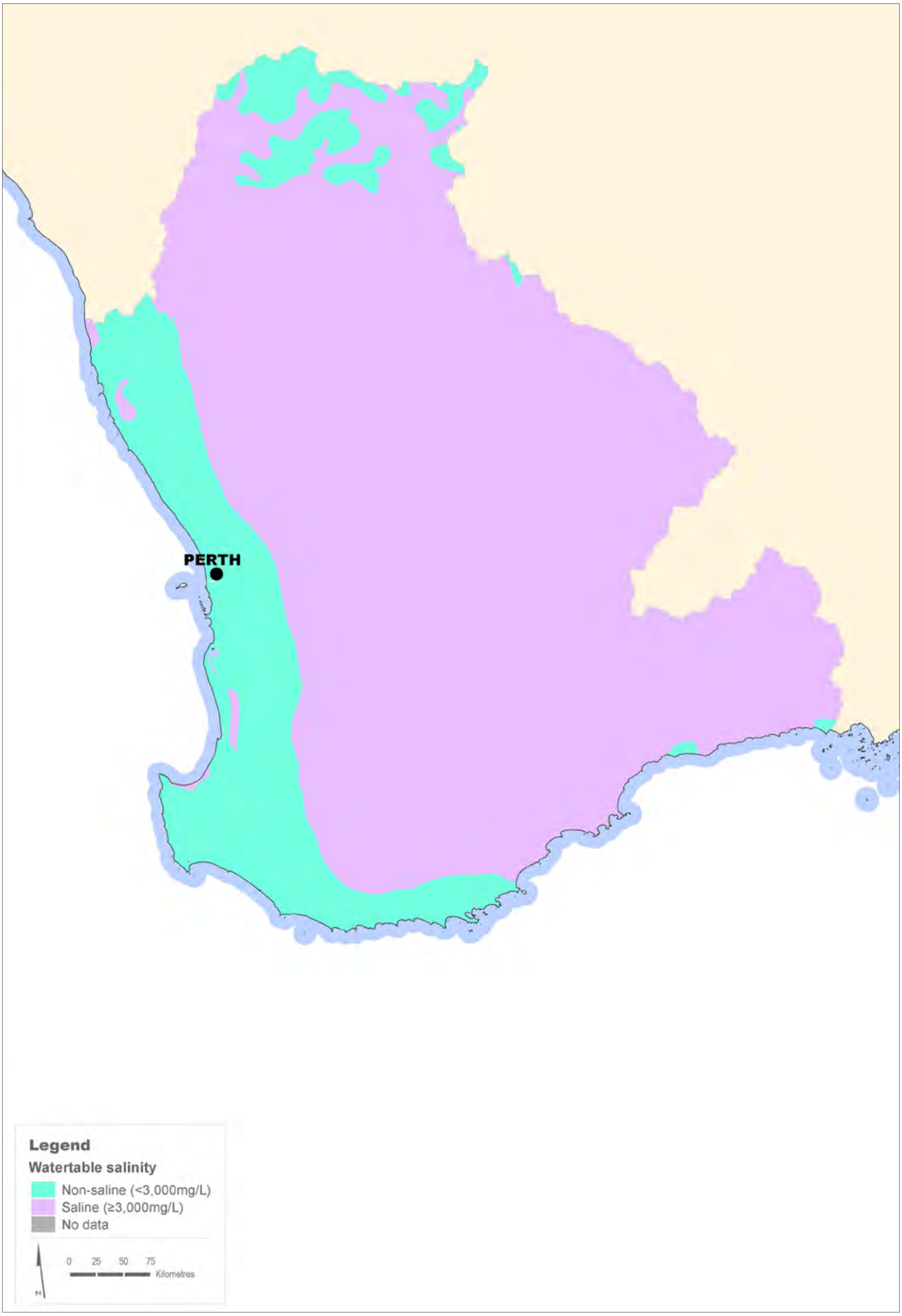


Figure 10.29 Watertable salinity classes of the South West Coast region; data extracted from the Groundwater Cartography of the Australian Hydrological Geospatial Fabric (Bureau of Meteorology 2012)

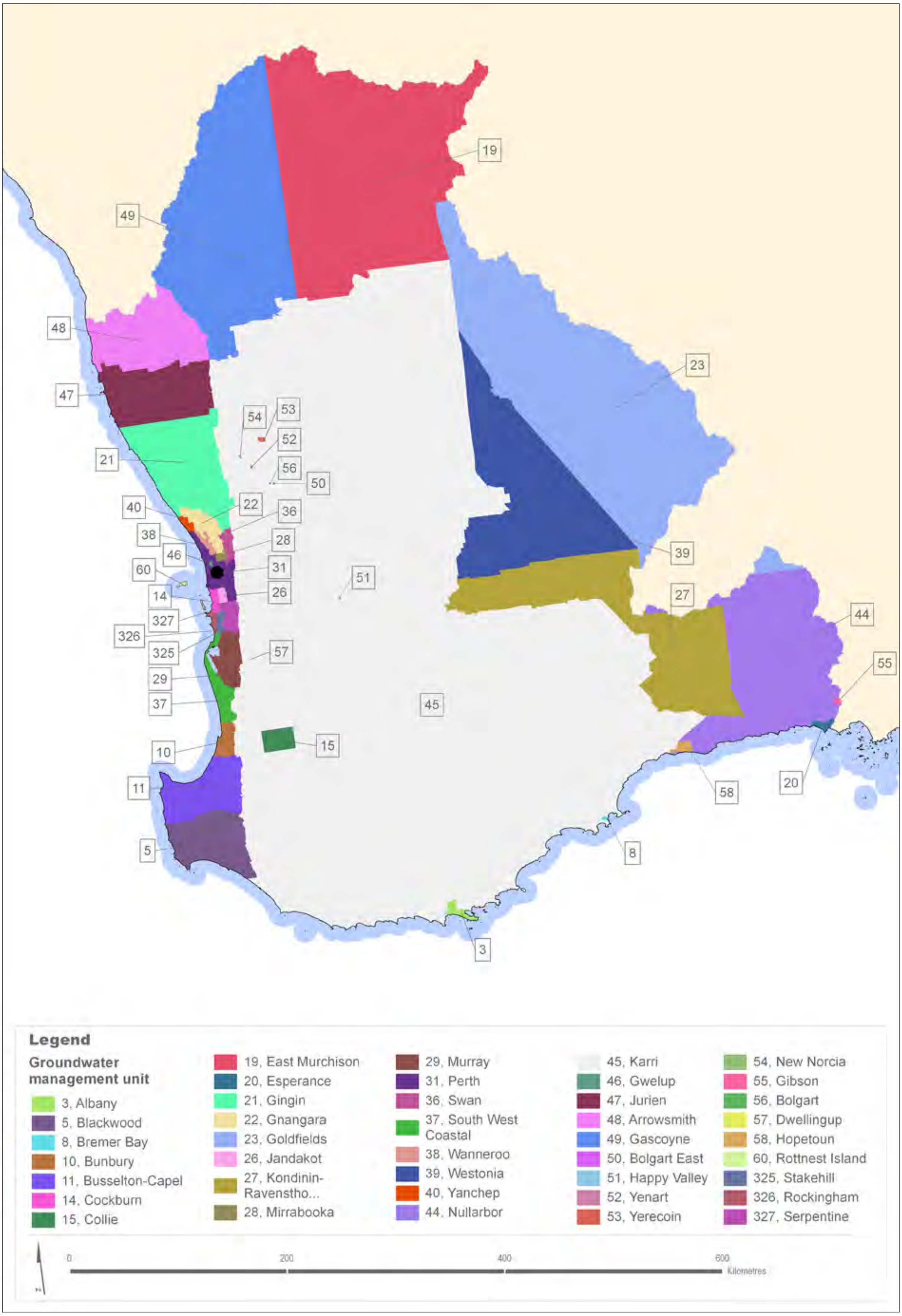


Figure 10.30 Groundwater management units in the South West Coast region; data extracted from the National Groundwater Information System (Bureau of Meteorology 2013)

10.6 Water for cities and towns

This chapter examines urban water supply in the South West Coast region in 2011–12 and over recent decades. The main urban centres in the region are discussed briefly. The main urbanised portion, the Perth water supply area, is presented in detail including their water supply systems, storage position, historical and current water restrictions, water sources and supply information. The main source of data for this section is the National Performance Report (National Water Commission [NWC] 2013).

10.6.1 Urban centres

Perth is the largest urban centre in the South West Coast region with a population of more than 1.6 million people. It includes the suburban centres of Joondalup in the north, Armadale in the southeast and Fremantle, Rockingham and Mandurah along the south coast. About 80% of the region's population lives in Perth.

Outside of Perth the region has two major urban centres (populations over 25,000 people). These are Bunbury and Albany. Table 10.4 provides a summary of their population, surrounding river basin and significant water storages.

Bunbury, situated 175 kilometres south of Perth, has a population of about 64,000. It is a port city, servicing the farming, mining and timber industries of the southwest.

The population of Albany, located about 400 km southeast of Perth, is just under 27,000 and it is also a port city. The main industries of Albany consist of tourism, fishing and agriculture.

In addition to its major urban centres the region has a number of small towns, in particular through its southwest. Figure 10.31 shows these regions cities and towns along with their population ranges.

Table 10.4 Cities and their water supply sources in the South West Coast region

City	Population[1]	River basin	Major supply source
Perth	1,630,000	Swan Coastal	Groundwater Canning, Serpentine and South Dandalup storages, desalination
Bunbury	64,000	Preston River	Groundwater
Albany	26,500	Kalgan River	Groundwater

[1] Australian Bureau of Statistics (2011b)

Figure 10.31. Population range of urban centres in the South West Coast region

10.6.2 Sources of water supply

Unlike much of Australia the region as a whole relies heavily on groundwater for the provision of its urban water supply. While surface water storages are an important component of supply systems, the region's highly variable rainfall and shifting climatic patterns have seen a need to augment supplies with water from additional sources. As a result desalination has become an important source of water for Perth.

In the more remote towns to the north and east of the region, groundwater is often a major source of water supply. The Western Australian Water Corporation has also connected many towns to their pipeline supply network, particularly in the southeast.

Recycled water and harvested storm and rainwater sources are also used to supply the urban water demands throughout the region.

10.6.3 Perth

The water supply system of Perth is controlled by the Water Corporation of Western Australia. It is the principal supplier of water, wastewater and drainage services to homes and businesses in the Perth water supply area, as well as providing bulk water to farms for irrigation. The Water Corporation manages Perth's Integrated Water Supply Scheme (IWSS).

The Water Corporation also recycles water, mainly for supply to sporting ovals and golf courses, but also for industry and agriculture. Various trials for topping up groundwater supplies with recycled wastewater are also being conducted, including the Beenyup Replenishment Trial.

With growing urban water demand, sources of water, in particular the groundwater systems, are being subject to significant stress. To manage groundwater abstraction sustainably, ecological water requirements and environmental water provisions are determined as part of water allocation processes (Water Corporation 2008).

Environmental water provisions are determined by the Western Australian Department of Water in accordance with the principles and processes set out in its Environmental Water Provision Policy (2000).

The environmental water provisions are the water regimes provided as a result of the water allocation decision-making processes. This is a comprehensive assessment that takes into account ecological, social and economic impacts.

Supply system

Perth obtains its water supply from a combination of groundwater, surface water, desalination and recycled water. Together these sources form the IWSS. A schematic of this scheme is provided in Figure 10.32.

Up until two decades ago surface water was the major source of water for Perth. However, consistently below average rainfall in the last three decades has seen groundwater become the major source of water supply for urban use.

With its reliance on the groundwater, drawn from the Gnangara and Jandakot mounds, and decreased recharge a result of changing climatic conditions, Perth's water supply aquifer levels have declined. In response to this, the State Government has begun construction of desalination plants to provide reliable and climate-independent water supply to the Perth region.

The first desalination plant, in Kwinana, was completed in 2006 with the capacity to produce 45 GL per year. The second desalination plant, in Binningup, became operational in September 2011. Together these desalination sources provide about half of the water needed for the Perth metropolitan area.

Surface water supplies for Perth are drawn from ten major water storages located in the catchments to the east of Perth. These storages are shown in Figure 10.33. Together they have a combined total accessible storage capacity of 580 GL.

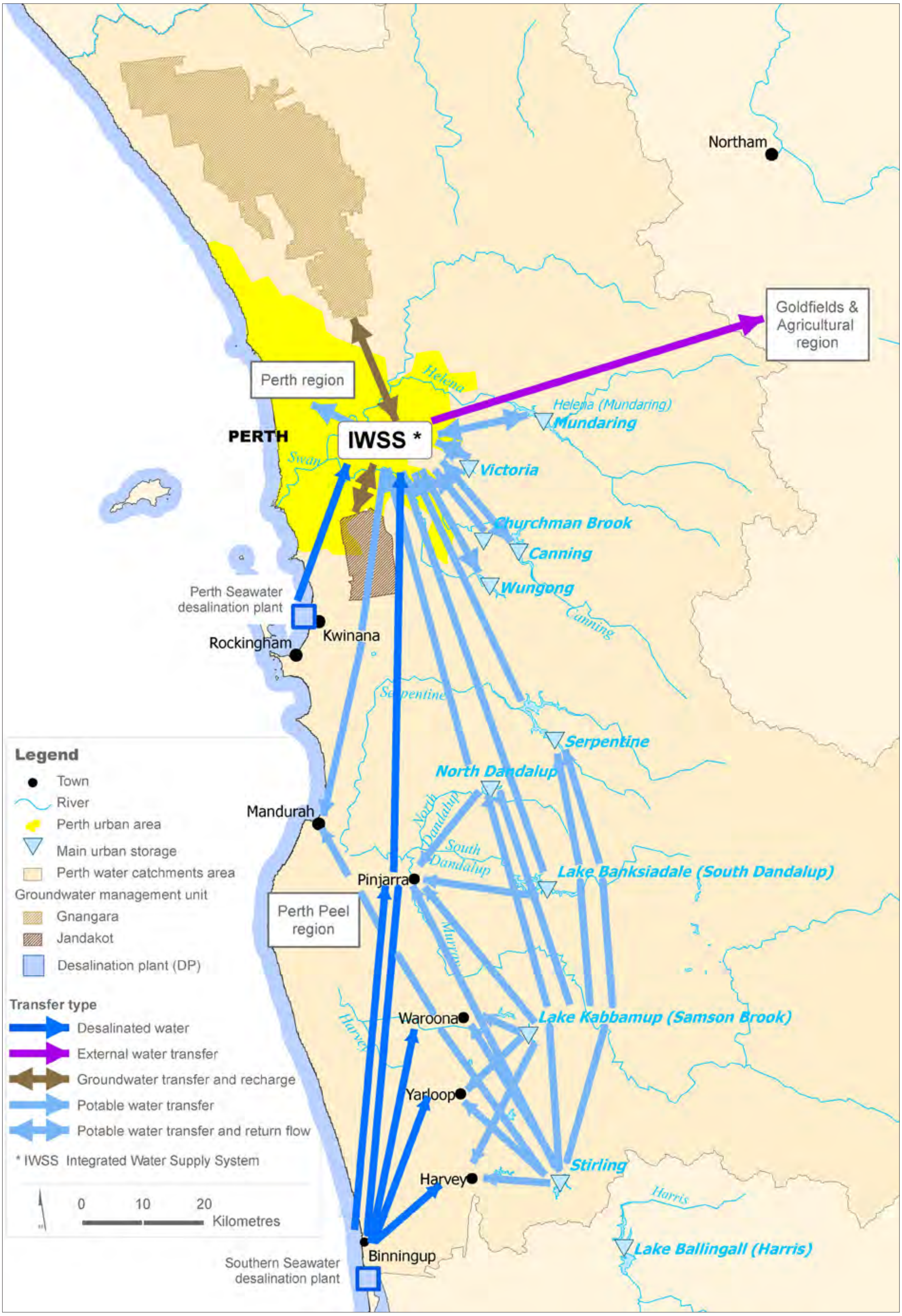


Figure 10.32 Water supply schematic for Perth and surrounds

Figure 10.33 Urban supply storages in the South West Coast region

Storage volumes

The historical time series of the accessible volume of Perth's three major storages (Serpentine, Canning and South Dandalup) are shown in Figure 10.34. Together these storages comprise almost 60% of Perth's total surface water storage capacity.

The significant decline in storage volumes that has resulted from shifting climatic patterns and the resulting decrease in surface water run-off can be clearly observed across all storages. In particular, reduced winter rainfalls and drying catchments have played an important role in the decline of these storages.

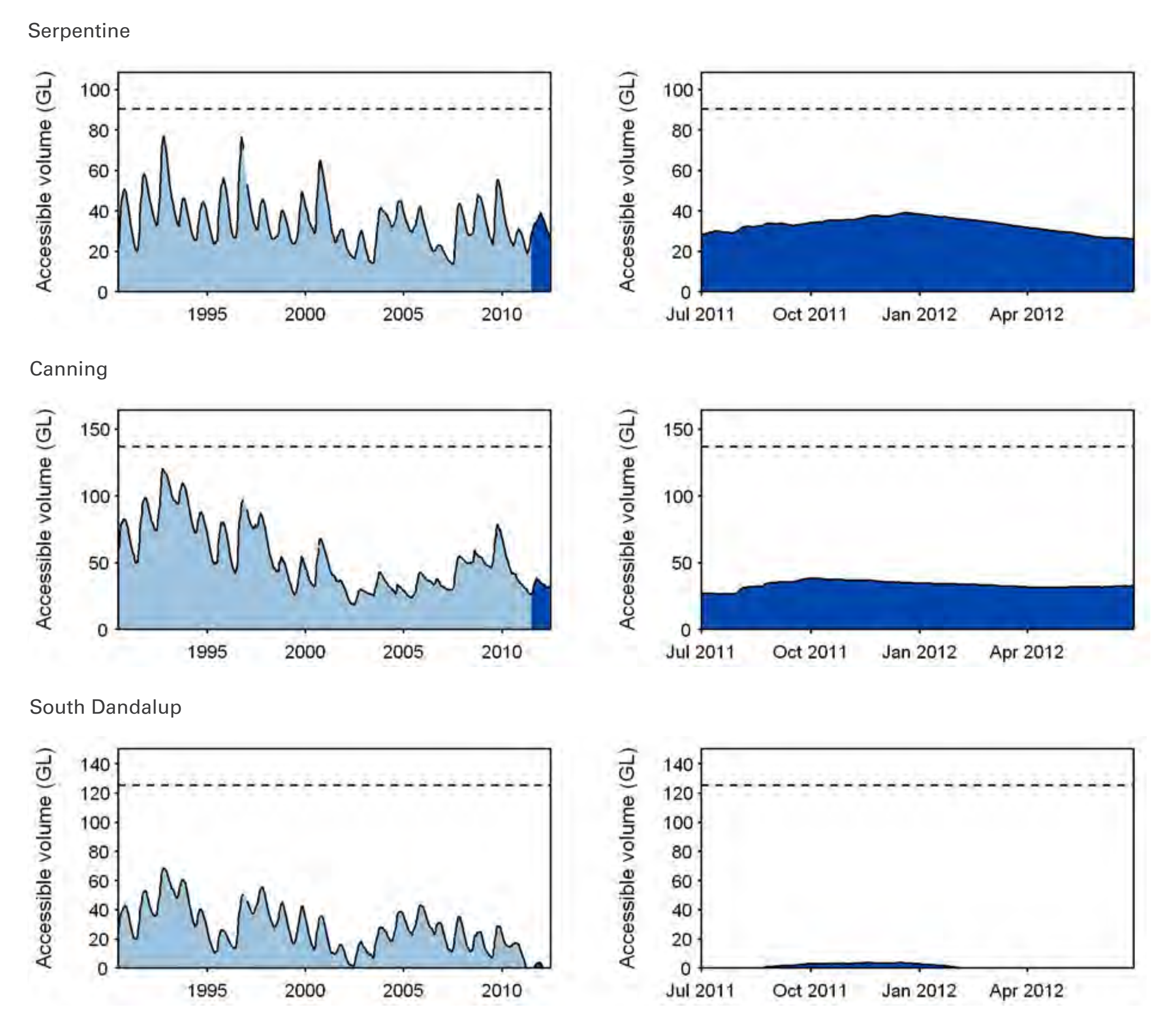


Figure 10.34 Variation in the amount of water held in storage for the combined area over recent years (light blue) and over 2011–12 (dark blue), as well as total accessible storage capacity (dashed line)

Water restrictions

Water restrictions in Perth are set by the State Government and enforced by the Water Corporation. Water restriction policy, including restriction levels, is enacted through Water Agencies (Water Use) by-laws and legislated under the Western Australian *Water Agencies (Powers) Act 1984*.

A historical time series of water restrictions for Perth is presented in Figure 10.35. The figure highlights the decline in surface water resources and the significant role water restrictions have played in the lives of Perth residents as well as its commercial and industrial sectors over the last decade.

In September 2011, following an increase in winter rainfall and the commissioning of Perth's second desalination plant, an easing of restrictions to Stage 5 was allowed. However, in June 2012 restriction levels were back to Stage 7.

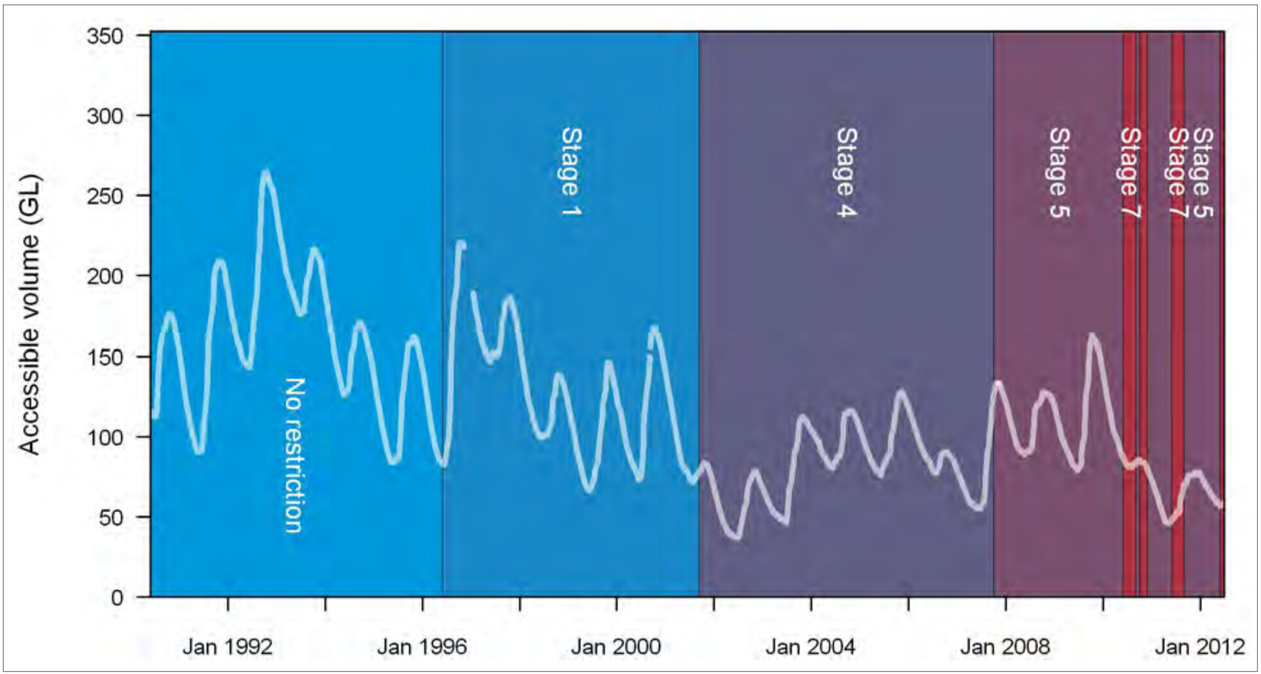


Figure 10.35 Urban water restriction levels for Perth since 1990 shown against the combined accessible water volume of Serpentine, Canning and South Dandalup storages

Sources of water obtained

Groundwater continues to be the main source of water supplied to Perth; however, in the future this may not be the case due to the low recharge of groundwater aquifers. Figure 10.36 illustrates that, on average, more than 50% of the bulk water sourced by the Water Corporation is from groundwater (National Water Commission 2011a).

An increase in desalination capacity, as a result of the Binningup desalination plant becoming operational in 2011, has seen water supplied from this source grow from 18 GL in 2006–07 to just over 50 GL in 2011–12.

Recycled water continues to play a comparatively minor role in Perth's urban water supply. Water supplied from this source has exhibited modest growth, reaching 6 GL in 2011–12, up from 4 GL in 2006–07.

Despite record growth, the total water sourced for Perth water supply has remained relatively consistent over the analysis period. This is directly attributable to demand management and water conservation measures implemented throughout Perth as well as the broader area.

On average, about 5 GL of water has been sourced from recycling on an annual basis since 2006–07. This water is supplied to consumers for a range of activities including the irrigation of agriculture, vineyards and market gardens.

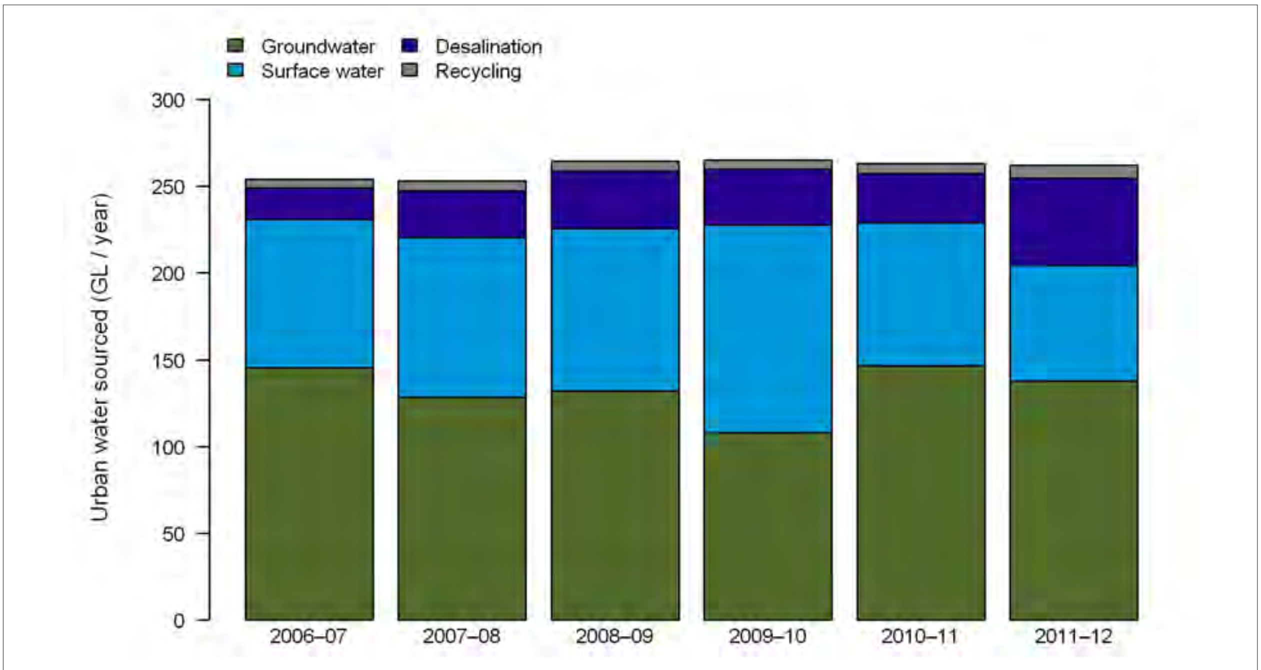


Figure 10.36 Total urban water sourced for the Perth water supply area from 2006–07 to 2011–12

Categories of water delivered

Figure 10.37 shows the total volume of water delivered to residential, commercial, municipal and industrial consumers in the Perth water supply area between 2006–07 and 2011–12 (NWC 2013). The total water supplied increased by 8 GL over this period from 240–48 GL due to an increasing population.

On average about 70% of the water supplied each year was used for residential purposes.

Commercial, municipal and industrial water use comprised around 20% of the water supplied with the remainder accounted for by other water uses.

The average water supplied by the Water Corporation per property for residential use between 2006–07 and 2011–12 was estimated to be 269 kL. The maximum residential water use per property was 281 kL in 2006–07 and the minimum was 250 kL in 2011–12.

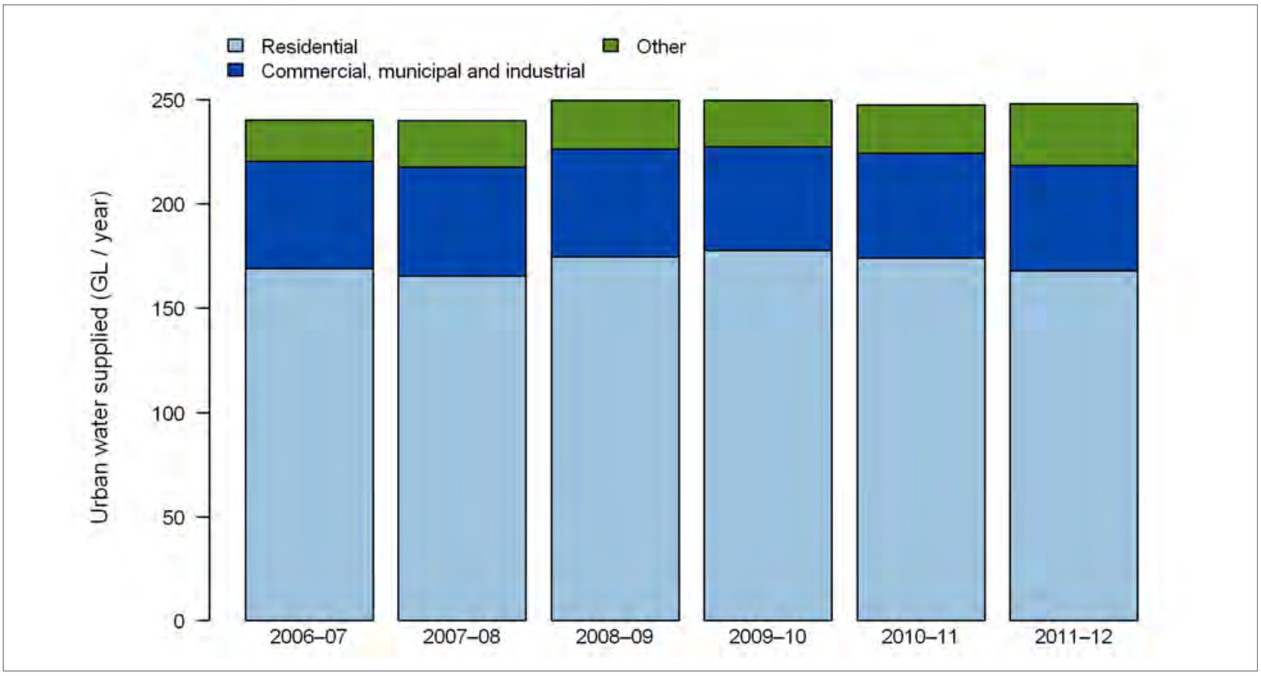


Figure 10.37 Total urban water supplied to Perth from 2006–07 to 2011–12

10.7 Water for agriculture

This section describes the water situation for agriculture in the South West Coast region in 2011–12. Soil moisture conditions are presented and important irrigation areas are identified. The Harvey Irrigation Area is described in more detail and information is provided regarding surface storage and groundwater.

10.7.1 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 for comparison 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 modelled soil moisture volumes of the 1911–2012 period, expressed in decile rankings.

Soil moisture distribution deciles for the region indicate very dry conditions during the year for a great portion of the region, as shown by the below average to very much below average soil conditions (Figure 10.38). Although the amount of rainfall in the southwest was higher than average during spring and early summer, evapotranspiration that was above or very much above the historic average in the region exceeded the rainfall inputs (see recent patterns in landscape water flows section, Figure 10.12).

The decile ranking of changes in soil moisture during the 2011–12 shows that the region experienced below average conditions throughout the whole year. A marginal rise was observed due to high rainfall periods in spring and early summer (Figure 10.39).

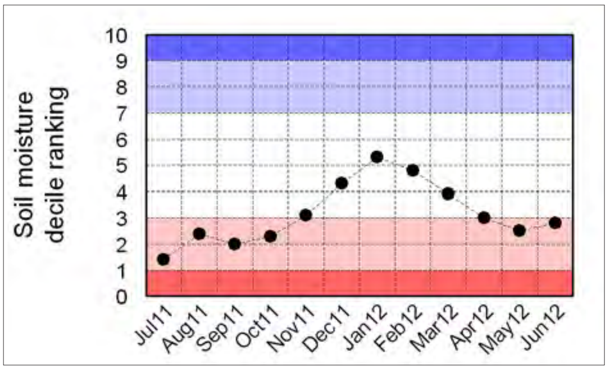


Figure 10.39 Decile ranking of the monthly soil moisture conditions during the 2011–12 period in the South West Coast region

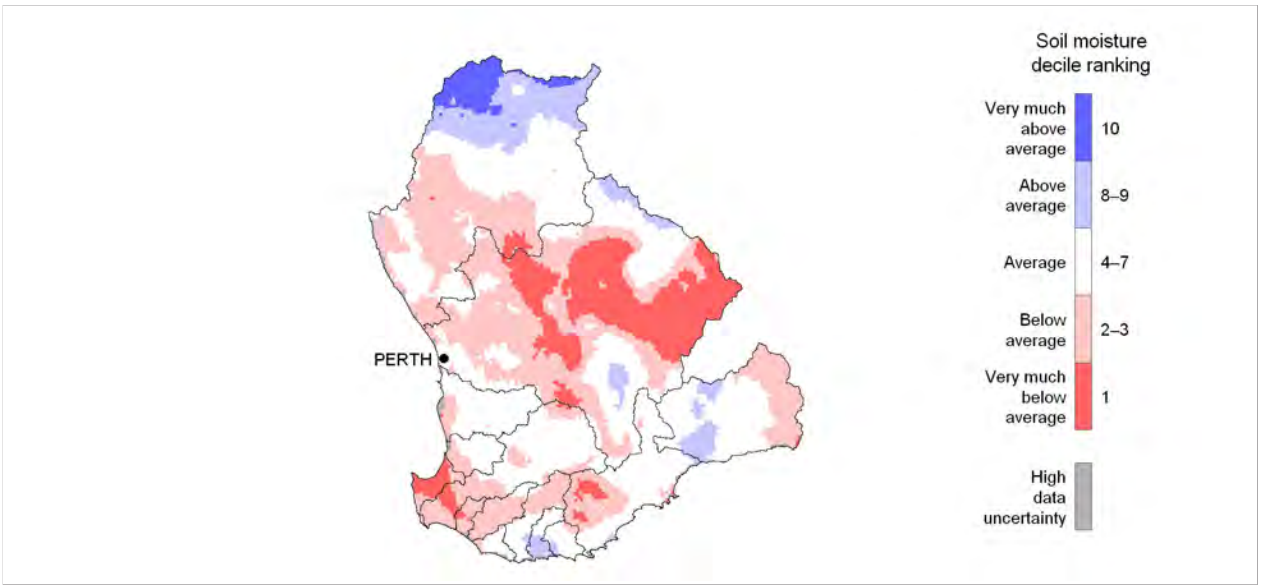


Figure 10.38 Deciles ranking of annual average soil moisture for 2011–12 with respect to the 1911–2012 period for the South West Coast region

10.7.2 Irrigation water

Comparison of annual irrigation water use between 2005–06 and 2010–11 across the South West Coast region by natural resource management regions (NRM) is shown in Figure 10.40. Figure 10.41 shows the map of annual water use of the same NRM regions in 2010–11.

Data for the 2011–12 year period was not available at the time of preparation of this report.

The Harvey Water Irrigation Area is described in subsection 10.7.4 as an example of water use by irrigated agriculture in the South West Coast region.

10.7.3 Irrigation areas

Much of the South West Coast region is cleared for grazing and dryland cropping. Principal land uses include annual dryland cropping (mainly wheat) and grazing (mainly sheep).

The region has a temperate climate with cool, wet winters and hot, dry summers. Rainfall declines rapidly further inland. The region's streamflow and groundwater recharge are generated mostly from rainfall during the cooler, wetter months of May–October.

Irrigated agriculture is carried out in the metropolitan area and parts of the southwest of the region. High salinity levels limit the suitability of water resources for agricultural production.

The main irrigation scheme providing water to irrigation areas in the metropolitan and southwestern parts of the region is the Harvey Water Irrigation Area (Figure 10.42) which is one of the main irrigation schemes in Western Australia after the Ord Irrigation Scheme, both constituting more than 60% of water allocations in the State. Irrigation in the Harvey Water Irrigation Area is mostly for pasture, followed by vegetables and horticulture.

The Preston Valley Irrigation Co-operative is another scheme and is operational in the Donnybrook Shire near Bunbury.

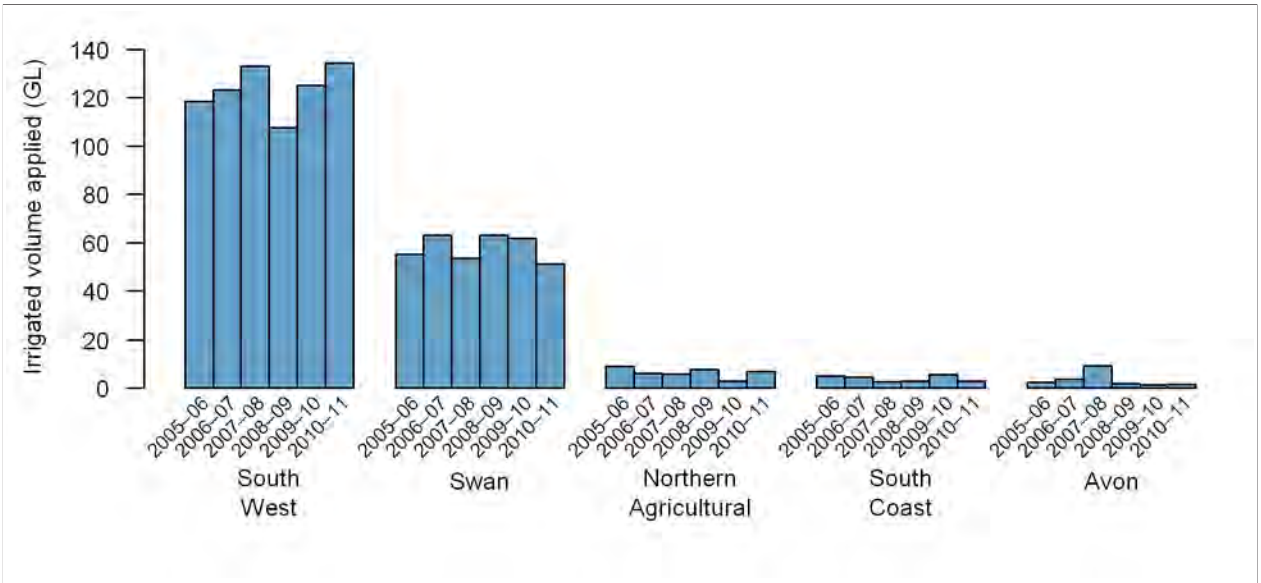


Figure 10.40 Total annual irrigation water use for 2005–06 to 2010–11 for natural resource management regions in the South West Coast region (ABS 2006–2010; 2011a)

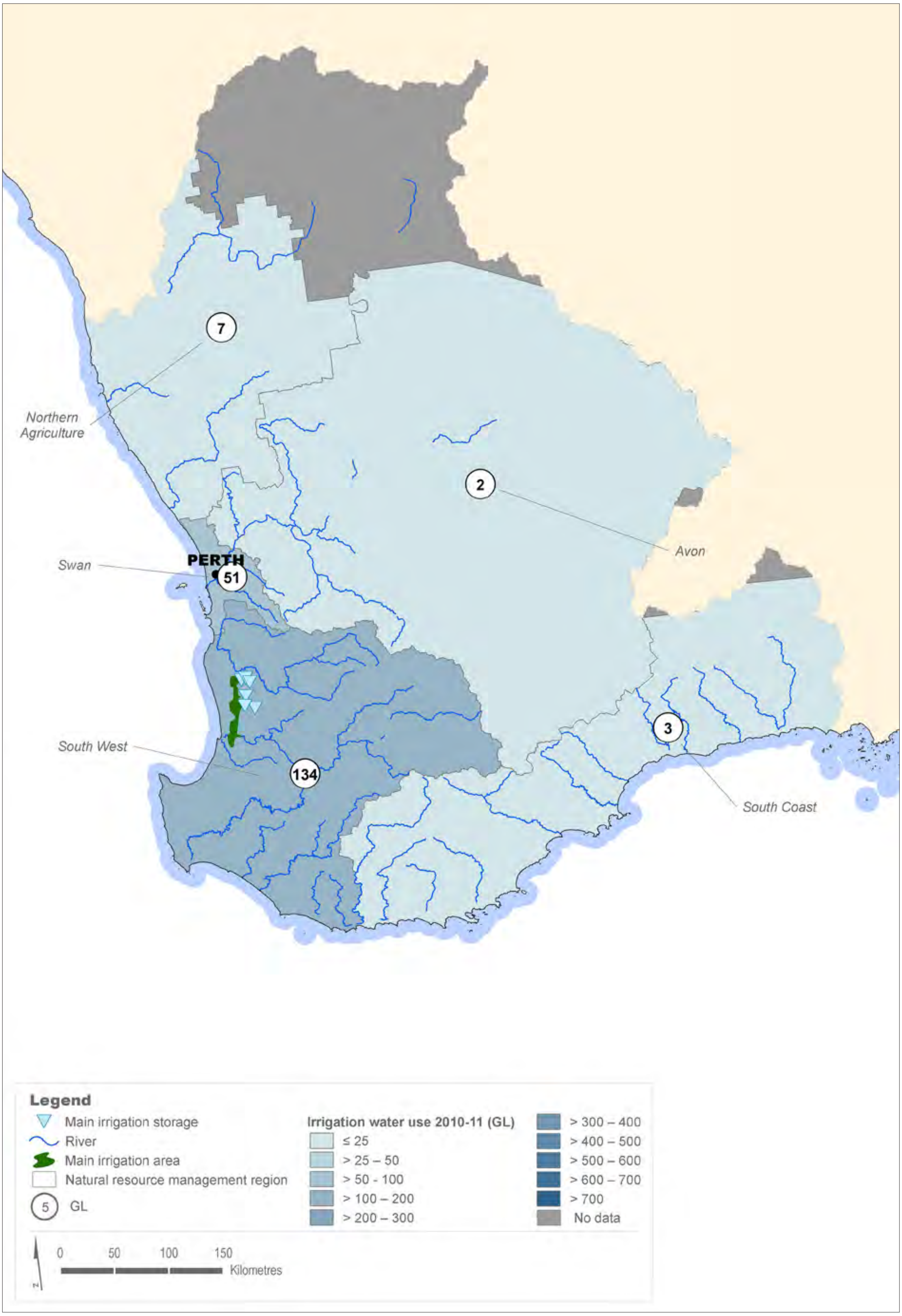


Figure 10.41 Annual irrigation water use (GL) per natural resource management region for 2010–11 in the South West Coast region (ABS 2011a)

Figure 10.42 Irrigation areas in the South West Coast region

10.7.4 Harvey Water Irrigation Area

The Harvey Water Irrigation Area is located to the west of the Darling Scarp on the Swan Coastal Plain (Figure 10.43). It lies within the Peel–Harvey catchment that includes the Harvey, Collie and Preston river basins covering an area of 3,000 km^2.

The Harvey Water Irrigation Area covers an area of 1,000 km^2 in three irrigation zones: Harvey, Waroona and Collie. The majority of land is used for dairy farming and beef production. Currently around 100 km^2 of land is under permanent irrigation for dairy farming, beef grazing and horticulture, with a total irrigable area of approximately 300 km^2 (Harvey Water 2011). It is Western Australia's prime irrigated dairy area, supplying Perth and the southwest with more than 40% of its milk.

Harvey Water is responsible for the water delivery infrastructure and is licensed to draw water from Drakes Brook (Lake Moyanup), Harvey, Logue Brook (Lake Brockman), Samson Brook (Lake Kabbamup), Stirling, Waroona (Lake Navarino) and Wellington storages. Water is supplied by gravity flow from storages to farms via a network of open channels and pipes. The transfer system is progressively being made more efficient by the use of high density piping.

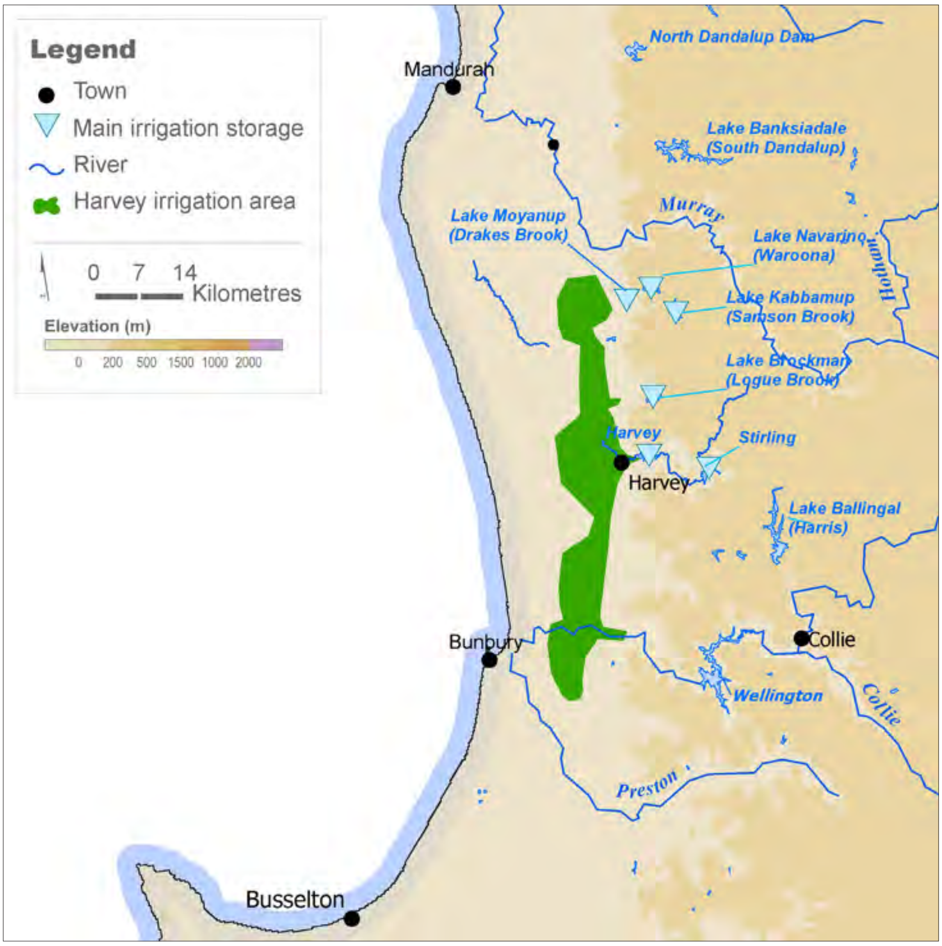


Figure 10.43 Harvey Water Irrigation Area

Surface water storage volumes

Total volume for the seven water storages in the irrigation area between 1990 and 2012 are shown in Figure 10.44. The total storage volume was drawn down to low levels, approximately 20% of capacity, during the 2002–03 drought. The data indicate storage total volume during 2011–12 period recovered from similarly low levels in spring 2011 to be in excess of 200 GL in summer 2011–12. This recovery did not extend into the following autumn due to reduced inflow to the storages.

The irrigation water use in the three districts of Collie, Harvey and Waroona in the Harvey irrigation area has dropped from an average of 70 GL per year since 1996 to just 48 GL per year between 2010 and 2012 (Figure 10.45). The reduction in water use in recent years has been related to deterioration of water quality and reduction in demand.

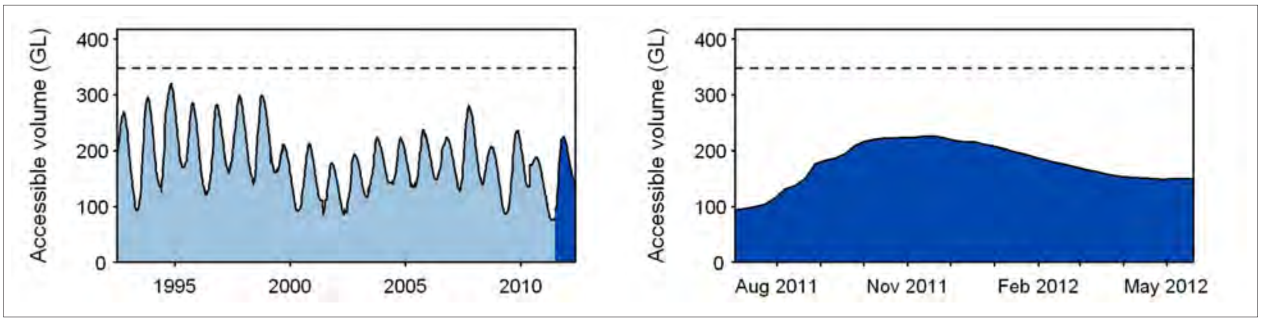


Figure 10.44 Variation in the amount of water held in seven storages supplying the Harvey Water Irrigation Area over recent years (light blue) and over 2011–12 (dark blue), as well as total accessible storage capacity (dashed line)

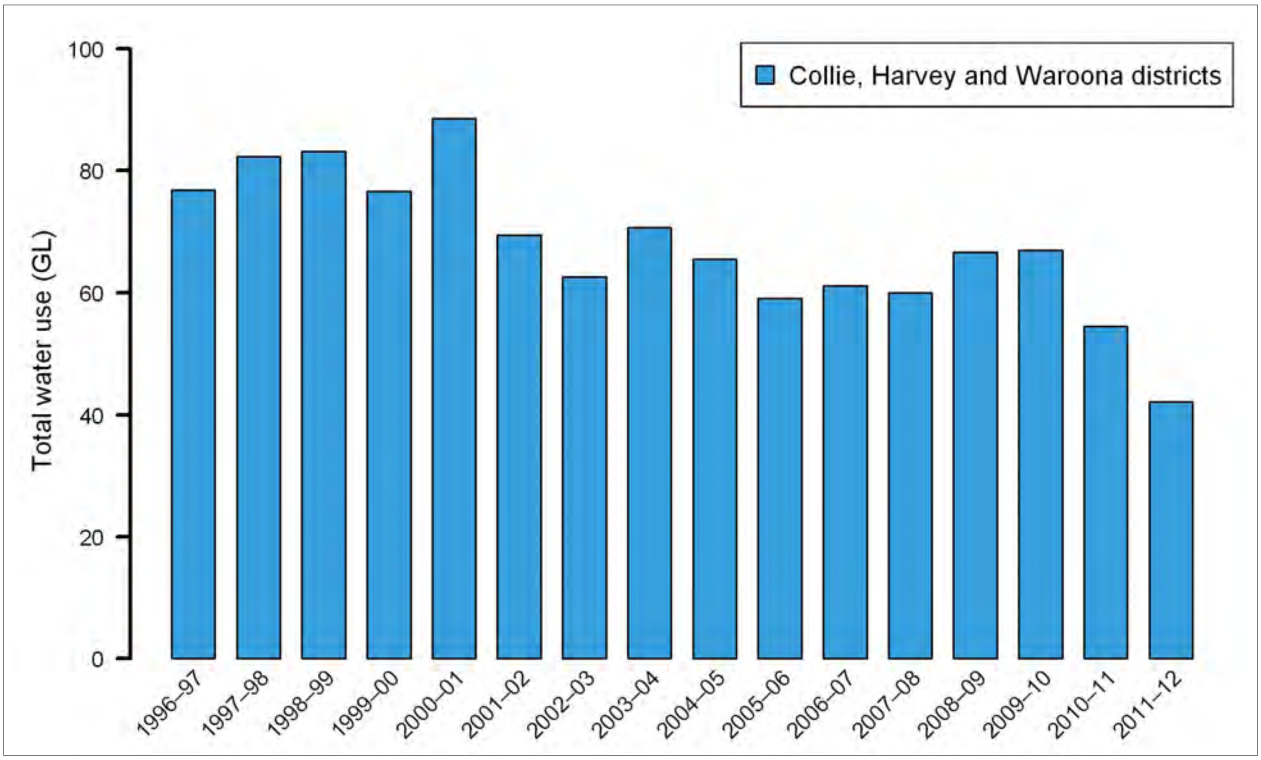


Figure 10.45 Water use in the three irrigation districts of the South West Coast region between 1996 and 2012