Australian Water Resources Assessment 2010

Australian Government
Bureau of Meteorology

Water Information
DATA › INFORMATION › INSIGHT

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Foreword

The Commonwealth *Water Act 2007* charges the Bureau of Meteorology with 'providing regular reports on the status of Australia's water resources and patterns of usage of those resources'. The Australian Water Resources Assessment 2010 is the first in a regular series of such reports.

This report presents data and information on the extent and magnitude of Australia's water resources in 2009–10 in the context of the long-term record. It updates earlier assessments of Australia's water resources, the most recent of which was produced for the 2004–05 year by the National Water Commission, as a baseline for the National Water Initiative of 2004.

The Australian Water Resources Assessment 2010 includes comprehensive information on the nation's surface water resources and more limited information on its groundwater resources. Information is presented in the form of maps, graphs and tables with an accompanying narrative.

The body of the report consists of a national overview and 13 regional chapters, with the regions based on the new drainage division boundaries derived from the Australian Hydrological Geospatial Fabric. A Technical supplement provides additional detail on the data selection, analysis and water balance modelling techniques used in preparing this report and the level of peer review and acceptance they have received.

I hope that this report assists all Australians, but particularly policy-makers and planners, to understand the current state of the nation's water resources and to gauge the impact of past and present water management practices. Your feedback on the report's use will help us ensure that future reports achieve this aim.

The Bureau of Meteorology is currently building its water resources information systems. As these systems develop, more data and different data types will become available for inclusion in our assessments and a richer understanding of the nation's water resources will be possible.

I would like to thank all those who have assisted us in the preparation of this report including the State and Territory water agencies that operate the vital water monitoring networks across our country, our water science collaborators in CSIRO in particular those within the Water Information Research and Development Alliance between the Bureau of Meteorology and CSIRO, and the many many reviewers of report drafts – your diligence and expertise has greatly enhanced the quality of this report.

Finally I would like to acknowledge the dedication and professionalism of the Bureau of Meteorology staff who have brought this landmark report to publication. Well-done!

Dr Rob Vertessy
Acting Director of Meteorology
November 2011

1. Introduction

1.1 Background

The Commonwealth *Water Act 2007* gives responsibility to the Bureau of Meteorology (the Bureau) for compiling and delivering comprehensive water information across Australia. This includes conducting timely, rigorous and independent assessments of the status of Australia's water resources.

National water resource assessments were undertaken by various Australian Government agencies and partners at irregular intervals over the last 50 years, each with a slightly different purpose and approach. The two assessments published since 2000 are noted below.

The Australian Water Resources Assessment 2000 report, AWRA 2000 (Commonwealth of Australia 2001), was undertaken by the Australian Government in partnership with State and Territory Government agencies for the National Land and Water Resources Audit. It was published in 2001 and presented a snapshot of the quantity, quality, use, allocation and management of Australia's water resources.

The most recent assessment, Australian Water Resources 2005 (National Water Commission 2007), was undertaken as a baseline for measuring the success of reforms under the National Water Initiative. It reported on the 2004–05 water year. Baseline information on water availability, water use and river/wetland health was assembled for future comparisons. Regional water resource assessments were undertaken for a number of surface water management areas and groundwater management units.

From 2005, the Bureau and water agencies around the country started delivering a range of water data and information products that provide certain components of the information included in previous water resource assessments. Through strategic water research and development investments, new assessment methodologies were developed that enhance our assessment capabilities.

This report is the first of the Bureau's Australian Water Resources Assessments that evaluate the nation's water resources. In contrast to previous Australian water resources assessments, the Bureau's reports are focused on consistency in reporting over time at key sites, highlighting patterns, variability and trends. These assessments aim to:

- monitor the hydrological state of rivers, storages, wetlands and aquifers and publish hydrometric statistics for key sites
- highlight patterns, trends and variability in water availability, water quality and water use
- present outputs of varying complexity to meet the information needs of a range of users, predominantly in the form of readily interpretable maps, graphs and tables.

Water assessments are undertaken at regional and national spatial scales and time scales ranging from months to decades. The reports are intended to assist assessment of the impact and sustainability of current water management practices and inform the design of water resource plans, supporting the goals of the National Water Initiative.

The Bureau's Australian Water Resources Assessment reports are:

- freely available and published regularly
- nationally consistent
- informative at regional and national scales
- scientifically robust
- transparent about the source and quality of data presented and about the modelling and analysis techniques used
- unbiased in the presentation of data and information.

The Bureau's Australian Water Resources Assessment reports will be conducted and published regularly from 2011.

There are a number of additional reports on water status, now in the public domain. These are published by various government agencies and are detailed in the Technical supplement.

1.2 Scope and purpose

This report, Australian Water Resources Assessment 2010 (the 2010 Assessment), presents assessments of Australia's climate and water resources in 2009–10 (July 2009 to June 2010). It discusses regional variability and trends in water resources and patterns of water use over recent seasons, years and decades, using the currently accessible data.

The 2010 Assessment is focused on aspects of national and regional water availability rather than water allocation, trading or quality. In particular, no attempt in this assessment was made to report on water use by the mining industry or on water quality, other than groundwater salinity. The 2010 Assessment is structured into the following sections:

- Introduction
- National overview
- 13 regional assessments
- Technical supplement.

A summary report is also available.

The national overview provides a national scale assessment of climate and water flows and stores in Australian landscapes in 2009–10. This includes national landscape water balance model outputs for the year including rainfall, evapotranspiration, landscape water yield and change in soil moisture, and consideration of changes in surface water storage in each region. The chapter examines important Australian climate drivers and their impact on rainfall over the year. Information on nationally significant weather and water events experienced in 2009–10 is also presented.

The regional assessments consider trends in water availability and use in 13 regions which cover the Australian continent. Analyses presented include climate impacts on water resources over 2009–10 and also in recent decades (1980 to 2010). Modelled regional data and data from priority monitoring sites provide more detail at particular locations.

Finally, the Technical supplement provides background on previous water resources assessments as well as additional detail on the landscape water balance modelling techniques, methods, data and analyses used to generate information in the report.

Information and data provided in this 2010 Assessment reflects the quantity and quality of data currently available for analysis. It is expected that as data supplied to the Bureau under the Commonwealth *Water Act 2007* are further stored, standardised and quality assured by the Bureau, analysis and reporting in the Australian Water Resources Assessment reports will be enhanced. In addition, feedback from users is being sought to improve future reports in terms of methods used, data interpretation and contextual information.

The report addresses focal questions (Section 1.3) and seeks new questions from users to shape future reports.

1.3 Focal questions

A number of questions are addressed at various scales in Australian Water Resources Assessment 2010 depending on the availability of suitable data. The scales vary from national in Chapter 2 to regional and local in the subsequent chapters. The types of questions addressed are dependent on the availability of suitable data and include:

1. Was there any significant flooding or drying in 2009–10 as a result of extreme weather conditions? *– Section 11 of Chapter 2; Section 5 of the regional chapters (Chapter 3–15)*
2. Which ocean and atmospheric circulation patterns influenced rainfall in different parts of the country in 2009–10? *– Section 9 of Chapter 2*
3. How much of the rainfall received in 2009–10 ended up in rivers and groundwater and how does this compare with the past? *– Section 3 of Chapter 2; Section 4 of the regional chapters*
4. How much of the rainfall received in 2009–10 was evaporated or used by plants and how does this compare with the past? *– Section 3 of Chapter 2; Section 4 of the regional chapters*
5. How wet were soil profiles across the country in 2009–10 and how does this compare with the past? *– Section 4 of Chapter 2; Section 7 of the regional chapters*
6. Are there any regional trends evident in seasonal rainfall, evaporation, transpiration, soil moisture, landscape water yield or groundwater levels? *– Sections 4, 5 and 7 of the regional chapters*
7. How do seasonal inflows to, and outflows from, nationally significant wetlands vary from year to year and are they changing? *– Section 5 of the regional chapters with wetland data available*
8. What seasonal to decadal patterns and trends are evident in water storage inflows and volumes, and in groundwater levels, particularly in relation to rainfall? *– Sections 5, 6 and 7 of the regional chapters*
9. Where does the water for cities and irrigation areas come from and is this changing? *– Sections 6 and 7 of the regional chapters*
10. How does water use in cities and irrigation areas vary from year to year, particularly in relation to water availability? *– Sections 6 and 7 of the regional chapters*

1.4 Assessment approach

This section outlines the techniques used to produce the 2010 Assessment and provides context to the data and information presented in the following chapters. Further detailed information about the methods used to derive and analyse water and climate data is provided in the Technical supplement.

1.4.1 Reporting units

The Australian Water Resources Assessment 2010 report is structured around 13 regions covering the Australian continent, based on drainage division boundaries (see Figure 1-1). Drainage divisions represent the catchments of major surface water drainage systems, generally comprising a number of river basins. In Australia, 12 drainage divisions were first defined in the 1960s by the Australian Water Resources Council and the boundaries were formally published in the 1990s (Hutchinson & Dowling 1991). They were recently modified by the Bureau of Meteorology and research partners at Geoscience Australia and the Australian National University using the most current data set for land surface topography. This dataset is described in the Geofabric Product Guide at: www.bom.gov.au/water/geofabric/documentation.shtml.

Drainage divisions provide a scientifically robust framework for assessing hydrological flows in the landscape while also allowing information to be presented and discussed in broadly identifiable regional and climatic contexts.

For the purposes of reporting in the 2010 Assessment, one drainage division, the South East Coast, was split into two regions to distinguish New South Wales coastal river basins from Victorian and south-eastern South Australian coastal river basins (Figure 1-1, 2a and 2b).

Within the reporting regions shown in Figure 1-1, various time-series analyses and reporting techniques were applied depending on the availability of data. Analysis and reporting units at the sub-regional level include hydrological units (surface catchments and groundwater aquifers), water management and planning areas, water supply systems and reference or monitoring sites or clusters of sites (e.g. stream gauges on tributaries flowing into a dam).

1.4.2 Reporting period

Data and information presented are generally for the 12 months from July 2009 to June 2010 and/or months and seasons therein. Time-series analyses were restricted to consideration of the past 30 years where data permits, in order to focus on variability and trends in recent decades.

1.4.3 Landscape water balances

For the first time in a national water resources assessment, insights into landscape water balances for each region in 2009–10 are provided in this report. This development supports the need for consistent information on water resources across the whole country on a continuing basis.

A landscape water balance has a number of standard variables:

- inflows (e.g. rainfall)
- outflows (e.g. evaporation, transpiration, run-off)
- change in storage (e.g. soil moisture).

These variables can be broken down further to explore detail with regards to run-off, infiltration, and recharge and discharge values.

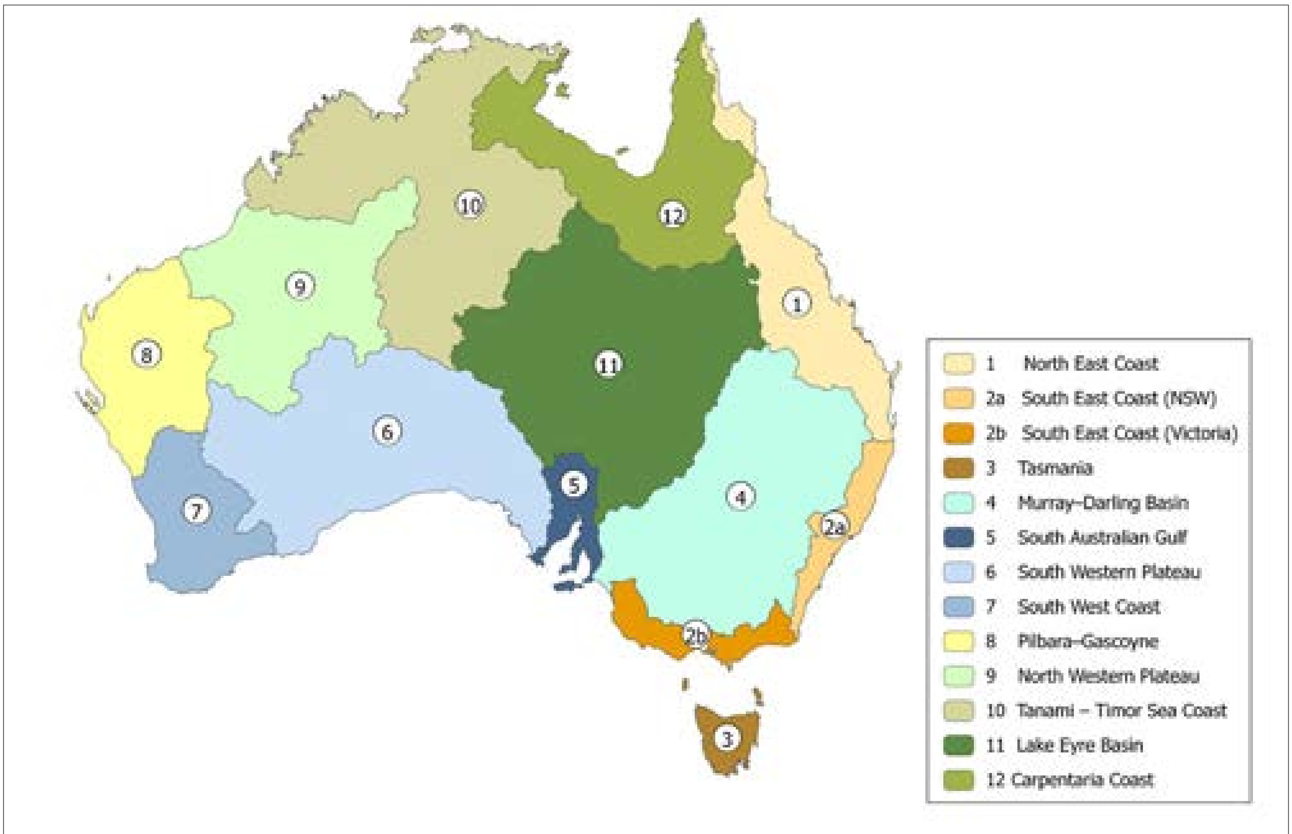


Figure 1-1. 2010 Assessment reporting regions and region numbers

1.4.3 Landscape water balance (continued)

The nature of a water balance depends primarily on three factors: (i) the water system boundary; (ii) the degree to which water flow and store components of the water balance are disaggregated into smaller components; and (iii) the selected timescale. The primary water flows and water stores that the Bureau aims to qualify or quantify in Australian water resources reporting are shown in Figure 1-2.

In the 2010 Assessment some of these components of regional water balances are reported for 2009–10, using outputs from water balance models combined with monitoring data on storage volumes in Australia's larger dams. The balances were not reconciled as not all water flows and stores in each region were modelled or measured.

Key terms used in this assessment:

- **Evapotranspiration** is the combination of evaporation from soil and transpiration from vegetation.
- **Landscape water yield** is the sum of surface run-off and groundwater discharge. This approximates streamflow at monthly to annual time scales in high rainfall areas and areas with steep slopes. In other areas it is an indication of potential water availability (especially groundwater).

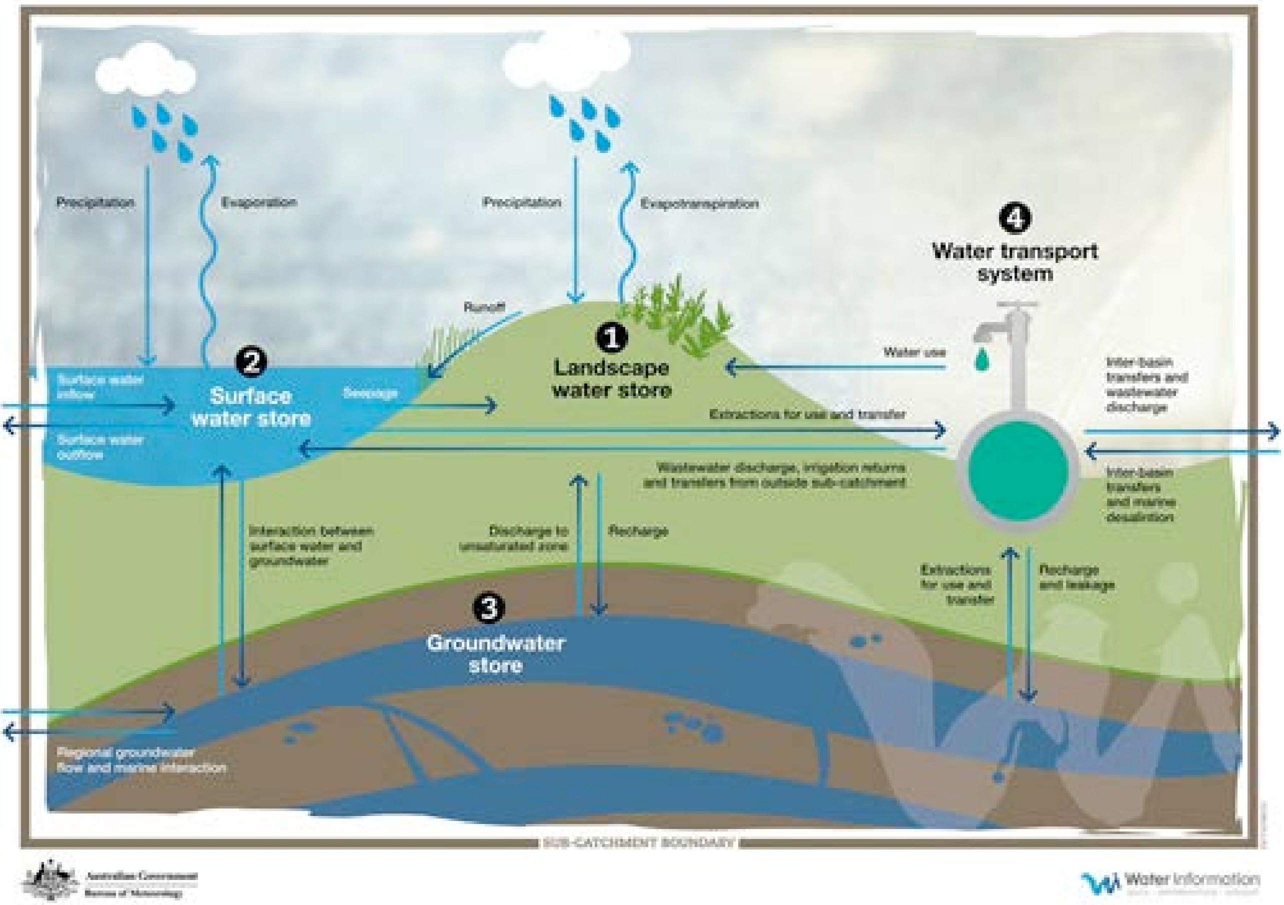


Figure 1-2. Primary water flows and water stores used in Australian water resources reporting by the Bureau

1.4.4 Mapped rainfall data

National daily and monthly rainfall grids were generated using rainfall station data from a network of persistent, high-quality sites (Figure 1-4) managed by the Bureau (Jones et al. 2009). The analysis method uses rainfall ratios (actual rainfall divided by monthly average) to incorporate the general influence of topography on prevailing weather systems, which is reflected in the monthly averages.

The grid resolution is constrained by the density of the network of rainfall stations across Australia, and is approximately 5 x 5 km (0.05 degree grid). The analysis provides an objective estimate of rainfall in each grid square and thus enables useful estimates of rainfall in areas with few rainfall stations.

Areas were excluded from the analysis where rainfall interpolation was assessed to be greater than 20 per cent unreliable (or less than 80 per cent reliable) for any period of the long-term record. Therefore, significant areas of central Australia as well as parts of northern Australia are not presented (classified as ‘No data’ areas) in the rainfall or landscape water balance modelling outputs. More details of these excluded areas are provided in the Technical supplement.

1.4.5 National landscape water balance modelling

Two water balance models (WaterDyn and AWRA-L) were used to generate estimates of landscape water flows and stores across the country in this report. Both models were run nationally on a 0.05 degree grid (approximately 5 x 5 km), consistent with the resolution of available climate data required as inputs to the models.

For this report, the WaterDyn model was used to derive estimates of monthly and annual landscape evapotranspiration. The WaterDyn model was also used to provide estimates of changes in the soil moisture store over 2009–10. Estimates of monthly and annual landscape water yield for each grid cell were produced by taking the average of surface run-off and groundwater discharge estimates from the AWRA-L and WaterDyn models. Validation studies against streamflow records by CSIRO and the Bureau indicated that, at the catchment scale, the average of landscape water yield outputs from the WaterDyn and AWRA-L models provided better estimates of monthly and annual streamflow (Bacon et al. 2010).

Both models are conceptually simple representations of the landscape water balance. They were deliberately kept simple so as to facilitate parameterisation at continental scale and provide a good level of computational efficiency. The equations used to represent water flow processes are the simplest that can be expected to lead to a reasonable water balance. They were directly derived from observations, or were selected through comparison against observations.

The assumptions, limitations and uncertainty inherent in these modelling approaches means discrepancies between modelled flows or storages and the actual values may occur. Both models do not adequately deal with the lateral transfer of water between grid cells and ignore some real world processes such as surface ponding. The input data for the models are also limited as climatic variables are not measured without error and are not measured everywhere. Therefore, the modelled results are best viewed in a relative sense as general patterns and changes of landscape water flows and storage over time and space. Despite these limitations, the models do provide a reasonable representation of the dominant water movement processes and produce plausible and useful spatial and temporal patterns of water as it occurs in the landscape.

Figure 1-3 is a schematic representation of the component (inputs, stores, flows and outputs) of the national water balance models used to derive estimates of evapotranspiration, soil moisture and landscape water yield presented in this report. Each model is described briefly in separate sub-sections and more information is also provided in the Technical supplement.

WaterDyn

A national landscape water balance model known as WaterDyn was developed and tested over the past six years by the CSIRO (Raupach et al. 2009). WaterDyn models the terrestrial water balance as a grid of conceptual soil columns and runs on a daily time-step. Each grid cell contains an upper and lower soil moisture store, with soil storage capacities of each layer defined by the Australian Soil Resource Information System mapping (Australian Soil Resource Information System, ASRIS 2011). There is no lateral flow of water between grid cells.

The WaterDyn model uses the following principles:

- rainfall, solar radiation and minimum and maximum temperature are external inputs
- transpiration, made up of contributions from each soil layer, is defined as the lesser of energy-limited and water-limited rates of transpiration by plants
- soil evaporation is the product of an upper-limit value (Priestley-Taylor evaporation), the relative water content in the upper soil layer raised to a power (a model parameter) and the fraction of bare soil
- surface run-off is given by a step function: all rainfall runs off when the upper layer soil is saturated, and there is no run-off otherwise
- leaching or drainage downward out of each soil layer is given by the product of saturated hydraulic conductivity and a power of the relative water content in that layer.

Deep drainage is used as an approximation of groundwater discharge in determining the landscape water yield.

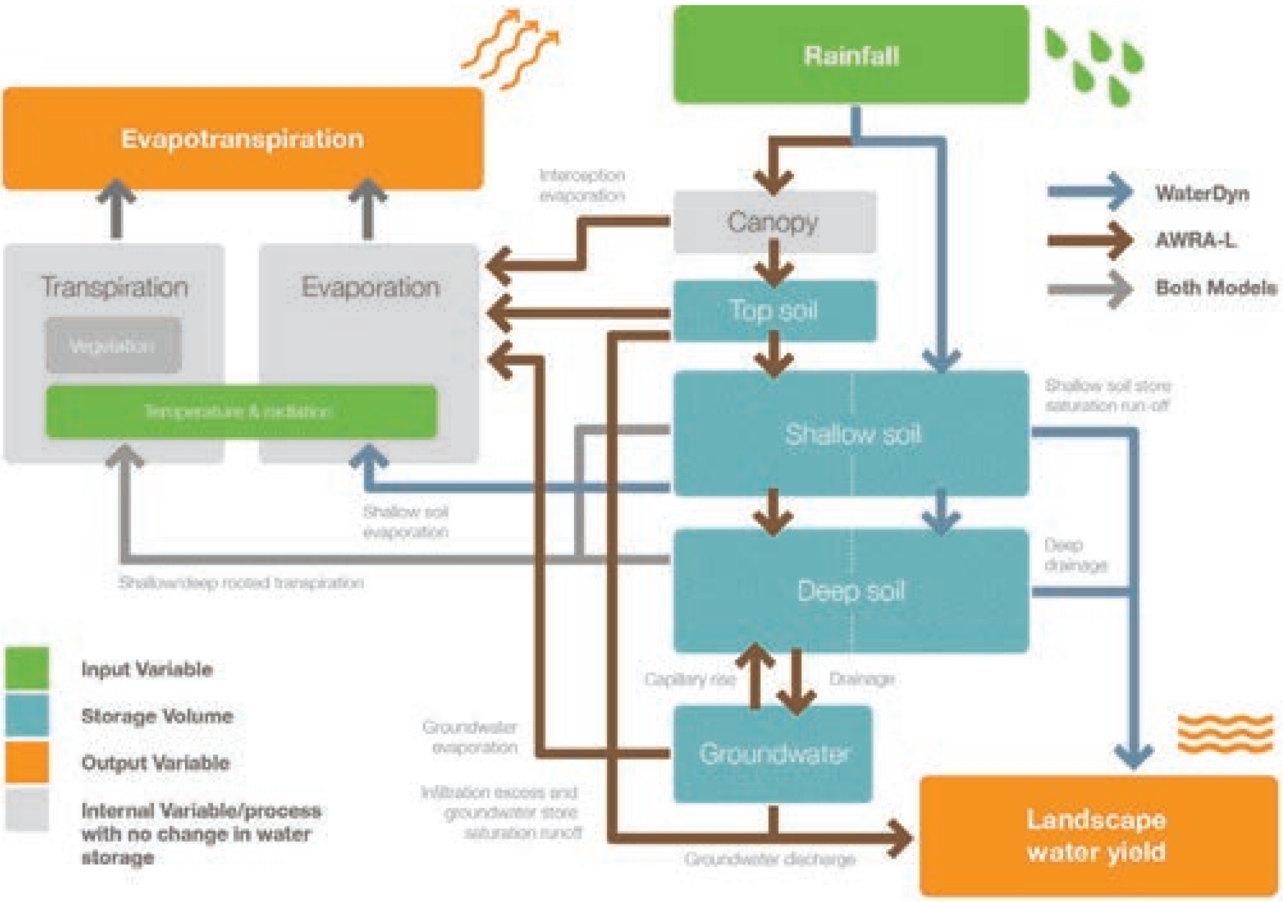


Figure 1-3. Schematic representation of inputs, outputs, flows and stores in the two landscape water balance models used in the 2010 Assessment

1.4.5 National landscape water balance modelling (continued)

AWRA-L

More recently, development of an Australian Water Resources Assessment System (AWRA-System) is also being led by researchers at CSIRO. The purpose of the AWRA-System is to provide up-to-date, credible, accurate and relevant information about the history, present state and future trajectory of the water balance in Australia to inform water resources management policy.

Within the AWRA-System, a landscape water balance model (AWRA-L) (Van Dijk 2010) that simulates water stores and flows in the vegetation, soil and local catchment groundwater systems was developed. AWRA-L uses lumped models of catchment water balance and vegetation ecohydrology and phenology. Like WaterDyn, AWRA-L is a national, distributed model and runs at a daily time-step.

AWRA-L describes water stores and fluxes on the landscape based on the following principles:

- Net rainfall is described after accounting for interception and evaporation losses.
- Run-off occurs from the surface top soil through the saturation or infiltration excess processes.
- Soil moisture storage and fluxes are described in three soil layers: top soil, shallow soil and deep soil. Infiltration to the surface top soil is drained to the deeper soil layers where root water uptake occurs.
- Groundwater balance typically comprises drainage from the deep soil layer, capillary upward flow, discharge into streams and change in storage.

1.4.6 Percentiles, deciles and anomalies

National rainfall and landscape water balance analysis outputs are presented in the form of monthly, seasonal and annual totals for 2009–10 and their decile rankings against long-term records. Percentiles and deciles denote the position of the reporting period observations or water balance term estimates in comparison to all values in the record. They provide a clear indication of above or below average values at a location. Box 1-1 describes the relationship between deciles, percentiles and decile ranges.

The advantage of presenting percentiles and deciles in addition to absolute values is that a term may vary considerably at different locations due to climate and landscape characteristics; however, percentiles and deciles express this variability relative to the long-term at a particular location.

Calculation of percentiles, deciles, extreme values and variability in climate datasets typically use all years of record to best describe extremes in these datasets. For example, to calculate the 'wettest month on record', data from all years in the record are required. However, limitations in the temporal and spatial extent and quality of data across the record also have a bearing on the most appropriate period to use for analyses. With this in mind, the 99-year period from July 1911 to June 2010 was used in this report to calculate deciles for rainfall and modelled landscape water balance outputs.

BOX 1-1: DECILES AND PERCENTILES

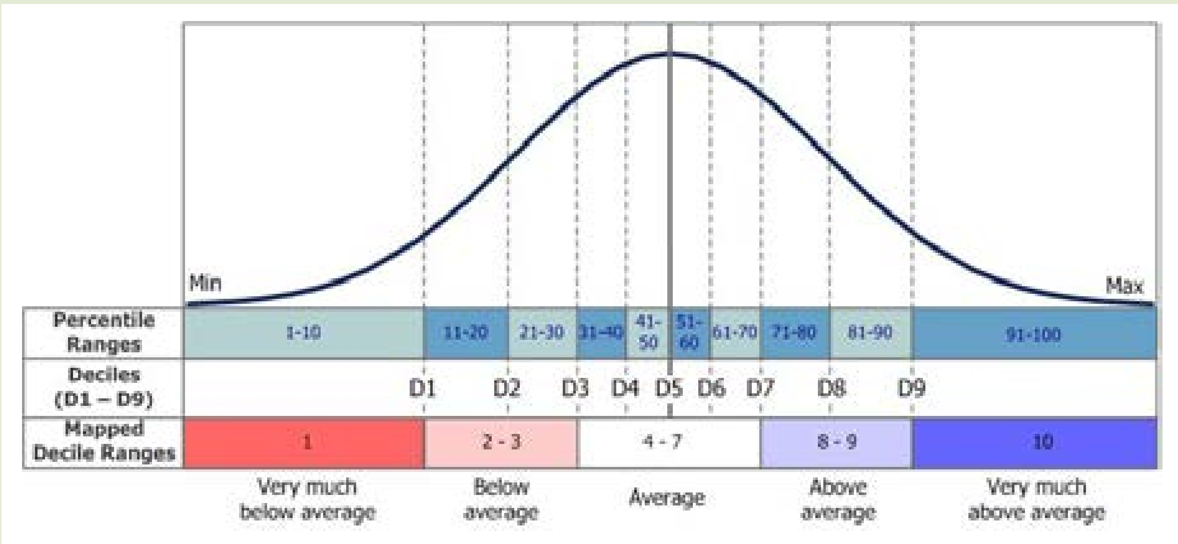
Deciles and percentiles are forms of descriptive statistics widely used in physical sciences to provide an easily interpretable and standardised summary of the position, or scale, of a value, measurement or observation relative to the full distribution of the data set.

A decile is one of the nine values that divide a ranked dataset into ten groups with equal frequencies, so that each part represents a tenth of the data set. Percentiles split the data into 100 equal parts.

If the graph presented in the figure below is assumed to represent the ordered distribution of a long time-series of observations (e.g. annual rainfall totals) then:

- Decile 1 (D1) is the highest value of the first (lowest) grouping; therefore in ten per cent of the years the annual rainfall total did not exceed the D1 value. This is equivalent to the 10th percentile value.
- Decile 9 (D9) is the highest value of the ninth (highest) grouping; therefore in ten per cent of the years the annual rainfall total exceeded the D9 value. This is equivalent to the 90th percentile value.
- The median, or decile 5 (D5) is that value which marks the level dividing the ordered data set in half, i.e. the midpoint of the ordered annual rainfall totals. This median value is equivalent to the 50th percentile value.

The example also illustrates the classification of decile ranges used in this report to describe values relative to their average range, i.e. within the 'average' range, 'above/below average' or 'very much above/below average'. For example, 'very much above average' is the classification of values that exceed decile 9 (D9) and are in decile range 10. These decile ranges are described in more detail in Section 1.6



An assumed distribution of ordered observations illustrating the relationship between percentiles and deciles and how these relate to the descriptive classifications used in this report (decile ranges).

1.4.7 Flood peak analyses

National and regional flood peak analyses for 2009–10 are presented. The Bureau definitions of 'minor', 'moderate' and 'major' flooding are used. These were adopted on a state-by-state basis, in consultation with stakeholders for key river gauges (indicated in Figure 1-4 bottom) around Australia based on impacts and risks to infrastructure and properties.

A national analysis in Chapter 2 of this report shows locations where peak river heights exceeded the major threshold during 2009–10. Tables are also provided in the regional chapters presenting peak weekly heights for key flood gauging sites within each region during 2009–10.

1.4.8 Regional time-series analyses

Climate and landscape water balance analysis for regional assessments (chapters 3–15) is the same as that used at the national scale. However, spatial trend analyses are also included at the regional scale. Trend values were determined from a straight line fit using ordinary least square regression. Trend maps enable comparisons of how rainfall and other water balance terms have changed in different regions of Australia over time.

These trend maps need to be interpreted with caution and report users are advised to interpret the trend maps in the context of the accompanying time-series. For example, a calculated trend could be due to a relatively rapid 'step' change, with the remainder of the series being fairly flat. Spatial surfaces such as rainfall are based on point observations and, therefore, the removal or addition of a station in the network can affect the temporal analysis (particularly if it is located in an area with significant topographical influence) and may introduce an artificial 'step change'. The trend maps aim to provide a very simple spatial assessment of the general direction and, to a limited degree, the scale or magnitude of the fitted linear trends in the climate and landscape water balance time-series. The significance of estimated trends is often low and is not presented in the regional trend analyses. The trend estimates are constrained by the assumptions associated with the statistical analysis, which are described in the Technical supplement.

The trend map values should not be used to imply future rates or directions of change. Due to the complex interactions between natural and human drivers of climate change, climate variability and catchment hydrology, the climate and hydrology at any location are always changing. Future rates of change will depend on how these drivers interact in the future, which will not necessarily be the same as in the past.

1.4.9 Site-based anomaly and time-series analyses

Water data from a wide range of organisations across Australia are currently being received by the Bureau under the Commonwealth *Water Act 2007* and associated Water Regulations 2008.

This includes data and information on:

- climate (including rainfall)
- streamflow
- surface water storage levels and volumes
- groundwater levels
- agricultural water supply and use
- water allocations and trade
- urban water supply and use
- urban water restrictions
- water quality.

At the time of publication of this report, only a subset of data in these categories had been stored and checked by the Bureau, allowing it to be available for analysis and presentation in this report. This subset included datasets on climate, streamflow and surface water storage, and selected datasets related to groundwater, urban water and irrigation water. Some data for urban water restrictions were also available.

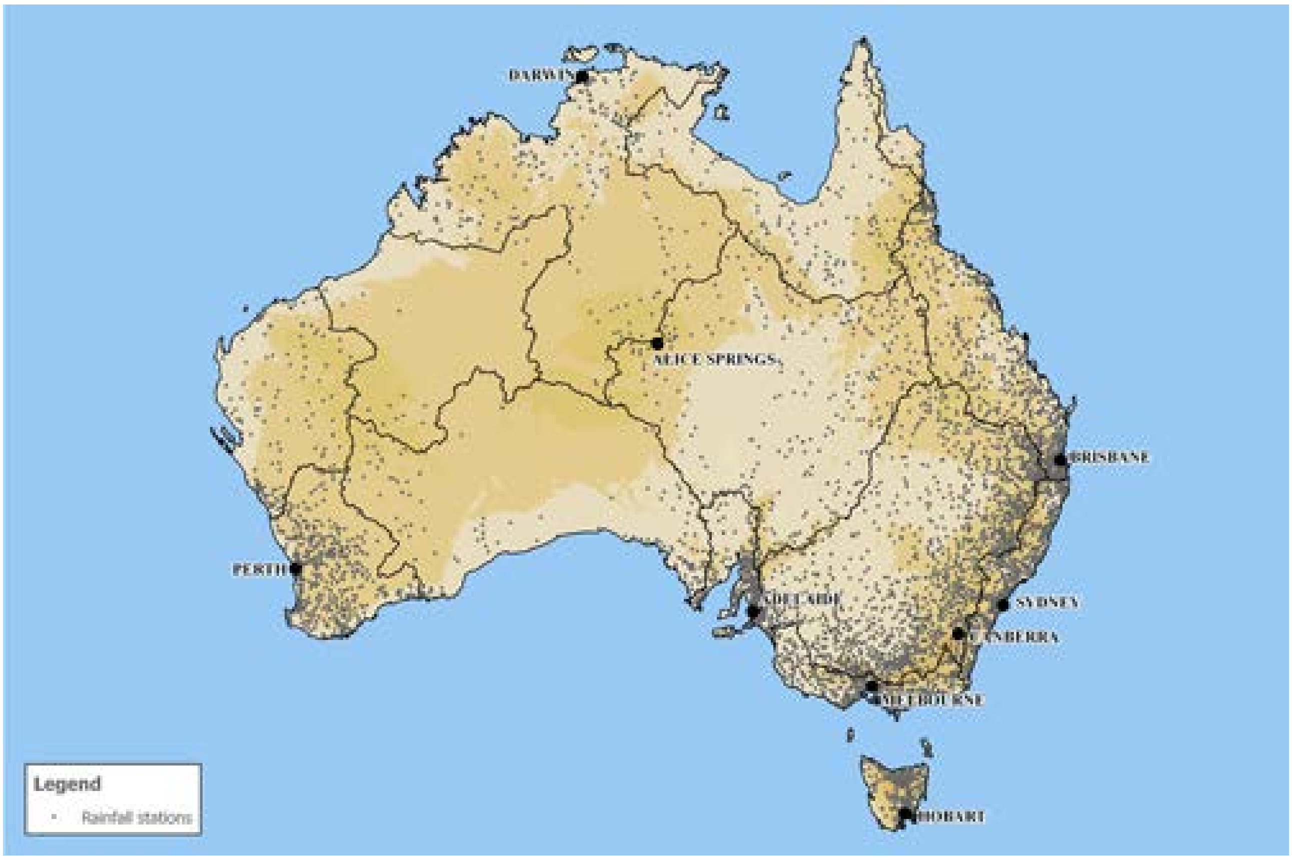
The location of monitoring sites for rainfall, streamflow and flood heights used in this report are shown in Figure 1-4. Locations of groundwater bores and water storages for which data are also presented are shown in Figure 1-5.

Where possible, reference sites, stations and datasets were identified to help present trends and variability in water availability and use around the country during 2009–10 and the past three decades.

Seasonal and annual discharges at selected river gauges for 2009–10 are compared to the deciles of the 30-year datasets at these gauges.

At river gauges important for describing wetland inflows or outflows, decile ranges for each month were determined based on the monthly flows over 30 years. Results for low, median and high monthly flow percentiles, based on daily flow values within a five-year moving window, are also presented.

Groundwater level and electrical conductivity readings indicating salinity over the past 20 years were plotted for monitoring bores in selected groundwater management units in regions where suitable data was available to the Bureau.



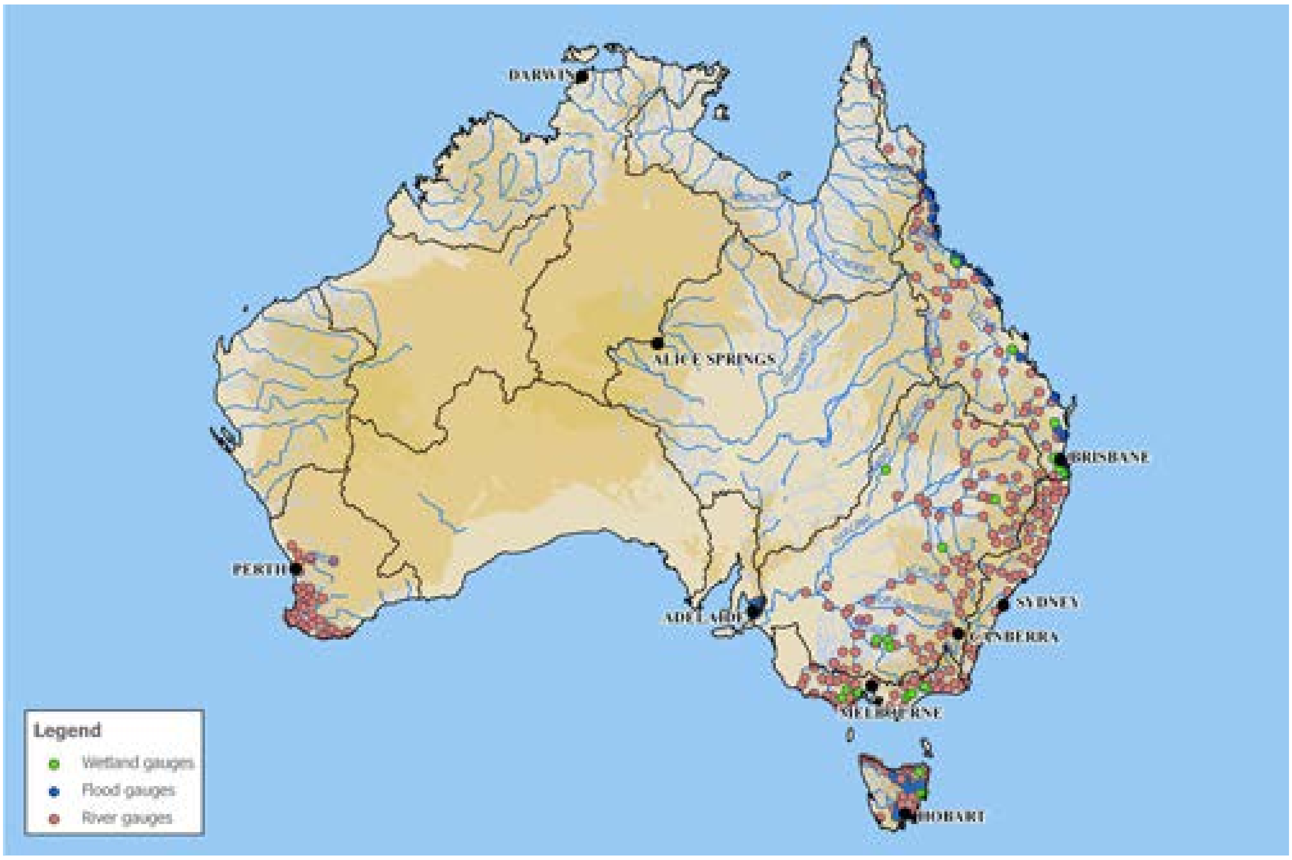
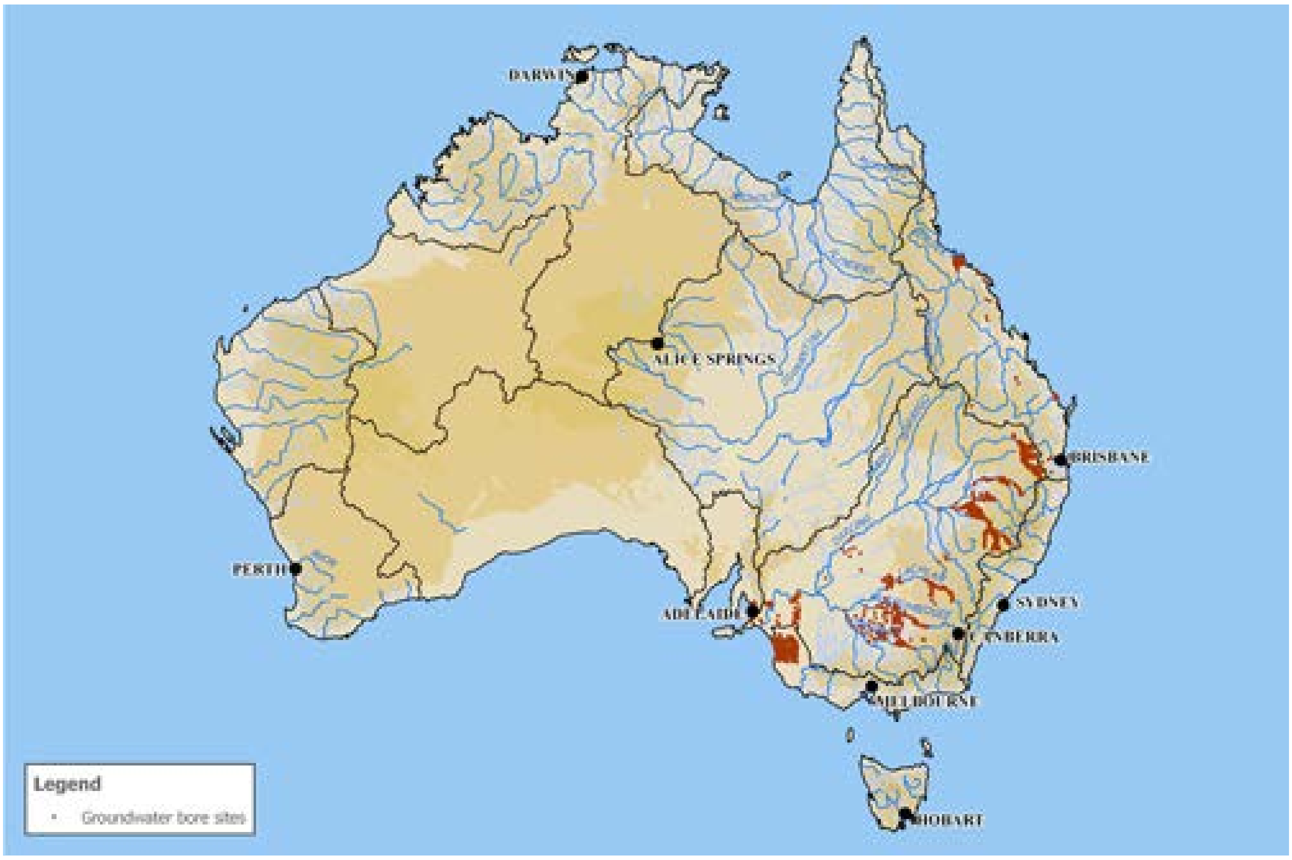


Figure 1-4. Location of rainfall stations (top) and stream gauges (bottom) selected for analysis in this report



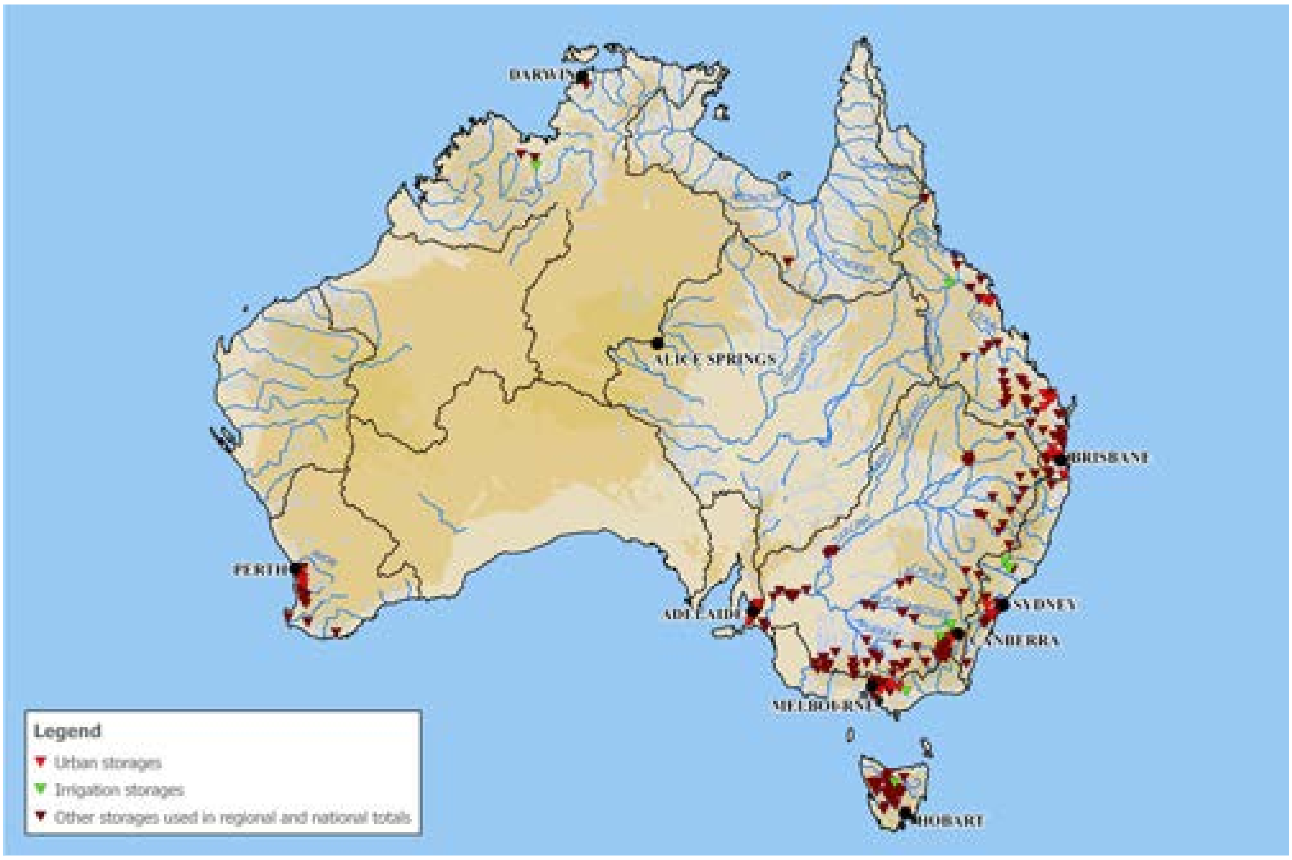


Figure 1-5. Location of groundwater bores (top) and surface water storages (bottom) selected for analysis in this report

1.5 Quality control and review – who was involved?

A project Steering Committee within the Bureau provided oversight of the production, review and publication of the Australian Water Resources Assessment 2010.

The implementation plan for producing the 2010 Assessment was developed in consultation with a number of organisations and based on a review of existing jurisdictional water reporting products.

A scientific review group comprising non-Bureau water domain and regional experts reviewed the report iteratively as it was developed.

These reviewers were requested to examine the report to improve its quality and credibility by evaluating:

- the suitability of data employed
- the validity and robustness of the methods employed
- the appropriateness and presentation of figures and tables
- the extent to which information is accurate, clear, complete and unbiased
- whether information is presented within a proper context
- the clarity of interpretations, conclusions and findings
- the extent to which conclusions are unambiguous and supported by results
- whether any important issues or data were omitted
- the overall quality, style and presentation of the material.

In addition, CSIRO provided technical expertise throughout the report development process specifically with regard to identifying appropriate report content and the modelling of landscape water flows. State and Territory water agencies, representatives of academia and professional services organisations provided water industry guidance. A general feedback group comprising likely users of the report was established to provide high-level advice on both the content and utility of the 2010 Assessment.

Overall, comments and suggestions were received from over 25 organisational stakeholders in the scientific community, State and Territory water agencies and from the general feedback group.

The communication and adoption strategy developed by the Bureau requires the reporting process be reviewed after the publication of each report. Comments and suggestions from stakeholders that have not been able to be implemented in this report will be considered as part of this evaluation process for future water information products and water resources assessments.

1.6 Terminology

Terminology used regarding landscape water balance results and observed time-series is defined as follows:

Very much above average	Observations or values are among the highest ten per cent of observations or values for the period in question (10th decile range).
Above average	Observations or values lie above the highest 30 per cent of observations or values (70th percentile) but below the highest 10 per cent (90th percentile) for the period in question (8th and 9th decile ranges).
Average	Observations or values lie between the 30th percentile and the 70th percentile for the period in question (4th to 7th decile ranges).
Below average	Observations or values lie above the lowest ten per cent of observations or values (10th percentile) but below the lowest 30 per cent (30th percentile) for the period in question (2nd and 3rd decile ranges).
Very much below average	Observations or values are among the lowest ten per cent of observations or values for the period in question (1st decile range).

1.7 Future reports

The Bureau's Australian Water Resource Assessments will develop over time as the availability and quality of data and modelling systems improve and as analytical and reporting methods are automated. Future reports will benefit from greater access to a range of water information stored and delivered through the Bureau's Australian Water Resources Information System, currently in development.

Reference and monitoring sites will be added as the coverage of the report is expanded and as additional information becomes available. In particular, it is anticipated that analysis and reporting of groundwater, water quality and water allocation, use and trading will be included or be increasingly evident in future reports as data availability and quality improve.

In addition, further enhancements in modelling and analytical methods for future reports will be achieved through research undertaken collaboratively by the CSIRO and the Bureau as part of the Water Information Research and Development Alliance. This will feature improvements in modelled data through the coupling of a landscape water balance model with river and groundwater models. It will also incorporate satellite data in the calibration and constraint of model processes and outputs. Further assessment of trend analysis techniques and methods for estimating unmetered water use may also be considered.

The implications of any changes made to methods used in previous reports will be clearly outlined in the Technical supplements to future reports.

2. National overview

2.1 Introduction

This chapter of the Australian Water Resources Assessment 2010 presents an assessment of climatic conditions and water flows and stores in the Australian landscape in 2009–10 at the national scale and discusses their variation between the regions (see Figure 2-1). The assessment contains national landscape water balance model outputs for the year including: rainfall, evapotranspiration, landscape water yield, change in soil moisture and consideration of changes in surface water storage in each region.

The important drivers of climatic conditions in Australia are examined and their impact on rainfall over the year evaluated. Information on nationally significant weather and water events experienced in 2009–10 focuses on abnormally heavy rainfall and flood events.

2.1.1 Australian landscape water balance modelling

Long-term average annual rainfall across Australia varies from less than 300 mm per year in the majority of central Australia to over 4,000 mm per year in parts of far northern Queensland.

Of this rainfall, about 85–95 per cent evaporates directly or is transpired by plants into the atmosphere. These two processes are collectively referred to as evapotranspiration. The remaining water finds its way into streams and other surface water features like dams and wetlands, or drains below the root zone into groundwater aquifers, which may subsequently discharge to surface water features.

The proportion of rainfall used by plants depends on soil type and depth, plant type and condition and the stage of plant growth. Annual crops and pasture use less water than perennial vegetation, such as trees, primarily because of their shorter growing seasons and shallower root systems.

The processes mentioned above are conceptually represented in the landscape water balance models that were used in this report (see Chapter 1 for a description of the AWRA-L and WaterDyn models). A conceptual representation means that simplifications and assumptions were used so that the models only estimate the dominant water balance components.

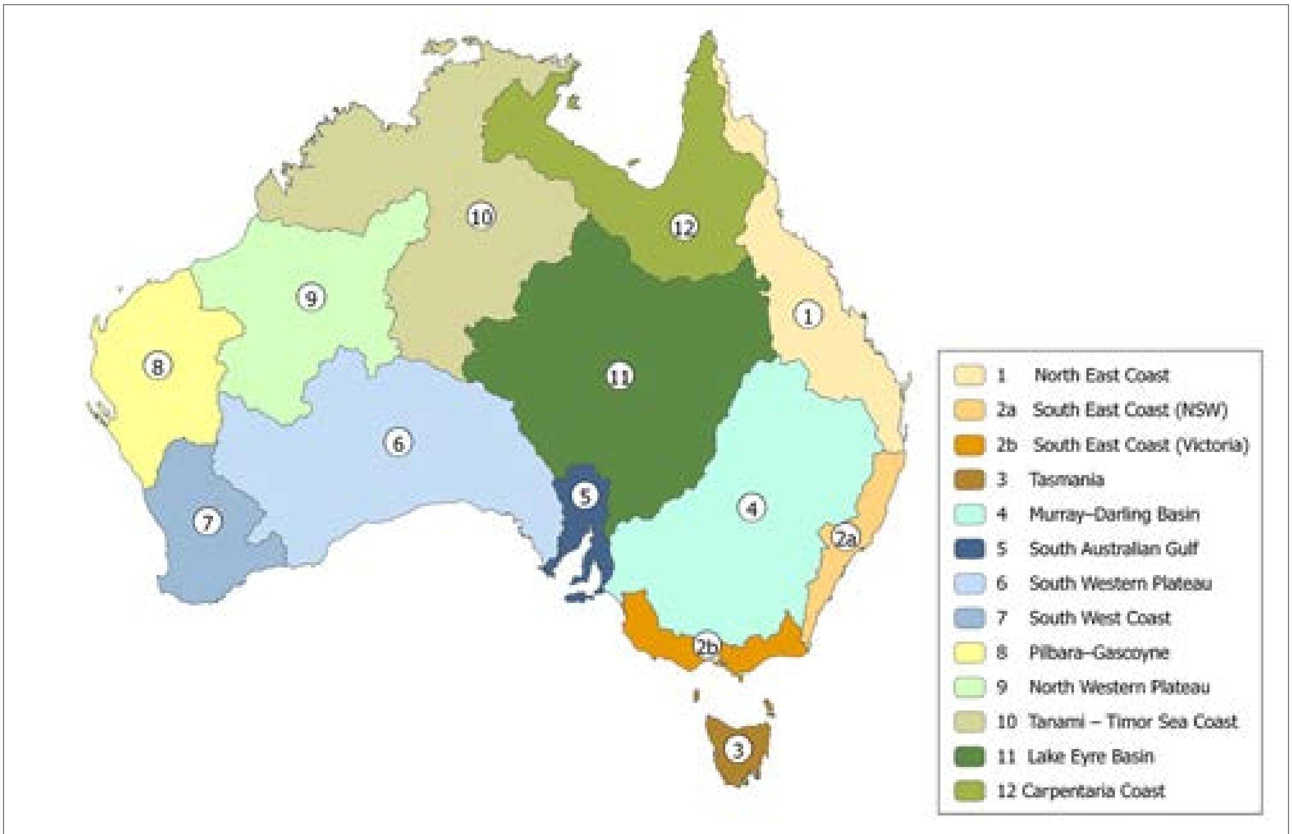


Figure 2-1. 2010 Assessment reporting regions

2.2 Key findings

The Australian climatic condition in 2009–10 was characterised by an El Niño event in the Pacific Ocean, which broke down in early 2010 and was followed by a rapid switch to La Niña conditions[1]. The development of this significant La Niña event heralded the beginning of at least 12 months of very much above average rainfall in most parts of Australia. For more information see: www.bom.gov.au/climate/annual_sum/annsum.shtml.

It was relatively wet in the centre and north of the country from December 2009 onwards, resulting in above average evapotranspiration and landscape water yield for the year. Soil moisture stores increased for all of the North East Coast, Carpentaria Coast, Tanami – Timor Sea Coast, Lake Eyre Basin, Murray–Darling Basin and South Australian Gulf regions. However, total surface water storage in the Carpentaria Coast and Tanami – Timor Sea Coast regions decreased, which was largely due to significant releases in the few major storages in these regions.

In contrast to the centre and north of the country, 2009–10 was relatively dry in the west, particularly in the Pilbara–Gascoyne and South West Coast regions, where rainfall, evapotranspiration and landscape water yield were below average. This was also reflected in a decrease in soil moisture for these regions as well as for the North and South Western Plateau regions. Despite this, the total accessible volume of water held in surface water storages in the South West Coast region increased as a result of water restrictions and a number of significant coastal rainfall and run-off events in July, September and November 2009.

Rainfall conditions were around average in the South East Coast (Victoria), South Western Plateau, Tasmania and North Western Plateau regions.

Key information regarding the climatic conditions and water outcomes for Australia over 2009–10 is provided in Table 2-1. Some highlights were:

- Australian rainfall in 2009–10 was 13 per cent above the long-term (July 1911 to June 2010) average; evapotranspiration was four per cent above the long-term average and landscape water yield was 40 per cent above the long-term average.
- Deep soil moisture stores increased in the northeast and southeast of the country, but decreased in the west.
- The total water stored in major reservoirs in Australia increased from 46 per cent to 52 per cent of accessible volume, driven primarily by increases in the Murray–Darling Basin, Tasmania and North East Coast regions.
- Urban water use in the urban centres considered in this report decreased from 1,719 GL in 2005–06 to 1,497 GL in 2009–10. Residential water consumption accounted for 68 per cent of urban use in 2009–10.
- Annual agricultural irrigation water use in Australia in 2009–10 was approximately 6,600 GL, up one per cent on 2008–09.
- Widespread heavy rainfall was experienced in the Northern Territory and Queensland between 22 February and 3 March 2010 and caused significant flooding in the Lake Eyre Basin region, in the south of the North East Coast region and in the far north of the Murray–Darling Basin region.

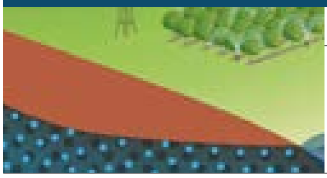
1. See Box 2-1 for explanations of El Niño and La Niña

Table 2-1. Key information on the water flows, stores, use and climatic condition in Australia for 2009–10[2]

Landscape water balance in 2009–10

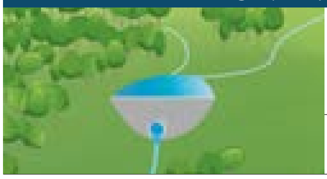
	Australian average	Difference from long-term mean	Rank (out of 99)*
	536 mm	+13%	80
	415 mm	+4%	71
	96 mm	+40%	86

Soil moisture in 2009–10



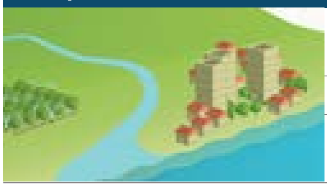
Regions that became drier	Regions that became wetter
North Western Plateau, Pilbara–Gascoyne, South West Coast, South Western Plateau, South East Coast (NSW) and Tasmania	Carpentaria Coast, Lake Eyre Basin, Murray–Darling Basin, North East Coast, South Australian Gulf, South East Coast (Victoria) and Tanami – Timor Sea Coast

Surface water storage (comprising approximately 94% of Australia's total surface water storage)



Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
78,500 GL	36,000 GL	46%	40,500 GL	52%	+6%

Comparison of water use between 2008–09 and 2009–10



Urban water use		Agricultural irrigation water use (natural resource management regions)	
Volume	Change	Volume	Change
1,568 GL in 2008–09 1,497 GL in 2009–10	-4.5%	6,530 GL in 2008–09 6,600 GL in 2009–10	+1%

Drivers of climatic condition in 2009–10

El Niño-Southern Oscillation	Central and eastern equatorial Pacific Ocean was warm (El Niño conditions) until February 2010 then cooled to La Niña conditions by April 2010. As a result the Southern Oscillation Index was negative until March 2010 then strongly positive
Indian Ocean Dipole	Positive during 2009 and negative during 2010

Major rainfall events in 2009–10

Timing	Location	Characteristics
22 February – 3 March 2010	Northern Territory, Queensland and far northern New South Wales	Monsoon low triggered very widespread heavy rainfall: 28 February – wettest day on record for the Northern Territory, 2 March – wettest day on record for Queensland

Major flood events in 2009–10

Timing	Location	Characteristics
February– March 2010	Gulf of Carpentaria, Lake Eyre Basin, North East Coast, Murray–Darling Basin	Short but large flood peaks in the major tributaries of the Darling River, with an estimate of only 15% reaching Menindee Lakes in western New South Wales

*A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

2.2 Key findings (continued)

Table 2-2 gives an overview of the region totals and rankings for the three water balance components (rainfall, evapotranspiration and landscape water yield) in comparison to the 99-year record. The values on the left side of the table show how the regions relate to each other in absolute terms for the year 2009–10. Values to the right show how 2009–10 compares to the historical model data for the 99 years of record.

High landscape water yield was associated with high rainfall in all but two regions. In the North Western Plateau region the rainfall was ranked close to median and evapotranspiration was higher than median, but still enough water was available for the generation of relatively high landscape water yield. The South East Coast (Victoria) region shows the opposite, where rainfall was ranked higher than median and evapotranspiration was lower than median, but landscape water yield was low. These discrepancies are explained by the intra-annual temporal and spatial variability of these flows and the soil moisture conditions at the start of the year (this is further discussed in the regional chapters).

Table 2-2. Region average rainfall, evapotranspiration and landscape water yield in 2009–10 by region (left), and 2009–10 ranking in the 1911–2010 record (right). The highest (blue) and lowest (red) values in each component (column) are highlighted

	Region average in 2009–10 (mm)			Rank (out of 99)*		
Region	Rainfall	Evapo-transpiration	Landscape water yield	Rainfall	Evapo-transpiration	Landscape water yield
North East Coast	866	675	172	64	42	73
South East Coast (NSW)	913	**840**	140	39	55	53
South East Coast (Victoria)	773	603	59	69	33	**11**
Tasmania	**1,481**	631	**769**	69	53	74
Murray–Darling Basin	533	428	45	81	55	78
South Australian Gulf	367	291	24	85	78	66
South Western Plateau	220	222	**6**	48	55	29
South West Coast	346	373	24	11	**15**	20
Pilbara–Gascoyne	**132**	**195**	9	**5**	19	12
North Western Plateau	311	297	48	52	65	76
Tanami – Timor Sea Coast	775	602	157	82	76	85
Lake Eyre Basin	387	220	74	**92**	81	**96**
Carpentaria Coast	976	679	268	89	**82**	94

* Indicates the lowest annual result on record, 99 the highest on record

2.3 Landscape water flows in 2009–10

2.3.1 Rainfall

Australian rainfall was 13 per cent above average in 2009–10

Average Australian rainfall for 2009–10 was estimated to be 536 mm, which is 13 per cent above the estimated national long-term average of 473 mm (calculated from July 1911 to June 2010). The year was wetter than average throughout much of the country, with the Lake Eyre Basin and Carpentaria Coast regions receiving well above average rainfall (Figure 2-2). In contrast, conditions were relatively dry in parts of the southern South East Coast (NSW) and northeast Murray–Darling Basin regions. In Western Australia, the South West Coast and Pilbara–Gascoyne regions received well below average annual rainfall.

The 2009–10 year began with hot and dry conditions prevailing between July and October 2009, particularly in the east of the country (Figure 2-3 and Figure 2-4) with August being Australia's warmest on record. Very much below average rainfall totals were experienced over large areas of the North East Coast, Murray–Darling Basin and South East Coast (NSW) regions, consistent with the El Niño event which was in place during this time (see Section 2.9 for a description of the drivers of the climatic condition).

In contrast, the 2009 winter had very much above average rainfall in Tasmania, ranking as the fourth-wettest on record (46 per cent above average). Winter rainfall in 2009 equalled or exceeded seasonal averages over areas of the South Australia Gulf region and much of the western half of the South East Coast (Victoria) region.

The summer of 2009–10 was relatively wet for most of Australia, particularly in the east. In the north, relatively dry conditions over winter and spring in 2009 gave way to a wetter than average summer and autumn 2010 (Figure 2-3 and Figure 2-4). Conversely, the average rainfall conditions that prevailed across much of Western Australia during the second half of 2009 gave way to dry conditions at the start of 2010, particularly across the South West Coast and Pilbara–Gascoyne regions.

Widespread dry conditions in Western Australia in the first half of 2010 were associated with very much below average rainfall in much of northern Western Australia. This was combined with persistent and abnormally high pressure over southern Western Australia. Autumn 2010 was characterised by an unusual absence of westerly winds and a very low number of cold fronts passing over southern Western Australia. This deprived the region of its main rain producing mechanism. The extremely dry conditions continued and exacerbated a sequence of abnormally low rainfall that the southwest of Western Australia has experienced since the mid-1970s. Serious or severe water deficiencies became established over much of the South West Coast and Pilbara–Gascoyne regions by the end of 2009–10.

Autumn 2010 was generally warm and wetter than average in Australia. The most significant rainfall was in early March (see Section 2.10 on notable rain events) causing widespread flooding in inland southern Queensland and northern New South Wales (see Section 2.11 on major flood events). Rainfall continued through the season in many areas, giving parts of south-eastern Australia the first above average autumn rainfall since 2000 and first above average July to June rainfall in the Murray–Darling Basin since 2001. Very high rainfall totals occurred in April and May 2010 across the Carpentaria Coast and Tanami – Timor Sea Coast regions; typically the start of the dry season for these areas. June 2010 was subsequently relatively dry over most parts of the continent.

Current and historical daily, monthly, seasonal and annual rainfall maps and data are available at: www.bom.gov.au/jsp/awap

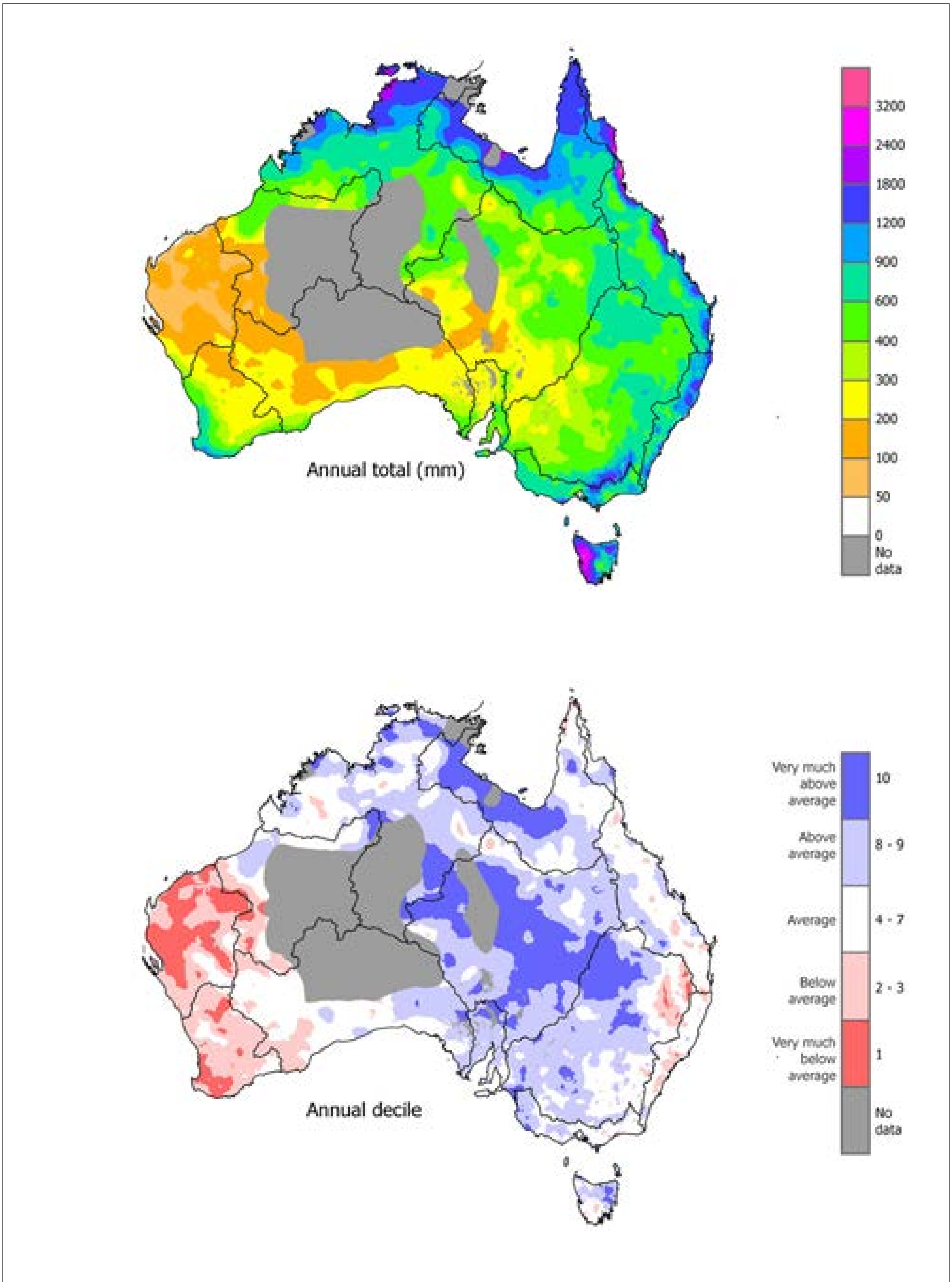


Figure 2-2. Annual total rainfall in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

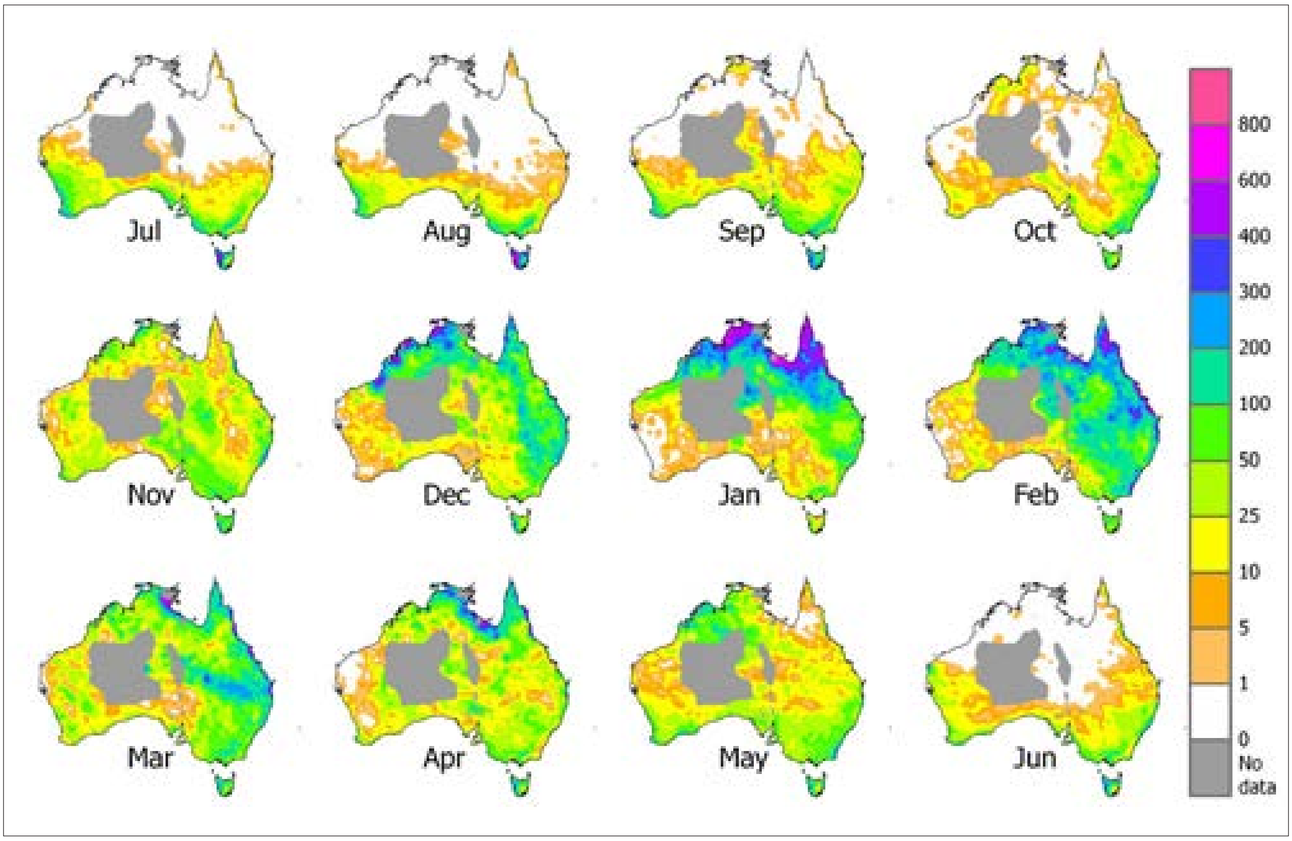


Figure 2-3. Monthly rainfall totals (mm) for 2009–10

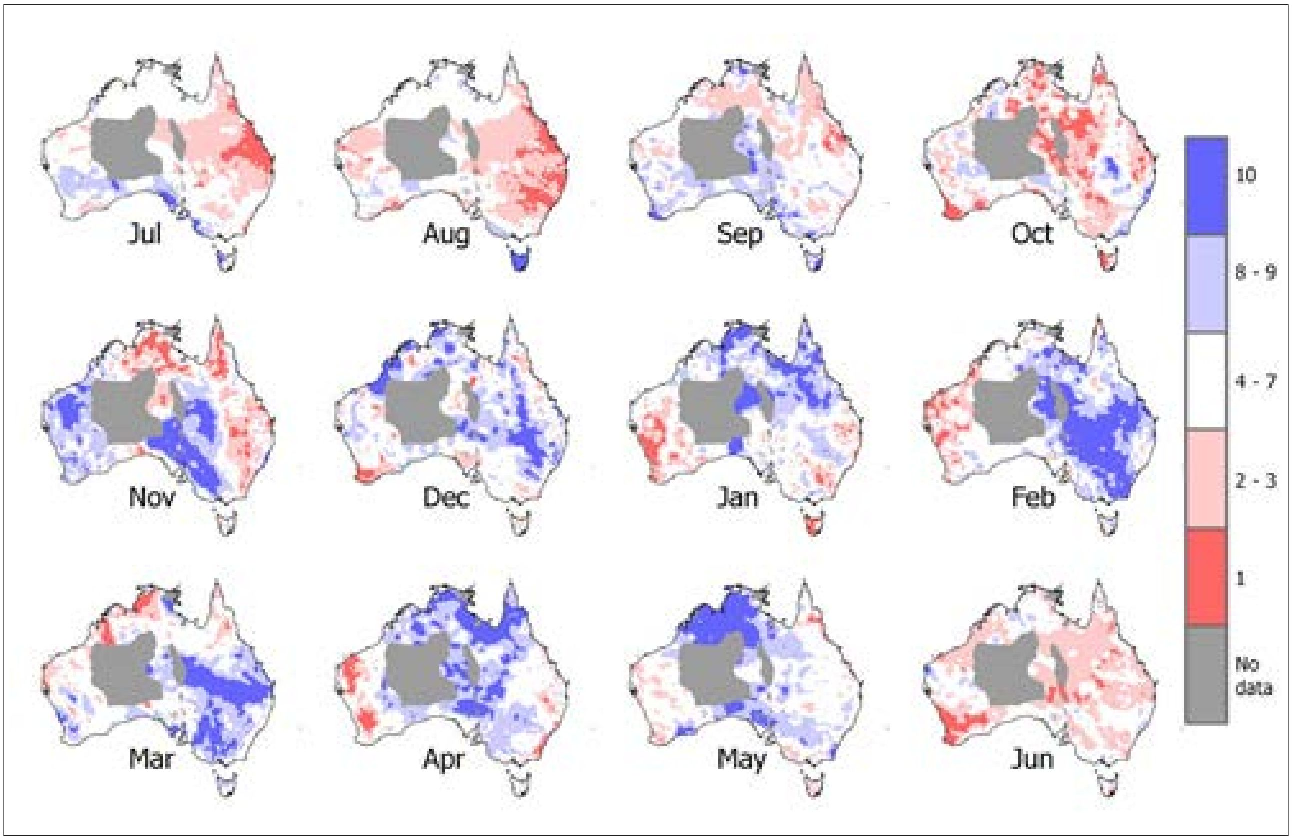


Figure 2-4. Monthly rainfall deciles for 2009–10 with respect to the 1911–2010 record

2.3.2 Evapotranspiration

Australian evapotranspiration was 4 per cent above average in 2009–10

Average Australian evapotranspiration for 2009–10 was estimated to be 415 mm, which is four per cent above the estimated national long-term (July 1911 to June 2010) average of 400 mm. Evapotranspiration for the year was generally higher than average across most inland areas, particularly in the Lake Eyre Basin region, as a result of above average rainfall. Below average levels of evapotranspiration occurred in the west and southwest of Western Australia (South West Coast and Pilbara–Gascoyne regions) and also across areas of the North East Coast, Murray–Darling Basin, South East Coast (Victoria) and Tasmania regions (Figure 2-5).

The above average Australian evapotranspiration for 2009–10 was due in particular to higher than average evapotranspiration in central Australia. Evapotranspiration across central Australia was well above average in both the Carpentaria Coast and Lake Eyre Basin regions. This was largely a consequence of heavy rainfall across northern and central Australia in the first four months of 2010, flooding large areas and filling lakes and wetlands (see Section 2.11).

Water flow from the land surface to the atmosphere via evapotranspiration can be limited by either available soil moisture or incident solar energy. In Australia evapotranspiration is mostly limited by available soil moisture therefore spatial patterns of evapotranspiration, both annual and seasonal, are generally closely related to patterns of rainfall (see Figure 2-3 and Figure 2-4). The most notable exceptions to this occur in winter in the south of the country, particularly in Tasmania, where evapotranspiration can often be energy limited.

Generally low rainfall across the south of the country during winter 2009 resulted in low evapotranspiration rates in these regions (Figure 2.6 and Figure 2.7). October 2009 saw above average evapotranspiration across much of Tasmania, western South East Coast (Victoria) and the South Australian Gulf following above average rainfall in these regions during the preceding months of August and September. Low rainfall over much of Queensland and New South Wales in winter and spring 2009 resulted in decreased evapotranspiration throughout spring, particularly in the south of the North East Coast region and the northeast of the Murray–Darling Basin.

Above average rainfall over the 2009–10 summer resulted in average or above average levels of evapotranspiration over much of the country except in Western Australia where levels were low in line with low rainfall conditions. Evapotranspiration in the north, east and centre of the country, especially across the Lake Eyre Basin and Murray–Darling Basin regions, reached very high levels during autumn and early winter as high rainfall continued. In the Western Australian regions of the Pilbara–Gascoyne and South West Coast, evapotranspiration levels remained relatively low over this period and were constrained to very much below average levels by June 2010. Below average early winter rainfall in the Tasmania and South East Coast (Victoria) regions also constrained evapotranspiration to below average levels towards the end of 2009–10.

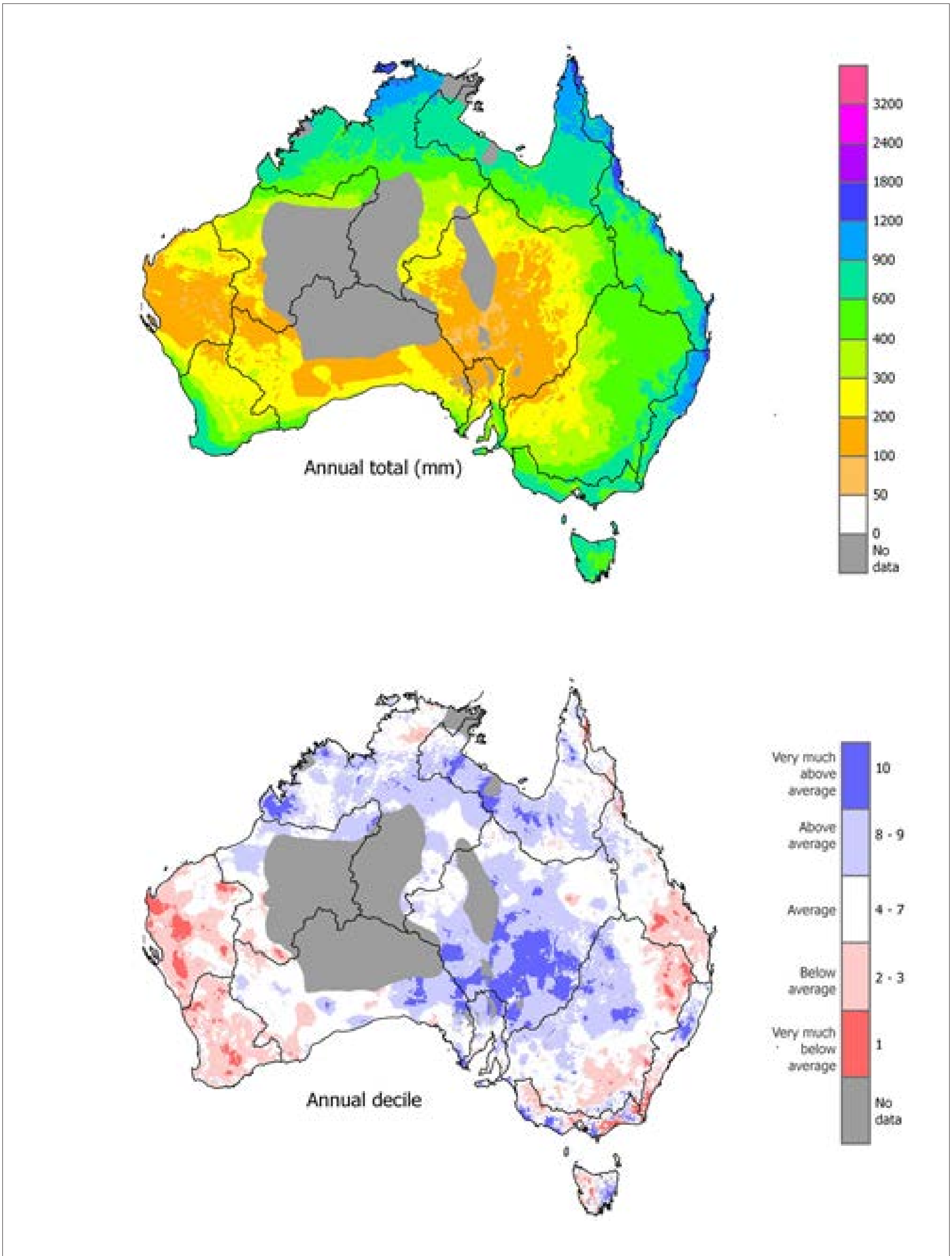


Figure 2-5. Modelled annual total evapotranspiration in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

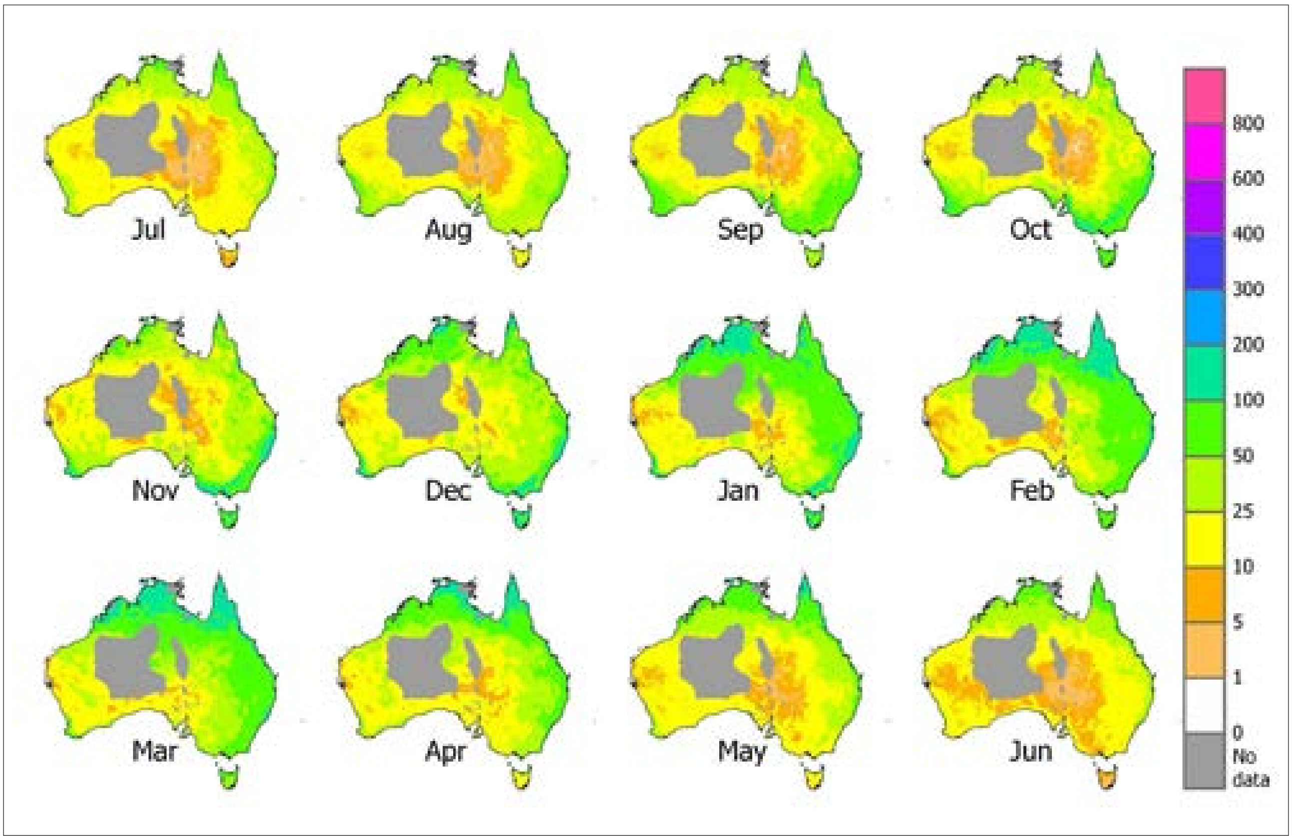


Figure 2-6. Modelled monthly evapotranspiration totals (mm) for 2009–10

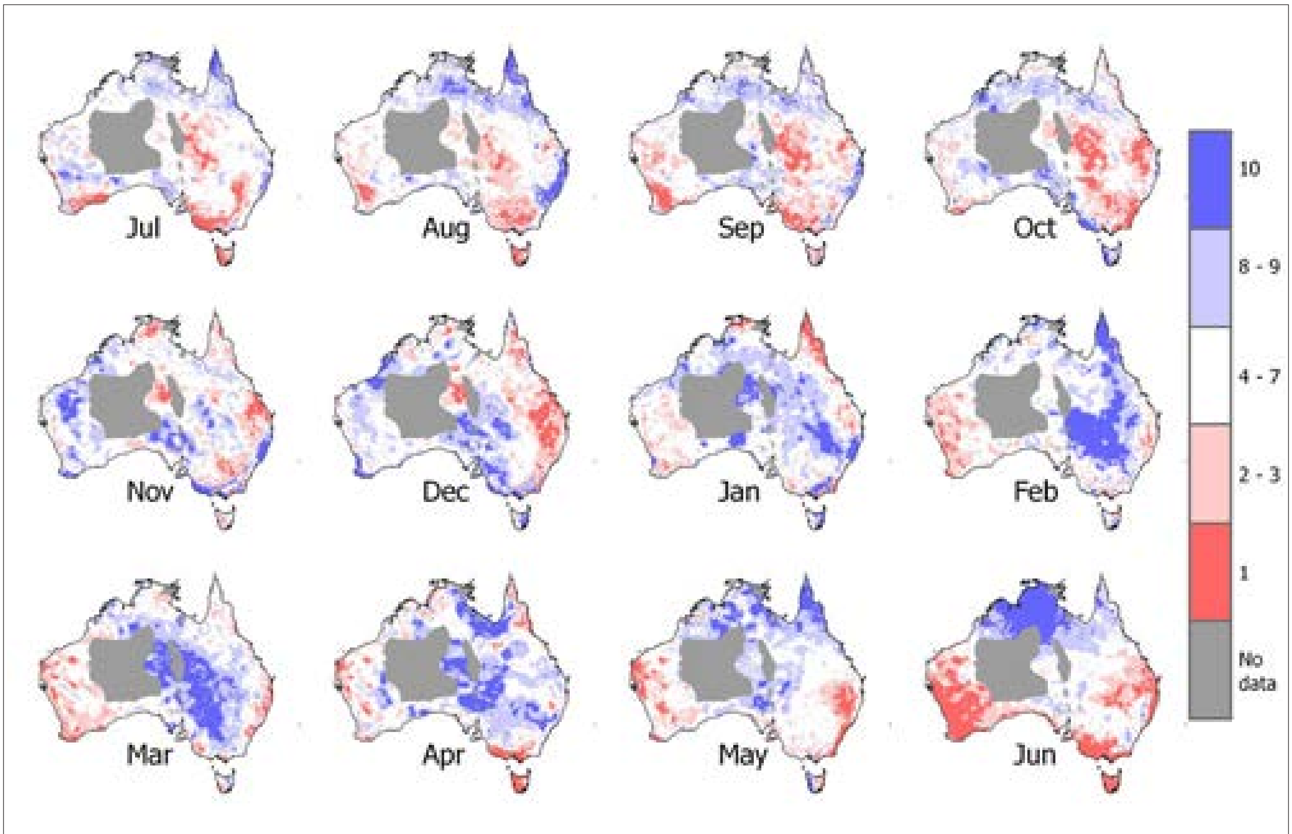


Figure 2-7. Modelled monthly evapotranspiration decile ranges for 2009–10 with respect to the 1911–2010 record

2.3.3 Landscape water yield

Australian landscape water yield was 40 per cent above average in 2009–10

Average Australian landscape water yield for 2009–10 was estimated to be 96 mm, which is 40 per cent above the estimated national long-term (July 1911 to June 2010) average of 68 mm. Landscape water yield for the year was above average in most parts of the country including the majority of the Murray–Darling Basin (Figure 2-8). Below average levels of landscape water yield occurred across much of the South West Coast, Pilbara–Gascoyne and South East Coast (Victoria) regions and also for southern areas of the South East Coast (NSW).

Landscape water yield in the context discussed here relates to flow entering river systems and aquifers from surface run-off and leaching from the sub-surface soil layer. Landscape water yield represents annual rainfall minus evapotranspiration plus, or minus, any change in soil moisture storage over 2009–10. As a result, landscape water yield patterns tend to follow those of rainfall (see Figure 2-2), albeit moderated by evapotranspiration, and may be affected by initial soil moisture levels.

Despite a generally drier than average start to the 2009–10 year, significant rainfall in the north of the country during the summer months contributed to above average run-off and drainage to rivers and aquifers across northern Australia (Figure 2-9 and Figure 2-10). Lake Eyre Basin and the Carpentaria Coast experienced very much above average landscape water yield totals for the 2009–10 year.

Given the rainfall received, landscape water yield was relatively low in the South Australian Gulf, South East Coast (Victoria) and Murray–Darling Basin regions. The initial dryness of these areas (see Section 2.4), resulting from preceding dry years contributed to lower landscape water yield for the year than would otherwise be expected, as water was retained in the landscape as increased soil moisture storage (see Table 2-3).

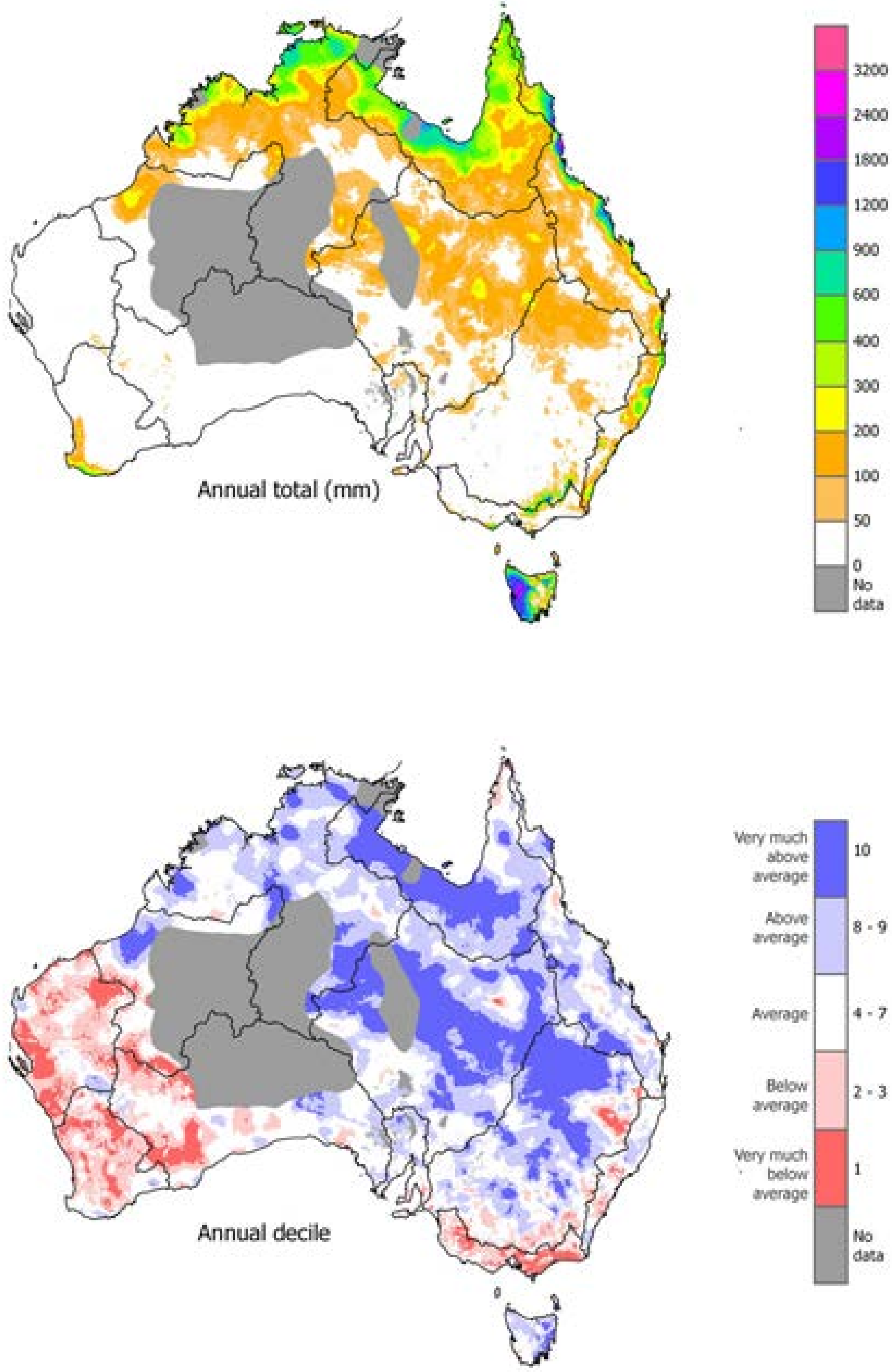


Figure 2-8. Modelled annual total landscape water yield in 2009–10 (top) and its decile range with respect to the 1911–2010 record (bottom)

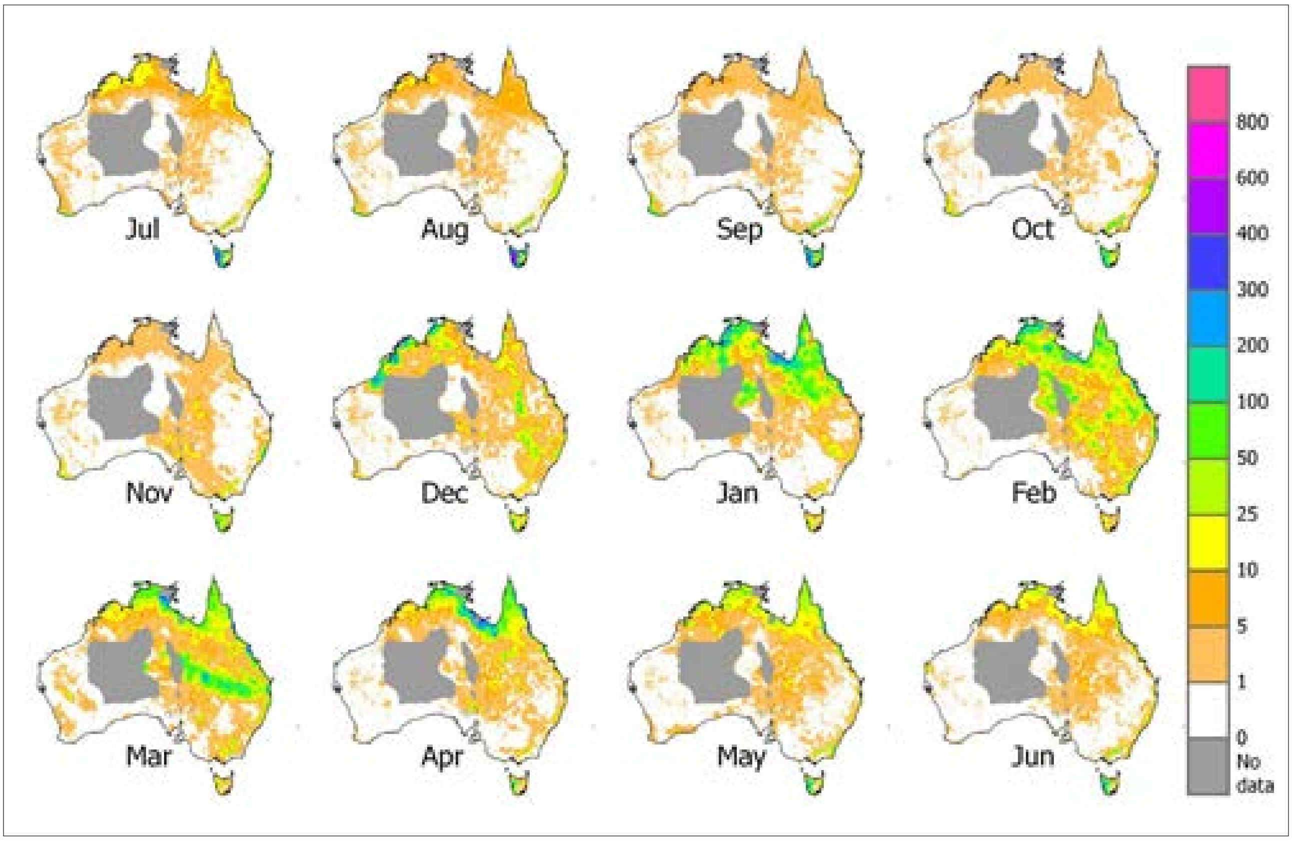


Figure 2-9. Modelled monthly landscape water yield totals (mm) for 2009–10

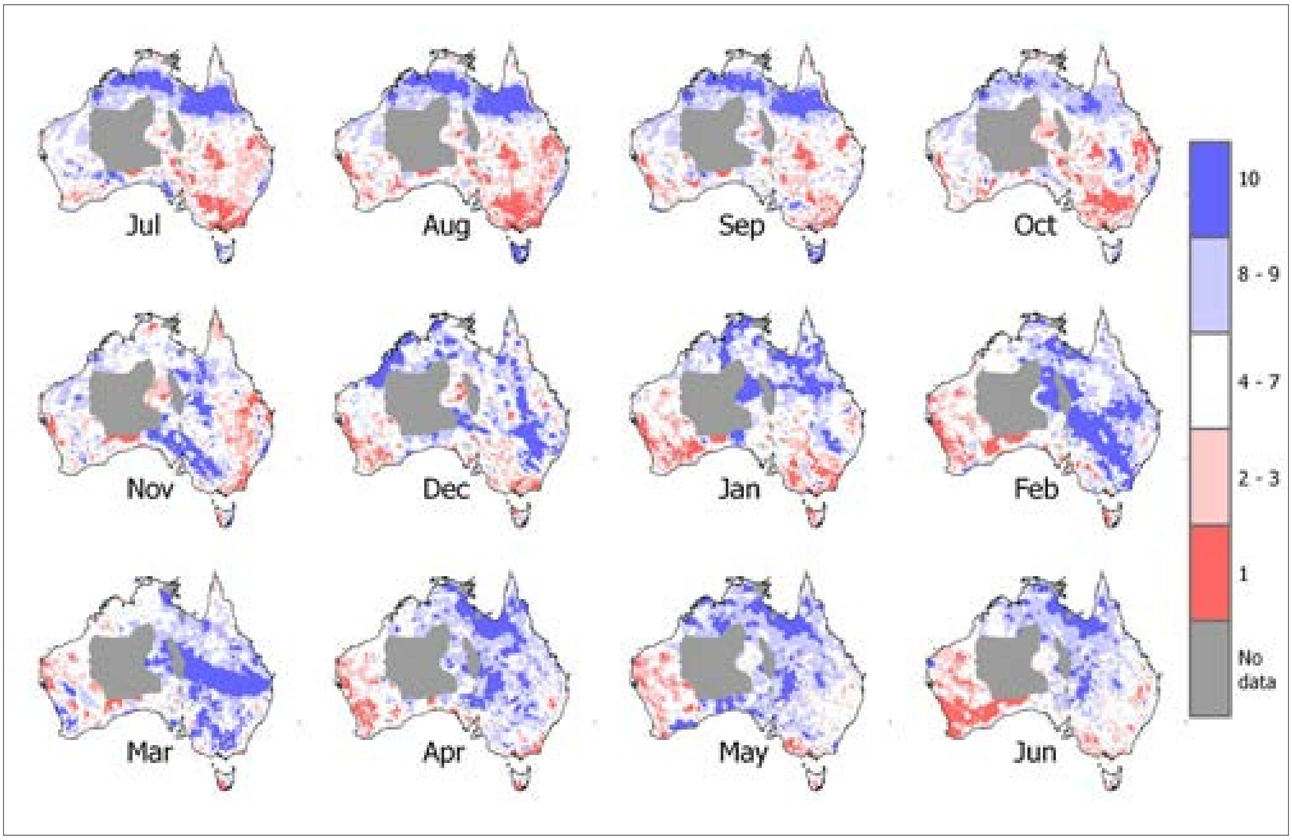


Figure 2-10. Modelled monthly landscape water yield deciles for 2009–10 with respect to the 1911–2010 record

2.4 Soil moisture store in 2009–10

Deep soil moisture stores increased in the north, centre and south of the country over 2009–10 but decreased over most of Western Australia and along the New South Wales coast

Deep soil moisture stores are estimated to have generally increased across the country in 2009–10 indicating more favourable conditions for drainage of soil moisture below the root zone and potentially groundwater recharge.

The most notable increases were in the Carpentaria Coast, North East Coast, Lake Eyre Basin and Murray–Darling Basin regions. The South Australian Gulf, South East Coast (Victoria) and Tanami – Timor Sea Coast regions also experienced increases in deep soil moisture storage (Table 2-3). The values shown in Table 2-3 provide a measure of deep soil moisture storage, ranging from completely dry (zero per cent) to saturated (100 per cent).

The Murray–Darling Basin region was relatively dry at the start of 2009–10, particularly in the south (Figure 2-11). Above average rainfall conditions resulted in deep soil moisture content increasing from 33–43 per cent over 2009–10 (Table 2-3). Deep soil moisture conditions were estimated to be average to very much above average over much of the centre and north of the Murray–Darling Basin region by the end of the year. In the far south of the region, including the major run-off generating areas in the New South Wales and Victorian Alps, soil moisture conditions had improved from very much below average to around average by the end of 2009–10 (Figure 2-11).

Table 2-3. Change in the modelled deep soil moisture store over 2009–10 by region

Region	Soil moisture storage		Change in deep soil moisture*
	July 2009	June 2010	
North East Coast	47%	58%	+11%
South East Coast (NSW)	73%	62%	–11%
South East Coast (Victoria)	38%	46%	+8%
Tasmania	91%	85%	–6%
Murray–Darling Basin	33%	43%	+10%
South Australian Gulf	45%	50%	+5%
South Western Plateau	33%	29%	–4%
South West Coast	38%	25%	–13%
Pilbara–Gascoyne	47%	34%	–13%
North Western Plateau	50%	43%	–7%
Tanami – Timor Sea Coast	51%	59%	+8%
Lake Eyre Basin	53%	66%	+13%
Carpentaria Coast	61%	75%	+14%

*As a percent of total deep soil water holding capacity

2.4 Soil moisture store in 2009–10 (continued)

There were also increases in soil moisture content over the course of the year in the Carpentaria Coast and North East Coast regions (Table 2-3). In the North East Coast region, some of the biggest increases in deep soil moisture were in the Fitzroy River basin which experienced major flooding in February and March 2010 (see Section 2.11). Deep soil moisture was very much above average over significant areas of the Carpentaria Coast region by June 2010 following significant rainfall during the summer of 2009–10 and subsequent flooding in the Nicholson, Flinders and Mitchell river basins (Figure 2-11).

In contrast, the deep soil profile dried in most parts of Western Australia, particularly in the South West Coast and Pilbara–Gascoyne regions. In the South West Coast region, deep soil moisture was average or below average for most of the region at the beginning of 2009–10. These conditions deteriorated over the year such that by June 2010 deep soil moisture was below average or very much below average across most of the region.

In the east of the country, there was also significant drying of the deep soil profile estimated for central and northern parts of the South East Coast (NSW) region over 2009–10 (Figure 2-11). This drying was largely the result of average levels of rainfall combined with relatively high levels of evapotranspiration estimated in these areas.

Deep soil moisture in the South East Coast (Victoria) region increased over 2009–10 in response to above average rainfall, particularly in November 2009 and February, March and April 2010. The region was exceptionally dry at the beginning of 2009–10. Although deep soil moisture was estimated to have increased across the region over the year, soil moisture stores at the end of the year were still below average in many areas. This retention of rainfall within the deep soil store contributed to the below average landscape water yield for the region in 2009–10, despite the generally average or better rainfall conditions.

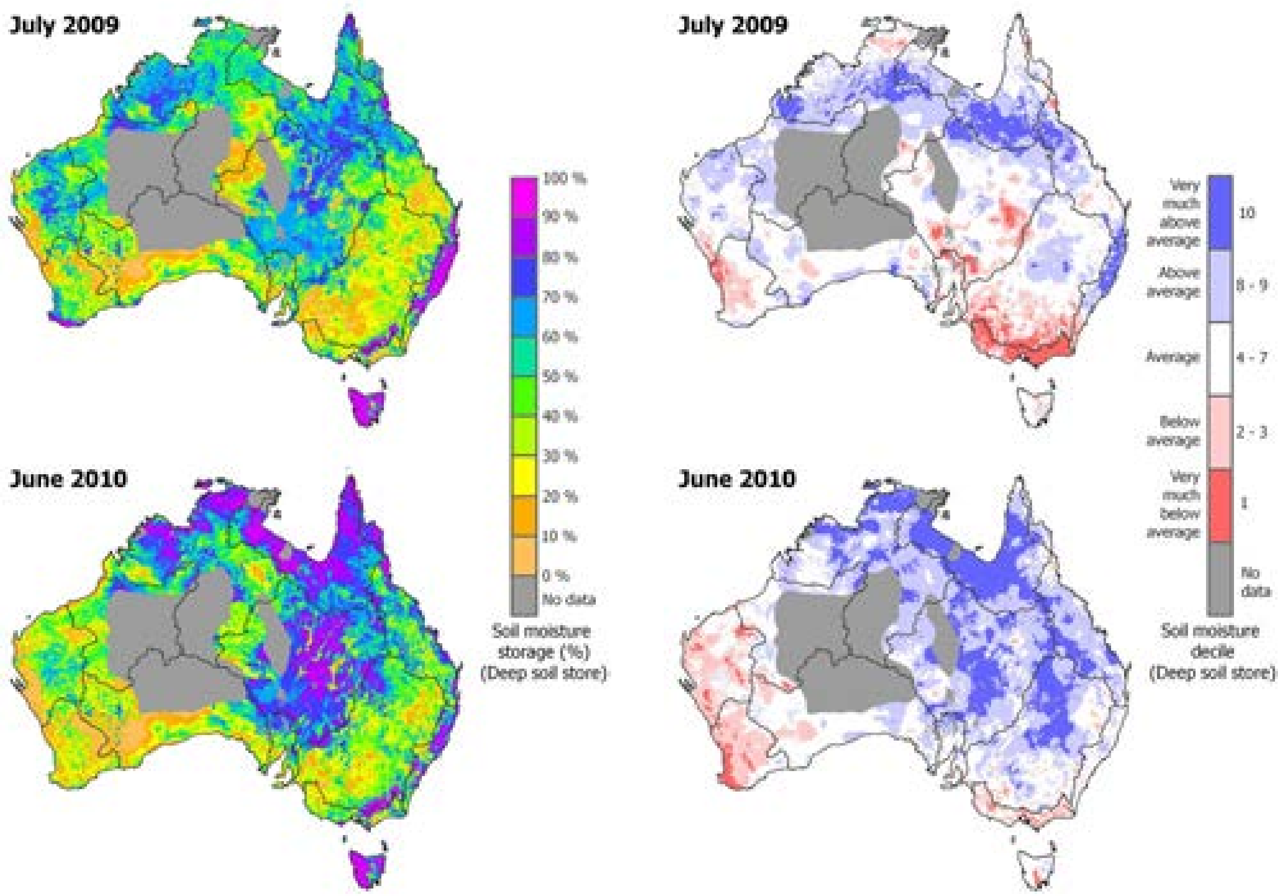


Figure 2-11. Modelled deep soil moisture index values for July 2009 and June 2010 (left) and their deciles with respect to the 1911–2010 record (right)

2.5 Surface water storage in 2009–10

Surface water storage in Australia increased from 46 per cent to 51.6 per cent of total accessible volume over 2009–10

The volume of water held in public water storages[3] listed in the Bureau's water storage database[4] on 1 July 2009 was 46 per cent of the total accessible volume of these storages. The total volume of water stored in major public water storages in Australia at the end of 2009–10 was at 51.6 per cent of their total accessible capacity which represented a 5.6 per cent increase compared with the previous year. Surface water storage in the South East Coast (NSW), Carpentaria Coast and Tanami – Timor Sea Coast regions decreased (Table 2-4). Regions absent from Table 2-4 have no significant surface water storages. As a percentage of total accessible volume, the biggest increase in storage was in the Murray–Darling Basin region (+12.4 per cent) and the biggest decrease was in the Tanami – Timor Sea Coast region (–17.1 per cent). These two regions also experienced the biggest volumetric increase of 3,143 GL and decrease of 1,827 GL in storage volume respectively.

Despite the increase in the volume of water in surface storages in the Murray–Darling Basin region, at 30 June 2010 the volume of water held was still only 32.5 per cent of total accessible volume (Table 2-4). The volume of water held in surface storages in the heavily populated South East Coast (Victoria) region had also not risen above 20 per cent of total accessible volume by 30 June 2010 (see Section 4.6 in Chapter 4 and Section 5.6 in Chapter 5 for more details).

While run-off for the year was below average in the South West Coast region, the volume of water in surface storage in this region increased from 35.3 per cent of accessible volume to 38.3 per cent of accessible volume. This was a result of a number of significant coastal rainfall and run-off events (in July, August, September and November 2009) and provision of other sources of water (such as groundwater) assisted by water restrictions in place in metropolitan areas. Conversely, despite above average run-off, the volume of water in surface storage in the Tanami – Timor Sea Coast region decreased from 97.3 per cent of accessible volume to 80.2 per cent of accessible volume. This was largely due to releases of water from Lake Argyle concurrent with average rainfall and run-off conditions in the Lake Argyle catchment.

Table 2-4. Change in surface water storage over 2009–10 by region

Region	Accessible volume in storage (GL)			Per cent of total accessible capacity		
	01 July 2009	30 June 2010	Difference	01 July 2009	30 June 2010	Difference
North East Coast	6,573	7,615	+1,042	77.1	89.4	+12.3
South East Coast (NSW)	2,402	2,237	-165	65.3	60.8	-4.5
South East Coast (Victoria)	891	1,288	+397	12.8	18.6	+5.8
Tasmania	10,209	11,969	+1,760	46.1	54.1	+8.0
Murray–Darling Basin	5,057	8,200	+3,143	20.1	32.5	+12.4
South Australian Gulf	107	109	+2	54.3	55.3	+1.0
South West Coast	339	367	+28	35.3	38.3	+3.0
Tanami – Timor Sea Coast	10,398	8,571	-1,827	97.3	80.2	-17.1
Carpentaria Coast	94	92	-2	94.9	92.9	-2.0

3. Refers to the accessible volume of water in the water storages.
4. Represents 94% of total accessible volume of public water storages in Australia (See http://water.bom.gov.au/waterstorage/awris/index.html).

2.6 Groundwater status

A truly national overview of groundwater status was not possible in this report due to the limited amount of quality-controlled data available in a suitable form. For example, the status of nationally-significant groundwater systems has not been assessed in Western Australia, Victoria, the Northern Territory, Tasmania and the Great Artesian Basin. Suitable groundwater data for these areas will be available in future.

The status of groundwater levels was evaluated in a number of aquifers in two regions where data were available. The data are presented in terms of linear trends for the period of 2005–10. The trends in groundwater levels in a subsystem are categorised for each 20-kilometre grid square (Murray–Darling Basin) or five-kilometre grid square (South Australian Gulf). The following categories are assigned when greater than or equal to 60 per cent of the bores in a grid square have a linear trend that is:

- lower than -0.1 m/year – decreasing
- between -0.1 m/year and 0.1 m/year – stable
- higher than 0.1 m/year – increasing
- has no dominant tendency – variable

As indicated above, the analysis was constrained by the limited amount of quality controlled data available in a suitable form. The available results are summarised in the tables below.

Table 2-5. Groundwater status for aquifers in the Murray–Darling Basin region

Groundwater subsystem	Change in groundwater levels
Condamine	decreasing or variable
Narrabri and Gunnedah	decreasing or variable
Cowra and Lachlan	decreasing
Shepparton	decreasing
Calivil	decreasing
Murray Group	decreasing or stable
Renmark	decreasing

Table 2-6. Groundwater status for aquifers in the South Australian Gulf region

Groundwater subsystem	Change in groundwater levels
Adelaide Plains watertable aquifer (upper)	decreasing
Tertiary aquifer T1 (middle)	decreasing
Tertiary aquifer T2 (lower)	decreasing
McLaren Vale watertable (upper)	decreasing or stable
Port Willunga (middle)	decreasing
Maslin Sands (lower)	decreasing or stable

2.7 Urban water use in 2009–10

Urban water use in the urban centres considered in this report decreased from 1,719 GL in 2005–06 to 1,497 GL in 2009–10. Residential water consumption accounted for 68 per cent of urban use in 2009–10.

The past decade in Australia was characterised by low rainfall conditions in the south, east and west of the country that resulted in the implementation of water restrictions in most cities and towns. Water restrictions led to a reduction of total urban water consumption for the eight major urban centres considered in this report, from a total of approximately 1,719 GL in 2005–06 to 1,497 GL in 2009–10 (National Water Commission 2011a). In the residential sector however, consumption has increased from 2007–08 as a result of higher rainfall and expectation of water security projects being completed. In 2009–10 the residential consumption of the urban centres considered in this report increased by 3.2% compared to 2008–09 and accounted for approximately 68 per cent of use whilst commercial, municipal and industrial used 24 per cent, with the remainder to other uses.

In Sydney, the annual residential water supplied increased from 198 KL/property in 2008–09 to 205 KL/property in 2009–10 (National Water Commission 2011a). In Melbourne, however, water use continued to fall as restriction levels remained unchanged over 2009–10 and average rainfall conditions experienced across the metropolitan area reduced water demand, particularly over summer and autumn 2010.

In the northeast and east of the country, above average rainfall in early 2010 led to a rapid increase in water storage levels for many urban areas and enabled utilities to ease restrictions. This resulted in a six per cent increase in annual household use in Brisbane, up to 143 KL/property (National Water Commission 2011a).

In Western Australia, annual household water consumption for Perth remained stable in 2009–10 at 276 KL/property, only one KL less than in 2008–09. Typically 50 per cent of Perth's total water consumption comes from groundwater, 40 per cent from surface water and ten per cent from desalination (National Water Commission 2011a).

2.8 Agricultural water use (2005–06 to 2009–10)

Between 2005–06 and 2009–10, agricultural water use in Australia decreased from 11,688 GL to 7,359 GL

Annual agricultural water use in Australia was 8,369 GL on average between 2005–06 and 2009–10, based on annual surveys of water use on Australian farms by the Australian Bureau of Statistics. Water use by agriculture over this period was highest in 2005–06 (11,688 GL) and lowest in 2007–08 (6,989 GL). Annual water use for irrigation over the period was 7,551 GL on average, with a high of 10,737 GL in 2005–06 and a low of 6,285 GL in 2007–08.

The highest levels of irrigation water use during 2005–06 to 2009–10 occurred in New South Wales (2,003 GL in 2009–10), which also experienced the greatest reduction in irrigation water use over the five-year period. Victoria and Queensland also show notable decreases in total irrigation water use. The Northern Territory uses by far the lowest irrigation volume (18 GL in 2009–10).

Figure 2-12 clearly shows that water use for irrigation decreased dramatically in the Murray–Darling Basin after 2005–06. In 2005–06, irrigation water use in the Murray–Darling Basin was more than double that of the rest of the country. By 2007–08, water use in the Murray–Darling Basin was approximately equal to the rest of Australia and has not noticeably increased in 2009–10.

Table 2-7. Agricultural water use in Australia between 2005 and 2010 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

Water use category	Total annual water use (GL)				
	2005–06	2006–07	2007–08	2008–09	2009–10
Irrigation*	10,737	7,636	6,285	6,501	6,596
Other agriculture^	951	885	704	785	763
Total agriculture	**11,688**	**8,521**	**6,989**	**7,286**	**7,359**

* Total volume applied

^ Including stock drinking, dairy and piggery cleaning

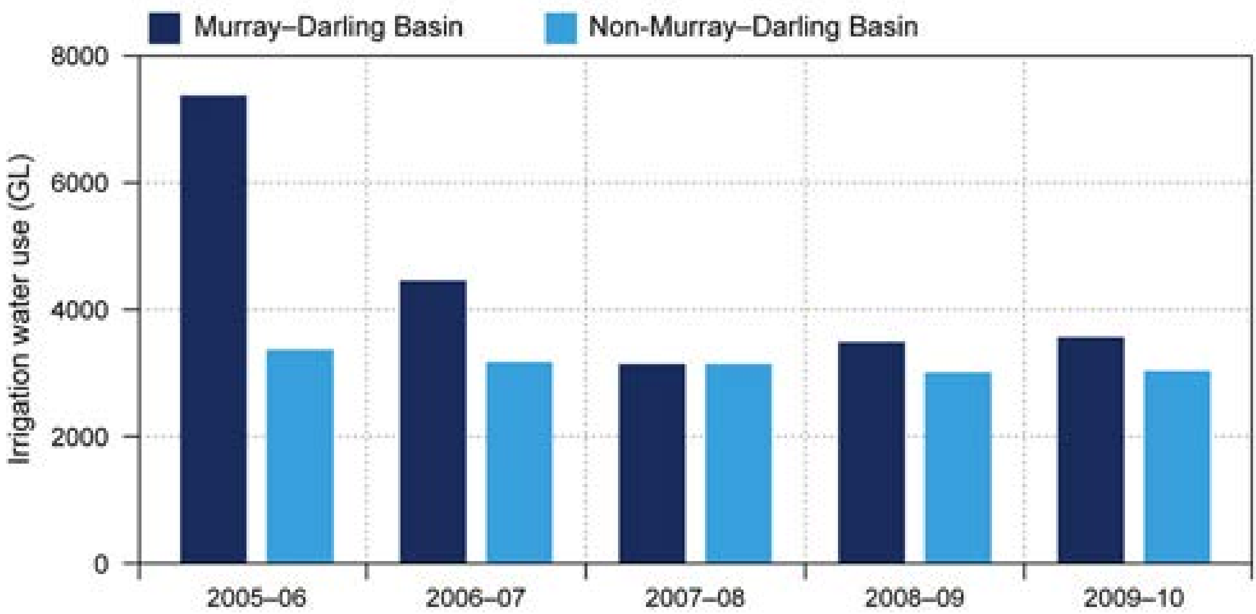


Figure 2-12. Changes in irrigation water use between 2005–06 and 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

2.9 Drivers of the Australian climatic condition in 2009–10

The central and eastern equatorial Pacific Ocean was warm (El Niño conditions) until February 2010 then cooled to La Niña conditions by April 2010

An El Niño event persisted in the Pacific Ocean region from July 2009 until February 2010. Trade winds in the tropics were weak from July to December as a result of the enhanced El Niño event, which peaked in late December 2009. The Southern Oscillation Index (SOI), which reflects the strength of the Pacific trade winds, remained negative and at levels typical of an El Niño event until early 2010.

With weak Pacific trade winds, surface water temperature conditions in the central and eastern tropical Pacific Ocean remained warm and cloudiness remained high. This pattern contributed to the drier than average conditions over northern and eastern parts of Australia during winter and spring 2009 and summer 2009–10. See Box 2-1 for more on the influence of Pacific Ocean temperatures on rainfall in Australia.

The shades of red in Figure 2-13 indicate uncharacteristically warm sea temperatures and the shades of blue indicate uncharacteristically cool sea temperatures when averaged over the top 150 metres of the ocean (approximating the well mixed surface layers). The first two four-month sequences in Figure 2-13 show the unusually warm sea surface temperatures across the central and eastern tropical Pacific Ocean, typical of an El Niño event, remaining until February 2010. However, as shown in the last four-month sequence (March to June 2010) in Figure 2-13, a steady cooling occurred in each successive month from February onwards, with a large volume of cooler than normal water extending across most of the tropical Pacific by the end of June. In some regions the sub-surface water was more than 3°C cooler than average by June 2010 and the SOI was consistent with the early stages of a La Niña event (Figure 2-14).

The breakdown of the El Niño event and establishment of a La Niña in 2010 was associated with strong Pacific trade winds and well above average rainfall in the north and east of the country. While rainfall in these areas was generally below average to very much below average to December 2009, rainfall in the north and east was generally average to very much above average for all subsequent months in 2009–10, except for June 2010. As a consequence of this marked reversal in rainfall conditions, total rainfall for 2009–10 over northern and eastern Australia was only below average in relatively small parts of the South East Coast (NSW) and North East Coast regions, and in the northeast corner of the Murray–Darling Basin region.

To the west of the continent, however, the Indian Ocean Dipole index was positive from October 2009 to June 2010, peaking at 0.8°C in late April 2010 (Figure 2-15). These ocean temperature conditions are likely to have contributed to below average rainfall experienced in the Pilbara–Gascoyne and South West Coast regions in 2009–10. See Box 2-2 for more on the influence of Indian Ocean temperatures on rainfall in Australia.

More information on the drivers of climatic conditions in Australia can be found on the Bureau's website at: www.bom.gov.au/lam/climate/levelthree/analclim/analclim.htm.

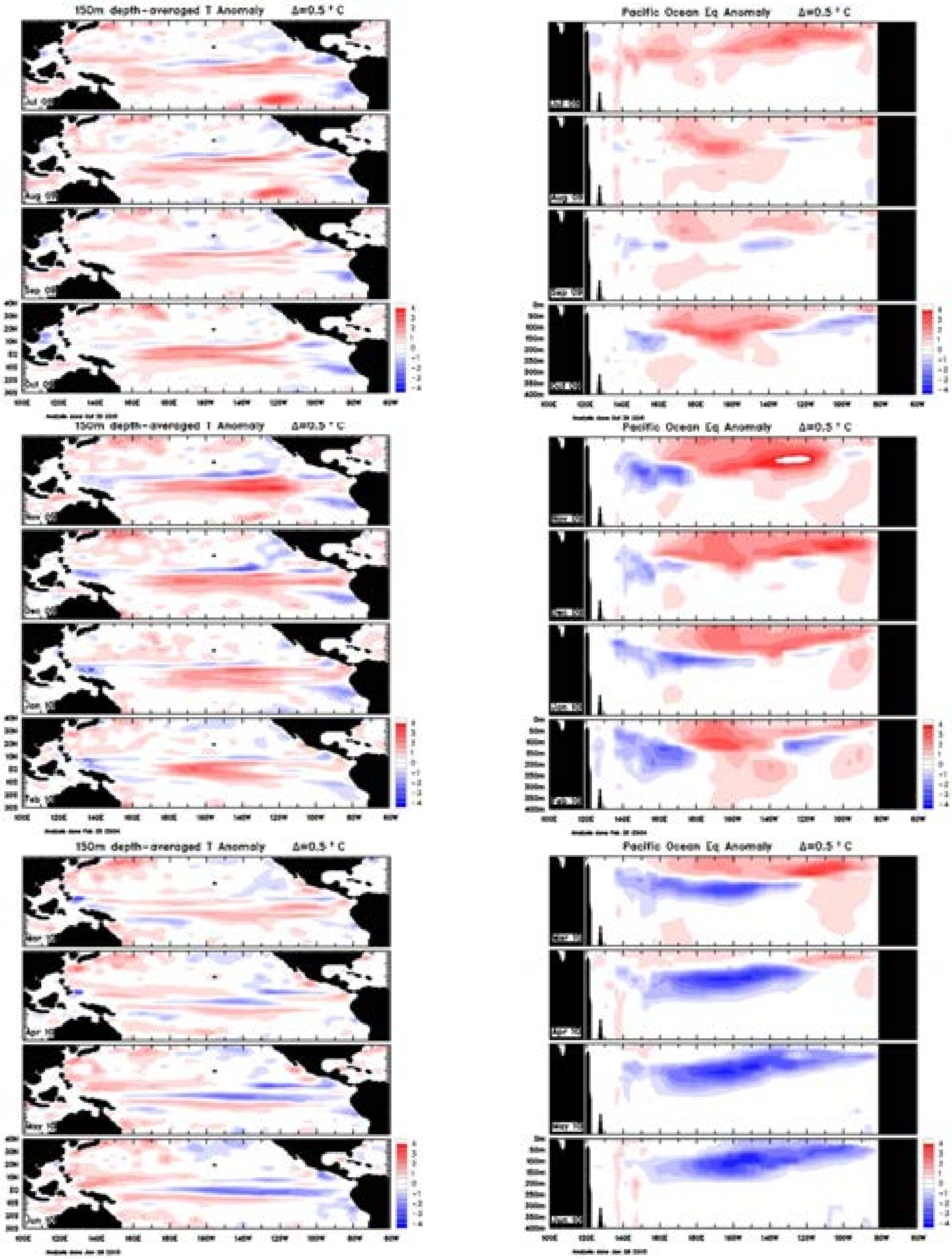


Figure 2-13. Pacific Ocean temperature profiles driving the Walker Circulation (see Box 2-1) in 2009–10. Monthly sequences of 150 m depth-averaged temperature anomalies (left) and vertical temperature anomaly sections at the equator (right). The historic archive of sub-surface temperature charts can be found at www.bom.gov.au/oceanography/oceantemp/pastanal.shtml

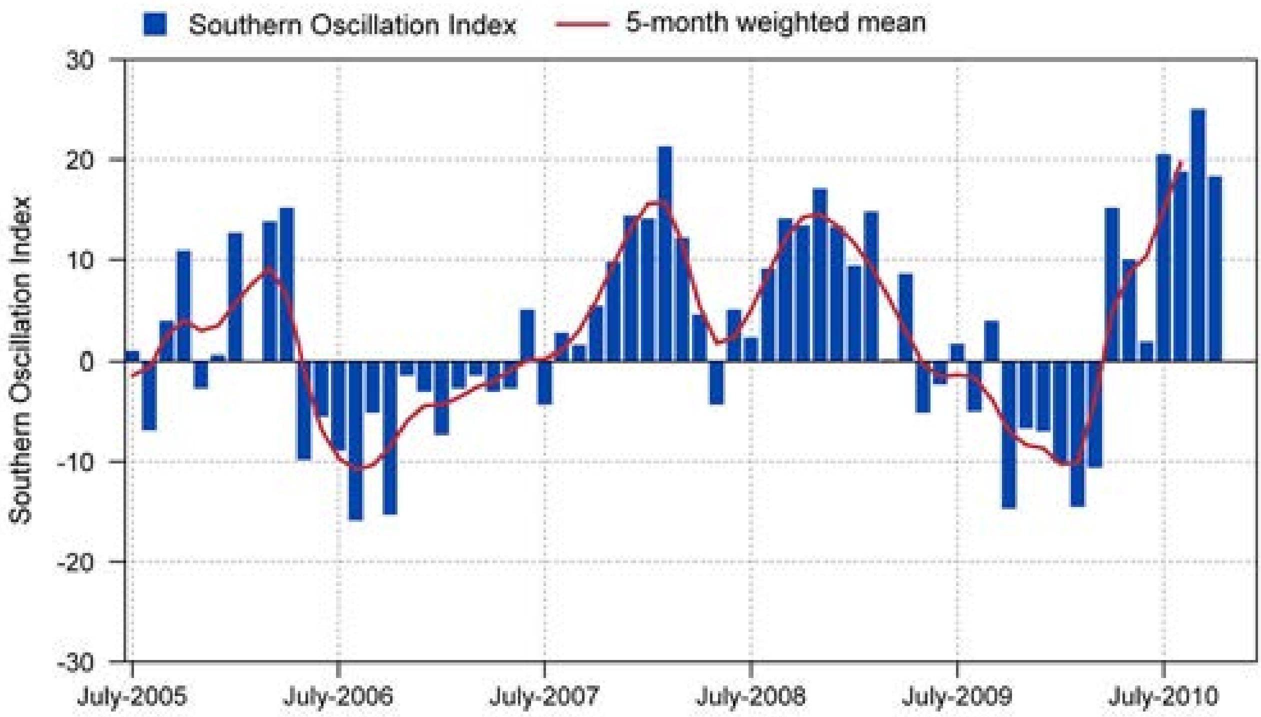


Figure 2-14. Southern Oscillation Index time-series (data available at: www.bom.gov.au/climate/enso/indices.shtml)

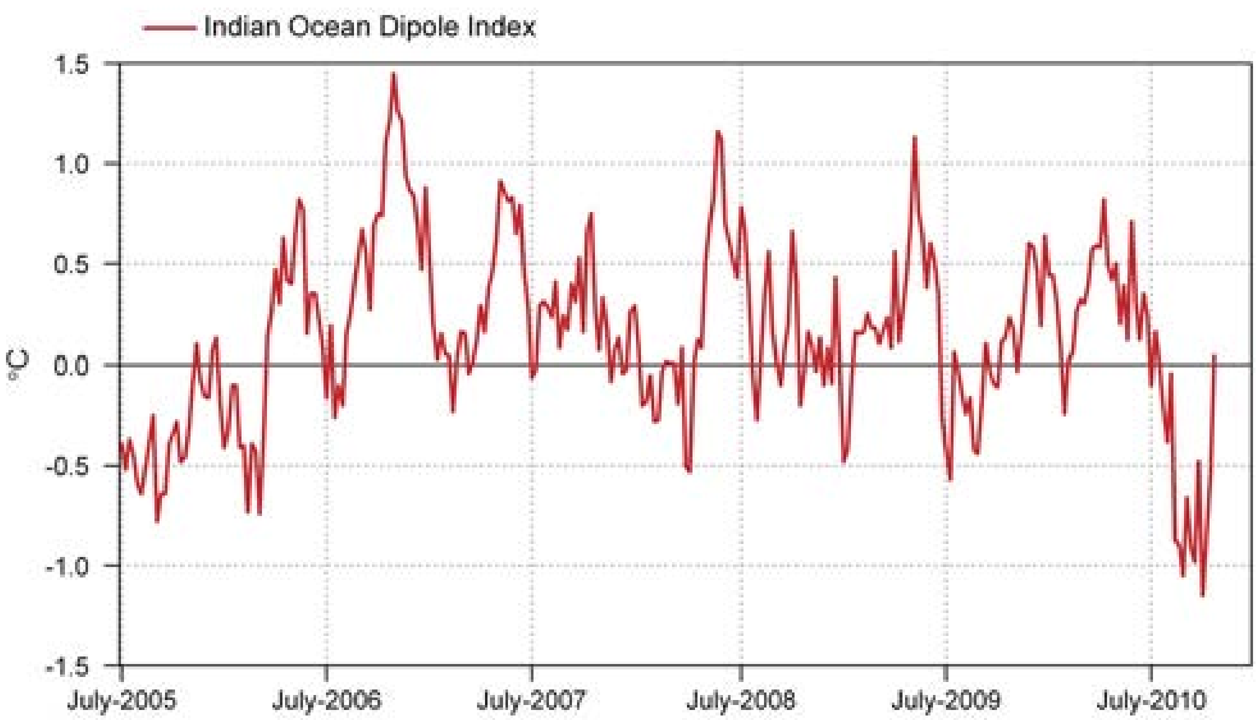


Figure 2-15. Indian Ocean Dipole time series (data available at: www.bom.gov.au/climate/enso/indices.shtml)

BOX 2-1: THE SOUTHERN OSCILLATION AND EL NIÑO/LA NIÑA

Much of the variability in Australia's climatic condition is connected with the atmospheric phenomenon called the Southern Oscillation, a major see-saw of air pressure and rainfall patterns between the Australian/Indonesian region and the eastern tropical Pacific. The Southern Oscillation Index (SOI) is calculated from the monthly mean air pressure difference between Tahiti and Darwin and provides a simple measure of the strength and phase of the Southern Oscillation and Walker Circulation.

The 'typical' Walker Circulation pattern shown in the top panel of the schematic below has an SOI close to zero (i.e. the Southern Oscillation is close to the long-term average or neutral state). Positive values of the SOI are associated with stronger than average Pacific trade winds blowing from east to west and warmer sea temperatures to the north of Australia. Together these give a high probability that eastern and northern Australia will be wetter than normal.

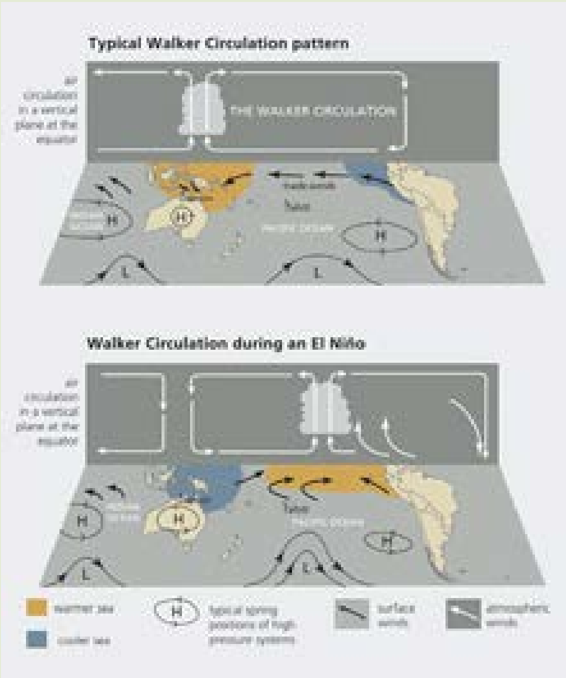
During El Niño episodes, the Walker Circulation weakens, seas around Australia cool, and slackened trade winds feed less moisture into the Australian/southeast Asian region (bottom panel of schematic). Air pressure is higher over Australia and lower over the central Pacific in line with this shift in the Walker Circulation, and the SOI becomes persistently negative (for example, below -7). Under these conditions, there is a high probability that eastern and northern Australia will be drier than normal.

In addition to its effect on rainfall, the El Niño phenomenon also has a strong influence on temperatures over Australia. During winter/spring, El Niño events tend to be associated with warmer than normal daytime temperatures. Conversely, reduced cloudiness means that temperatures tend to cool very rapidly at night, often leading to widespread and severe frosts.

When the Pacific trade winds and Walker Circulation are stronger than average, the eastern Pacific Ocean is cooler than normal and the SOI is usually persistently positive (e.g. above +7). This enhancement of the Walker Circulation, also called La Niña, often brings widespread rain and flooding to Australia.

The effect of La Niña on Australian rainfall patterns is generally more widespread than that of El Niño. During La Niña phases, temperatures tend to be below normal, particularly over northern and eastern parts of Australia. The cooling is strongest during the October to March period.

For more information see:
www.bom.gov.au/info/leaflets/nino-nina.pdf



Walker Circulation in neutral (top) and El Niño (bottom) conditions

BOX 2-2: THE INDIAN OCEAN DIPOLE

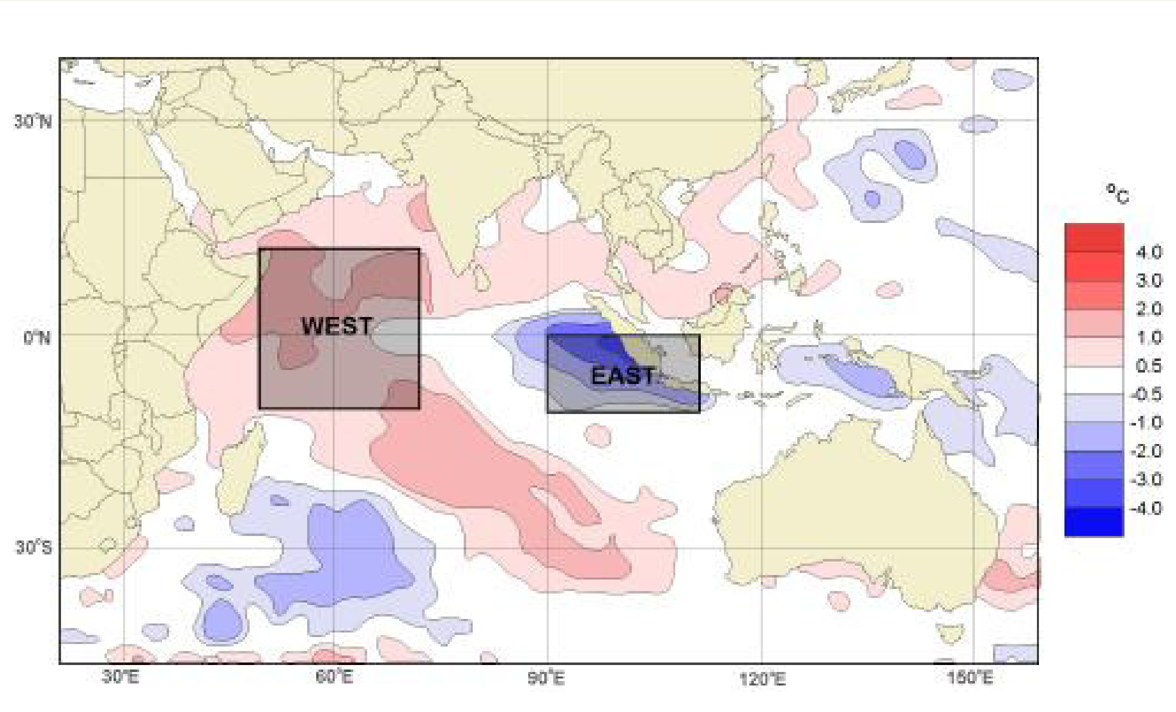
The Indian Ocean Dipole (IOD) is a coupled ocean and atmosphere phenomenon in the equatorial Indian Ocean that affects the climatic conditions in Australia and other countries that surround the Indian Ocean basin.

The IOD is commonly measured by an index that is the difference in sea surface temperature (SST) between the western (50°E to 70°E and 10°S to 10°N) and eastern (90°E to 110°E and 10°S to 0°S) equatorial Indian Ocean. The boxes on the map below show the east and west poles of the IOD.

A positive IOD period is characterised by cooler than normal water in the tropical eastern Indian Ocean and warmer than normal water in the tropical western Indian Ocean (see map below for an example of a typical positive IOD SST pattern). A positive IOD SST pattern can be associated with a decrease in rainfall over parts of central and southern Australia.

Conversely, a negative IOD period is characterised by warmer than normal water in the tropical eastern Indian Ocean and cooler than normal water in the tropical western Indian Ocean. A negative IOD SST pattern can be associated with an increase in rainfall over parts of southern Australia.

For more information see: www.bom.gov.au/climate/IOD/about_IOD.shtml



Departures from average ocean surface temperatures in November 1997 at the height of the 1997 positive IOD event.

2.10 Notable rainfall events in 2009–10

Widespread heavy rainfall occurred in the Northern Territory and Queensland between 22 February and 3 March 2010

An exceptional rain event affected the Lake Eyre Basin, northern Murray–Darling Basin and North East Coast regions during the last week of February and first week of March 2010. The event began on 22 February when a strong low pressure system developed over the Northern Territory within a monsoon trough. Over the following days the monsoon low tracked south, triggering heavy falls through central and southern parts of the Northern Territory.

From 28 February, the monsoon low moved eastwards into southwest Queensland, bringing widespread heavy rain on 28 February and 1 March, then spread further east into the southern interior on 1 March and 2 March (see Figure 2-16). Moist easterly flow, combined with a second low pressure system which formed off the coast near Fraser Island, also brought heavy rain to coastal regions of southeast Queensland and northeast New South Wales. The main low weakened and drifted south after 2 March. Rainfall amounts were smaller from this point, but remnant moisture from the system continued to provide substantial rain over eastern Australia for the next few days, particularly in Victoria and southern New South Wales over the period 6–8 March. The moisture also contributed to severe thunderstorms which affected parts of the region.

The most remarkable aspect of this event was the area covered by the heavy rainfall and the total volume of rainfall. Daily totals exceeded 100 mm over 1.7 per cent of Australia on 1 March and 1.9 per cent on 2 March (Figure 2-16). The latter is the largest area of 100 mm plus daily totals on a single day in the Australian meteorological record, breaking the previous record of 1.7 per cent set on 22 December 1956. In the Northern Territory, 28 February 2010 was the wettest day recorded, with a Territory-wide average of 29.23 mm, while 2 March set a new record for Queensland with a state-wide average of 31.74 mm.

Over the ten-day period ending 3 March 2010, an estimated 403,000 GL of rain fell across the Northern Territory and Queensland. This resulted in major flooding in most of the northern catchments of the Lake Eyre Basin and Murray–Darling Basin regions. Compared with a notable previous flooding event in the region in April 1990, peak rainfall amounts were smaller, but heavy rains (ten-day totals exceeding 200 mm) covered a much larger area.

The event of February–March 2010 occurred during the declining phase of an El Niño which was in place since mid-2009. While El Niño is typically associated with dry conditions in eastern Australia in winter and spring, it is not unusual for major rain events to occur during late summer or early autumn during its declining phase. Notable historical examples include those of February 1973, March 1983, January 1995 and January 2007.

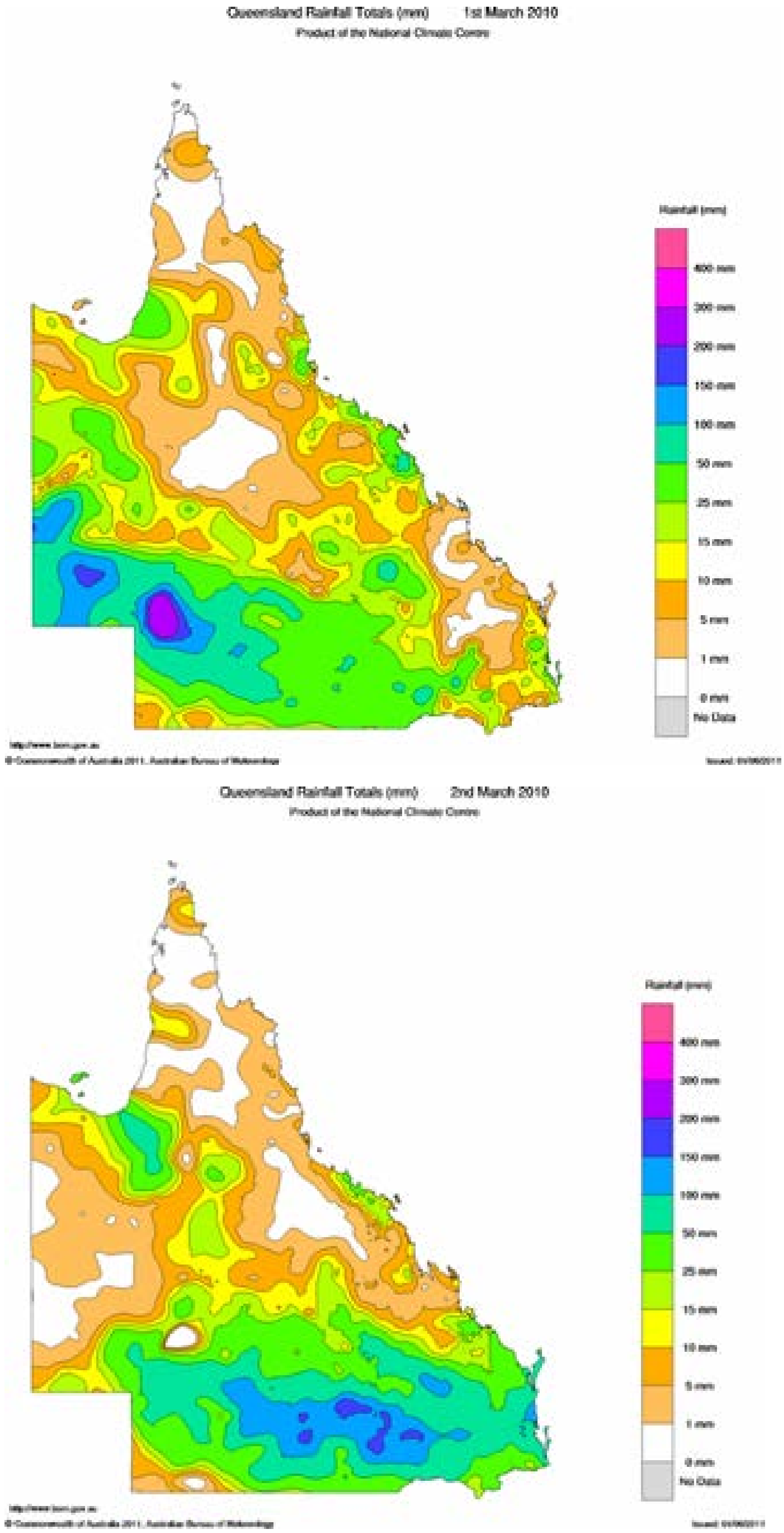


Figure 2-16. Rainfall that contributed to flooding in central Queensland in March 2010

2.11 Major flood events in 2009–10

The most significant flooding of 2009–10 occurred during February and March in the Lake Eyre Basin region, southeast Queensland and in the top of the Murray–Darling Basin region

Several short-term flood events occurred in eastern Australia in 2009. Parts of Tasmania were affected by repeated minor to moderate flooding during May to September. The calendar year ended with further flooding in parts of New South Wales and Queensland.

The most significant flooding of the reporting period occurred during February and March 2010 in the Carpentaria Coast, Lake Eyre Basin, North East Coast and Murray–Darling Basin regions as a consequence of the significant rainfall event described in Section 2-10. Locations where peak river heights exceeded 'major flood' thresholds (see Glossary for flood category definitions) during the year are shown in Figure 2-17.

The short but high flood peaks delivered an estimated 6,700 GL to the major tributaries of the Darling River and Lake Eyre, inundating floodplains and replenishing lakes and wetlands (Figure 2-18). The flows also increased the volume held in private storages by around 1,500 GL. However, the flows in the Darling River system were not sufficient to allow releases to the Murray mouth and Coorong or provide drought relief in the lower Murray–Darling Basin, with only about 1,100 GL reaching the Menindee Lakes in western New South Wales.

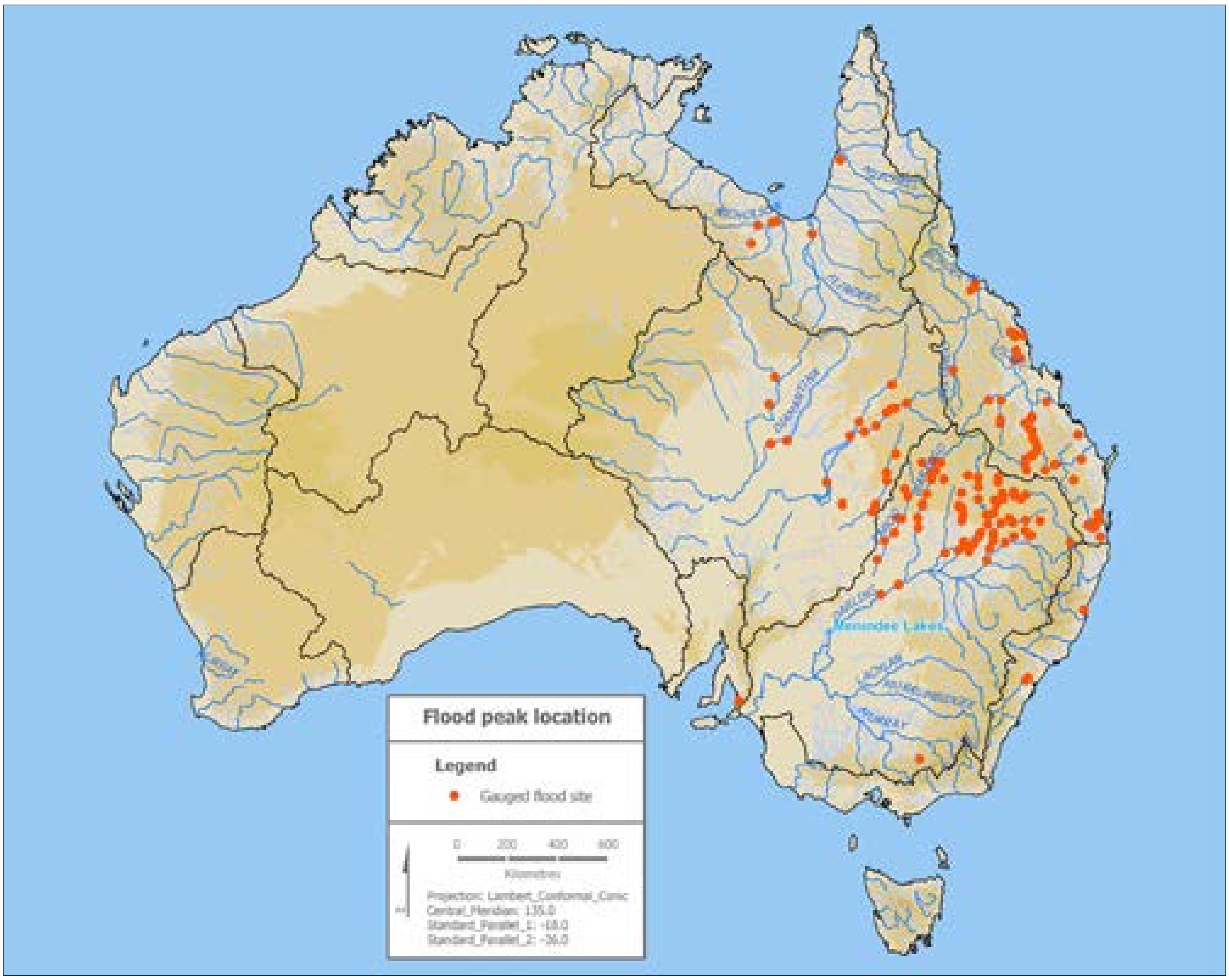
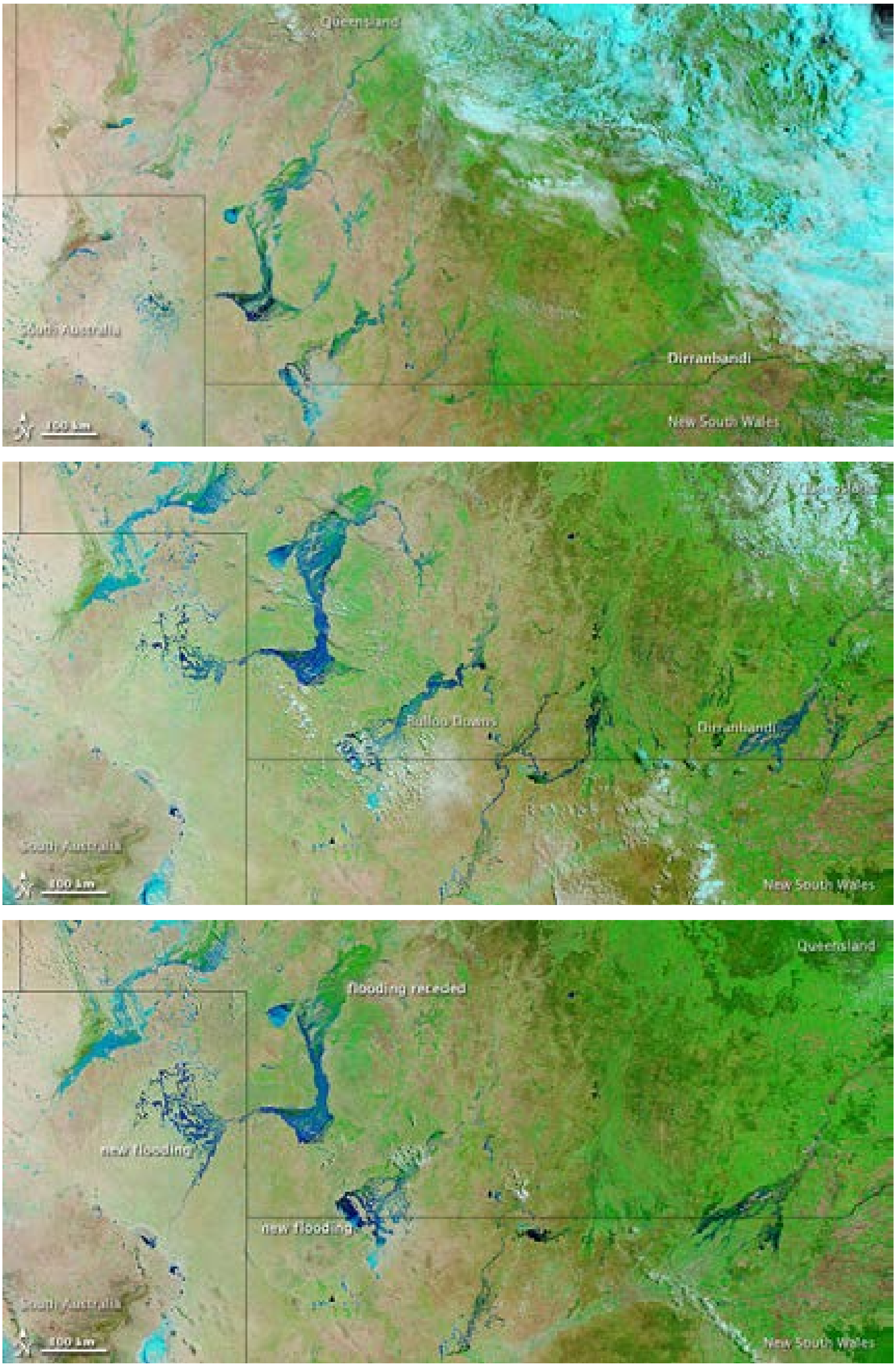


Figure 2-17. Location of flood peaks classified as 'major' in 2009–10



17 February 2009

14 March 2009

27 March 2009

Figure 2-18. Satellite derived images showing flood progression through the channel country in southwest Queensland, northwest New South Wales and northeast South Australia. Note that some cloud is apparent (coloured pale blue) particularly in the upper right of the first image (source: www.earthobservatory.nasa.gov)

2.12 Regional water resources assessments

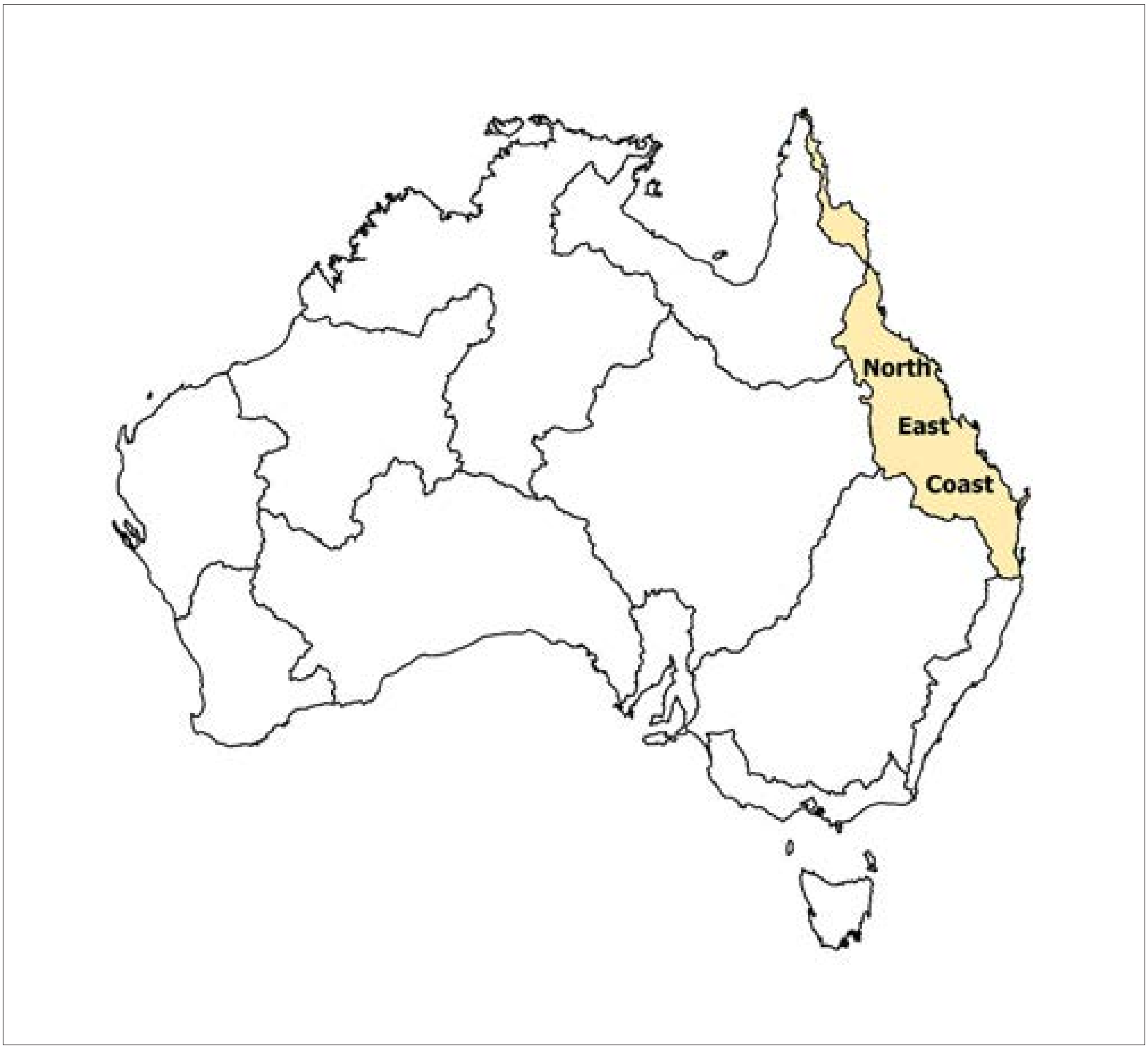
Chapters 3 to 15 detail assessments of water availability and use at regional scales. Within each reporting region, patterns, variability and trends in water availability and use are considered. Topics addressed include the impacts of the climatic condition on water resources over 2009–10 and between 1980 and 2010. There is a focus on presentation of annual to decadal patterns and trends, and monthly and seasonal effects.

Particular consideration is given to describing the hydrological state of rivers within each region over 2009–10 and over recent years. Groundwater resources are also described where data was available. Water availability and use in selected cities and irrigation areas is also presented.

Information is conveyed in general descriptions of each region and the results of analysis are presented in graphs, tables and diagrams. Landscape water balance data provide a spatially explicit regional perspective, and data from selected monitoring sites give more detail at particular locations.

3. North East Coast

3. North East Coast



3.1 Introduction

This chapter examines water resources in the North East Coast region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, water stores and water levels are evaluated for the region and also in more detail at selected sites for rivers, wetlands and aquifers. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Surface water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

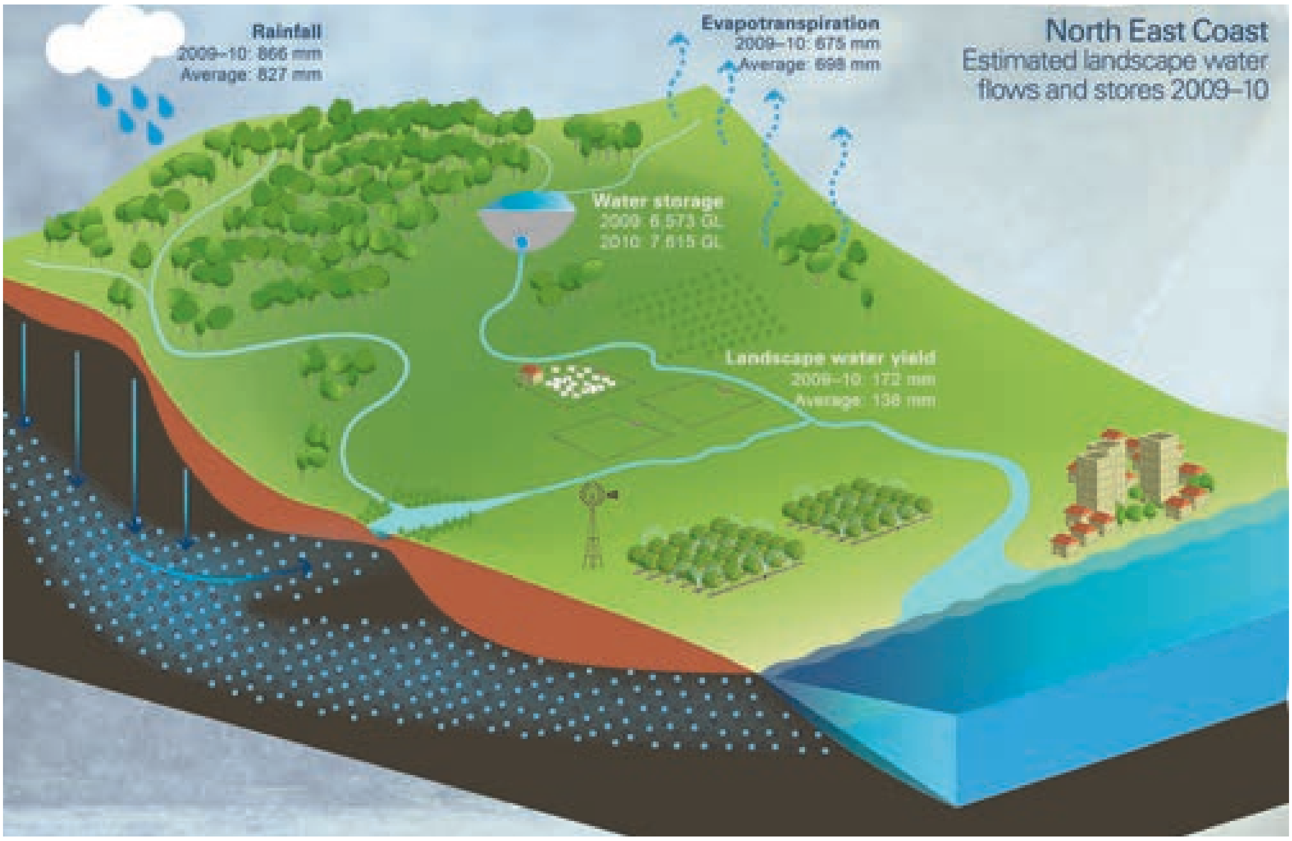


Figure 3-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the North East Coast region

3.2 Key data and information

Figure 3.1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the North East Coast region. Rainfall was slightly above average and evapotranspiration slightly below average (see Table 3-1), landscape water yield was higher than average. Soil moisture storage levels increased by 11 per cent and surface water storage levels also rose.

Table 3-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

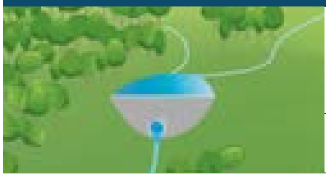
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 3-1. Key information on water flows, stores and use in the North East Coast region[2]

Landscape water balance

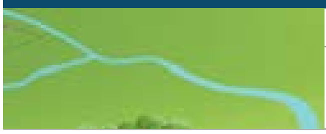
	During 2009–10			During the last 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	866 mm	+5%	64	1,124 mm (1988–89)	533 mm (1992–93)
Evapotranspiration	675 mm	-3%	42	818 mm (1998–99)	515 mm (1994–95)
Landscape water yield	172 mm	+25%	73	317 mm (1990–91)	51 mm (1986–87)

Surface water storage (comprising approximately 83% of the region's total surface water storage)



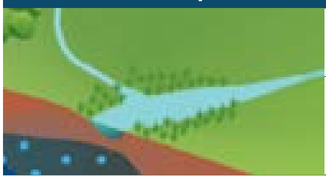
Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
8,520 GL	6,573 GL	77.1%	7,615 GL	89.4%	+12.3%

Measured streamflow in 2009–10



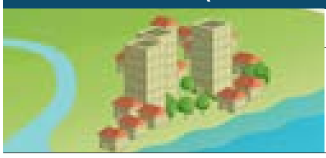
Northern rivers	Central north rivers	Central south rivers	Southern rivers
Average to above average	Average to above average	Above average to very much above average	Predominantly average

Wetlands inflow patterns in 2009–10



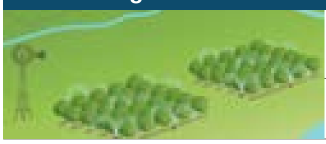
Bowling Green Bay	Great Sandy Straight	Moreton Bay	Southern Fitzroy River Floodplain complex
Average to above average in summer	Average to above average in late summer	Variable, above average in late summer	Average to exceptionally high in late summer

Urban water use (Brisbane and Gold Coast)



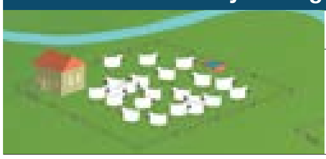
Water supplied 2009–10	Trend in recent years	Restrictions
176 GL	Steady (low relative to historical levels)	Eased from Medium level to Permanent Water Conservation

Annual irrigation water use in 2009–10 for the natural resource management regions



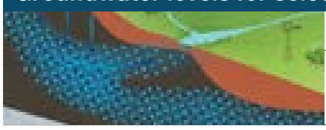
Burdekin	Burnett-Mary	Fitzroy	Mackay	South East	Wet tropics	Cape York
453 GL	252 GL	192 GL	179 GL	143 GL	107 GL	3 GL

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Average and above average in most areas, very much above average in the far west of the region	Above average to very much above average across almost the entire region

Groundwater levels for selected groundwater management units in 2009–10



Callide	Burdekin
Below average	Above average

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

3.3 Description of region

The North East Coast region is a long, narrow area of Queensland between the Great Dividing Range and the Coral Sea. It is bounded at the north by the Torres Strait and in the south by the Queensland–New South Wales border. The region covers 451,000 km^2 of land area. River basins vary in size from 257 to 143,000 km^2.

The climate of the region is subtropical to tropical with hot, wet summers and cooler, dry winters. The monsoonal summer rainfall is more reliable in the north and winter rainfall is more reliable in the south.

The region includes some of the most topographically diverse terrain in Australia, including high relief associated with coastal ranges and tablelands and a retreating escarpment with residual outliers on the coastal alluvial plains. North of Innisfail are the highest mountains in Queensland with the highest rainfall areas in Australia. In contrast, the area from just north of Townsville to as far south as Bundaberg is relatively dry.

Most of the region drains towards the Great Barrier Reef (Figure 3-2). The largest rivers are the Suttor and Belyando rivers in the Burdekin River basin and the Nogoa River in the Fitzroy River basin. Annual streamflow volumes at gauging sites on the Brisbane, Mary, Burnett, Fitzroy, Burdekin, North and South Johnstone, Mulgrave, Barron, Daintree, Bloomfield and Normanby rivers are examined in Section 3.5.

The region includes a number of Ramsar estuarine wetland sites which are of international ecological importance and provide a water quality filtering linkage to the Great Barrier Reef. The freshwater wetlands of the Southern Fitzroy River floodplain are an important habitat for waterbirds, shorebirds and various aquatic species. Recent flows into these wetlands are examined in Section 3.5.

The region has a population greater than 3.5 million. The largest population centres are Brisbane, the Gold Coast and the Sunshine Coast in the southeast. Other centres with populations greater than 25,000 include Hervey Bay, Bundaberg, Gladstone, Rockhampton, Mackay, Townsville and Cairns. The water supply to significant urban areas is addressed in Section 3.6.

Town centres in the region are supplied water from systems operated by local government councils except in southeast Queensland where water is supplied from a more complicated supply system operated by a number of organisations. The southeast Queensland Water Grid is an integrated system that secures and manages these water supplies. The Water Grid comprises a network of treatment facilities and two-way pipes that move water between new and existing sources across the region. The Gold Coast Desalination Plant and the Western Corridor Recycled Water Scheme provide water sources that are resilient to the climatic condition. Purified recycled water is supplied to Swanbank and Tarong power stations with the potential to supply water to industrial and agricultural customers in the future. It can also supplement drinking supplies from Lake Wivenhoe if storage levels drop below 40 per cent.

There are approximately 146 major storages in the region with a total accessible storage capacity in excess of 10,600 GL. The largest storages are Burdekin Falls Reservoir (Lake Dalrymple) in the Burdekin River basin and Fairbairn Reservoir (Lake Maraboon) in the Fitzroy River basin.

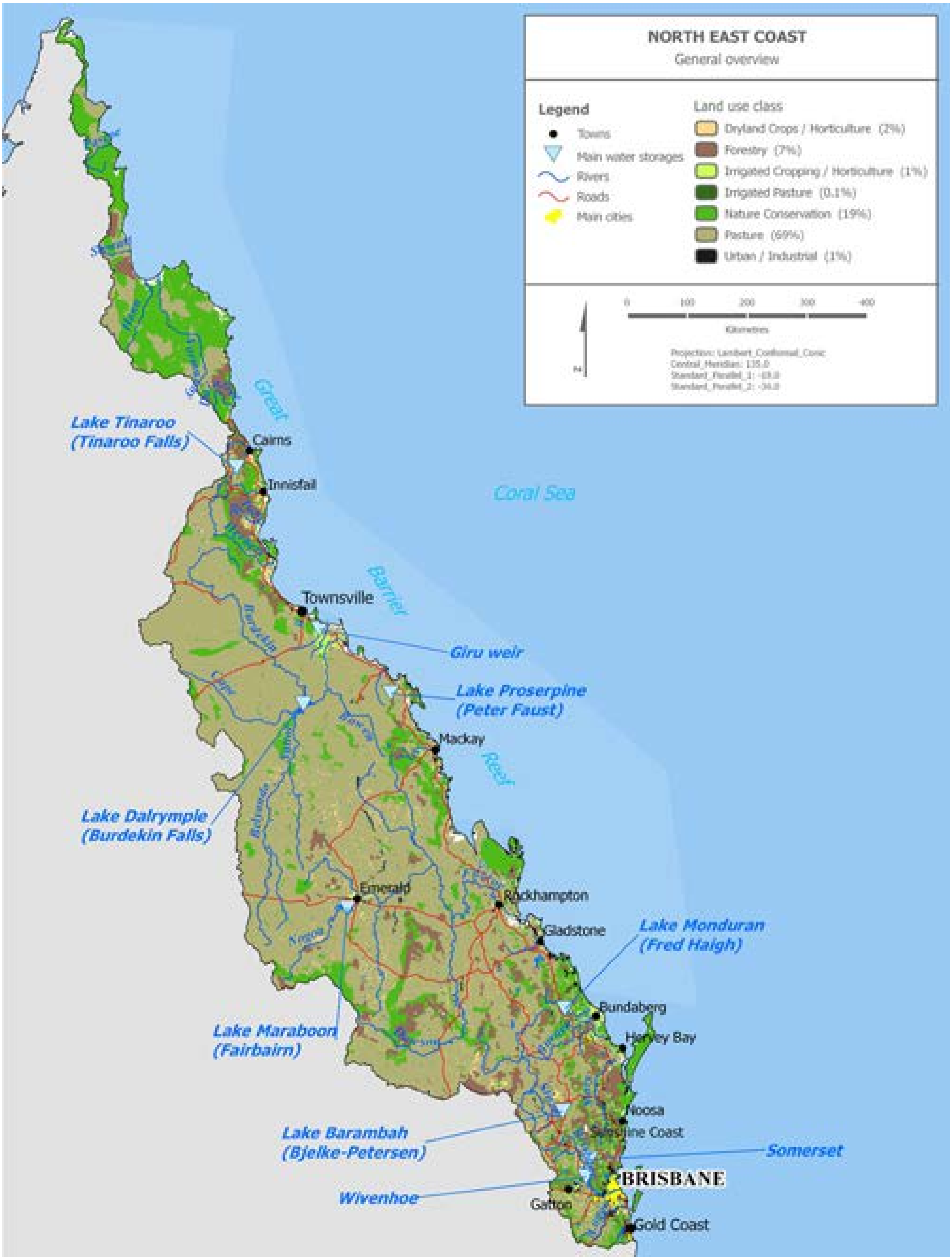


Figure 3-2. Key landscape and hydrological features of the North East Coast region (land use classes based on Bureau of Rural Sciences 2006)

3.3 Description of region (continued)

The mix of land use in the region is illustrated in Figure 3-2. Most of the region is relatively undeveloped, much of which is used for grazing. In the north this occurs on native rangelands with fewer management inputs and pasture improvement than in southern river basins. Dryland and irrigated agriculture account for approximately 0.4 per cent of the land use of the area. Intensive land uses such as urban areas account for 0.2 per cent of the area.

The largest areas of irrigated agriculture are located in the Brisbane, Mary, Burnett, Burrum and Kolan river basins in the south; Plane Creek, the Fitzroy and Pioneer river basins in the centre of the region; and the Haughton and Burdekin river basins in the north. Water supply to the Burdekin irrigation district is described in Section 3.7.3.

The hydrogeology of the region is dominated by a large area of outcropping fractured basement rock. The groundwater systems in fractured rock typically offer restricted low-volume groundwater resources. In contrast, significant groundwater resources are localised in alluvial valley systems and coastal sand deposits. A more detailed description of the groundwater status in the region is given in Section 3.5.3. Surface water is the primary source of water supply for public use with groundwater mainly used for irrigation in alluvial valleys like the lower Burdekin area and Lockyer Valley, and for private stock and domestic supplies. This is reflected by the relatively small size of the groundwater management areas and the limited groundwater use in the region.

Greater resource potential is associated with the aquifer groups labelled in Figure 3-3 as:

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

Another significant group is the Great Artesian Basin sediments, including the small area of intake beds of the Great Artesian Basin that are present along the western border of the region. The Great Artesian Basin is one of Australia's largest and most significant groundwater basins; however, it is not dominant in the region.

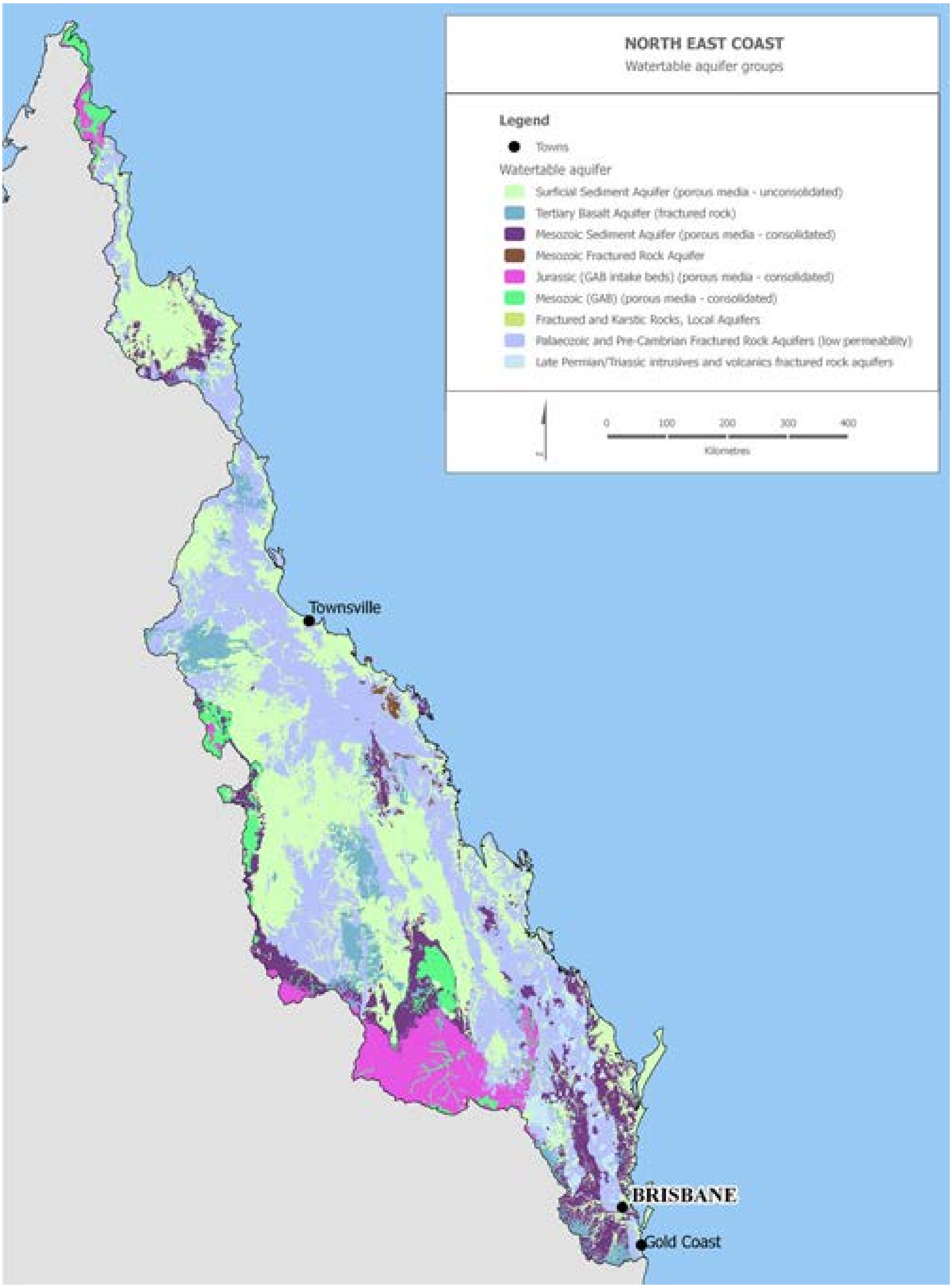


Figure 3-3. Watertable aquifer groups in the North East Coast region (Bureau of Meteorology 2011e)

3.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 3-4 shows that the North East Coast region experiences highly seasonal rainfall with a dominant wet summer period and a dry winter period. The 2009–10 year began with dry conditions prevailing between July and November. The summer was wetter than usual, with the dry El Niño conditions in preceding months giving way to very wet conditions, particularly in the south of the region. This change was largely due to the monsoonal low event of late February and early March 2010, generating extremely high rainfall and widespread flooding in southern Queensland. Tropical cyclone *Olga* passed over the Cape York Peninsula in late January 2010 causing higher than average rainfall in the north of the region.

The dry conditions experienced at the beginning of 2009–10 limited evapotranspiration to below normal levels between October and January. The wetter than usual summer, and resulting increased water availability, returned evapotranspiration to average levels from March to June 2010.

Monthly landscape water yield for the region remained low for the dry period between July and December 2009, but shows a clear response to the higher rainfall experienced during the wet season of 2009–10. The extreme January–March 2010 rainfall events generated a very noticeable response in regional landscape water yield which was maintained until May 2010.

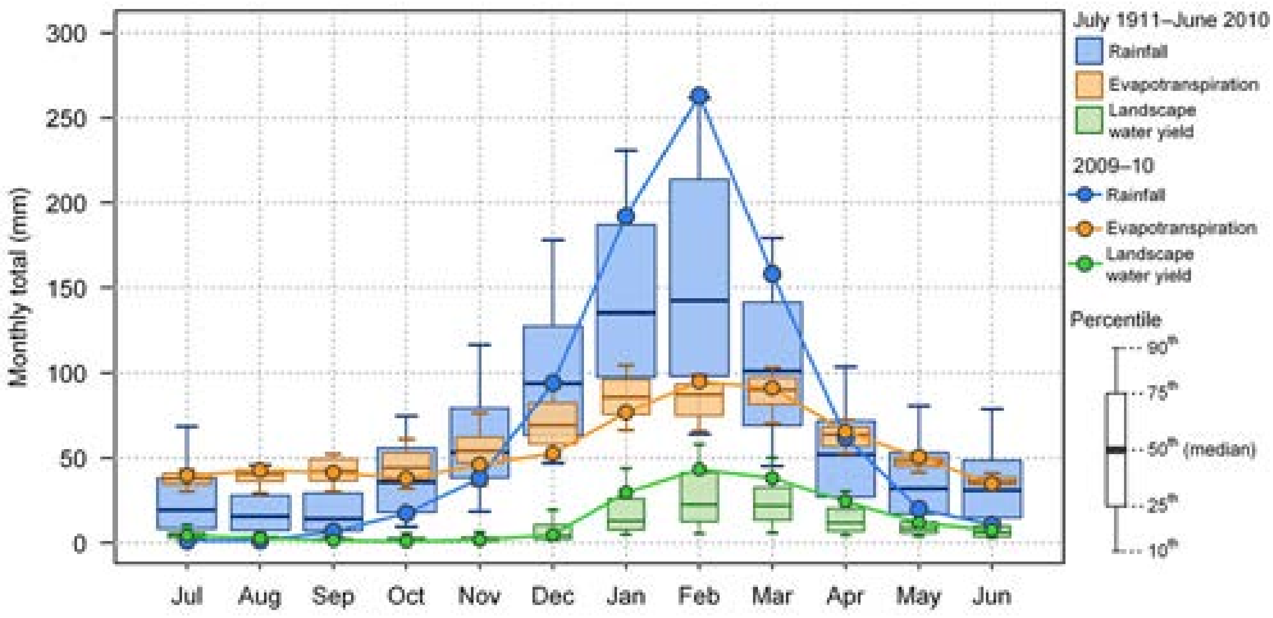


Figure 3-4. Monthly landscape water flows for the North East Coast region in 2009–10 compared with the long-term record (July 1911 to June 2010)

3.4.1 Rainfall

Rainfall for the North East Coast region for 2009–10 was estimated to be 866 mm, which is five per cent above the region's long-term average (July 1911 to June 2010) of 827 mm. Figure 3-5 (a) shows that during 2009–10, the highest rainfall occurred along the coastal areas and follows a general decreasing rainfall gradient heading inland to the west of the region.

Rainfall deciles for 2009–10, shown in Figure 3-5 (b), indicate that average levels of rainfall were experienced across most of the region. Some areas in the north and west were wetter than average. Below average rainfall conditions were observed for limited areas, particularly the centre of the region.

Figure 3-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 533 mm (1992–93) to 1,124 mm (1988–89). The annual average for the period was 804 mm.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 3-6 (b). Summer rainfall averages are consistently higher than winter. This reflects the general seasonal pattern of rainfall for the region with wet summer months and low winter rainfall, particularly to the north of the region.

These graphs of annual and seasonal rainfall indicate the presence of cyclical patterns in the region's annual rainfall over the 30-year period, which are particularly noticeable in the higher summer rainfall averages.

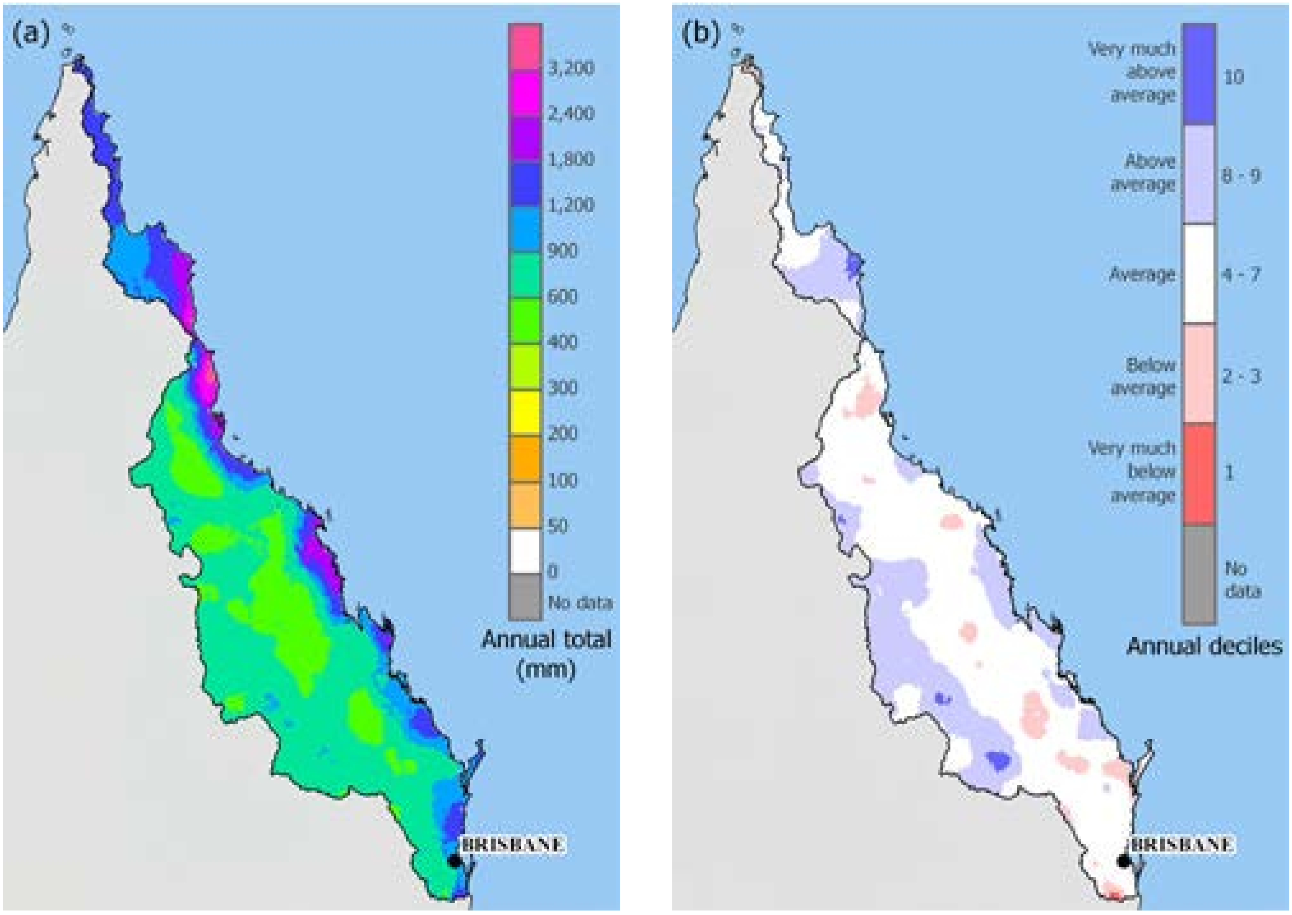
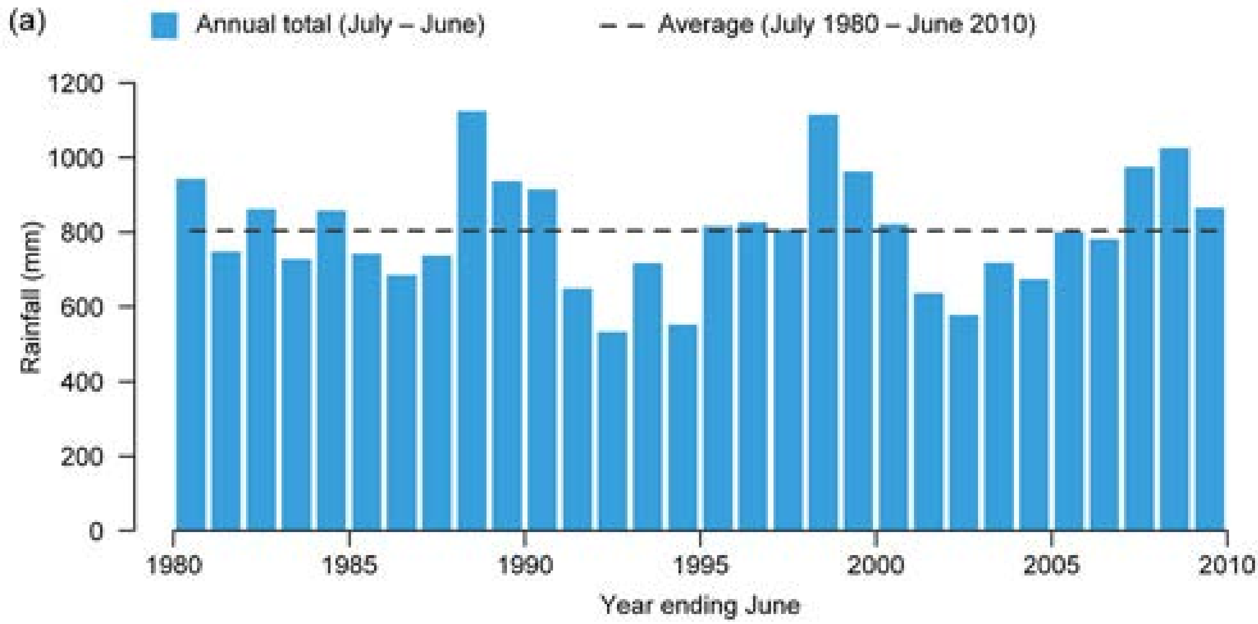


Figure 3-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North East Coast region



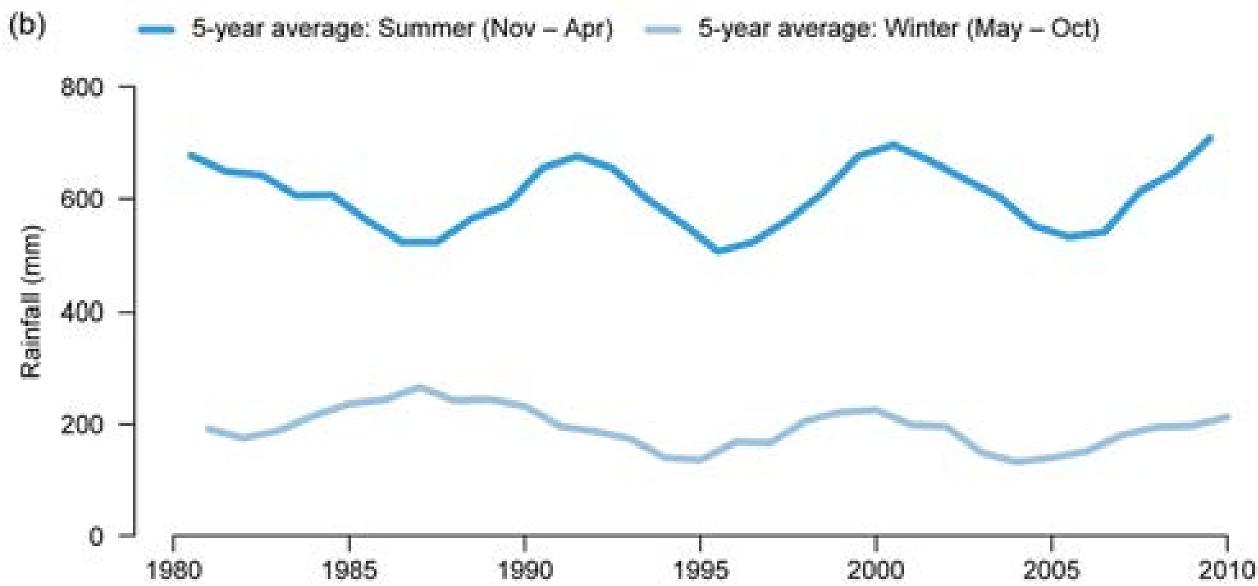


Figure 3-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the North East Coast region

3.4.1 Rainfall (continued)

Figure 3-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the modelled change in seasonal rainfall over the 30 years.

The analysis of summer rainfall indicates strong positive rainfall trends in the north and central areas of the region. Decreasing trends in summer rainfall are observed across the southern half of the region, strengthening toward the very far south. The equivalent analysis of the winter rainfall periods shows slight downward trends in rainfall across the majority of the region.

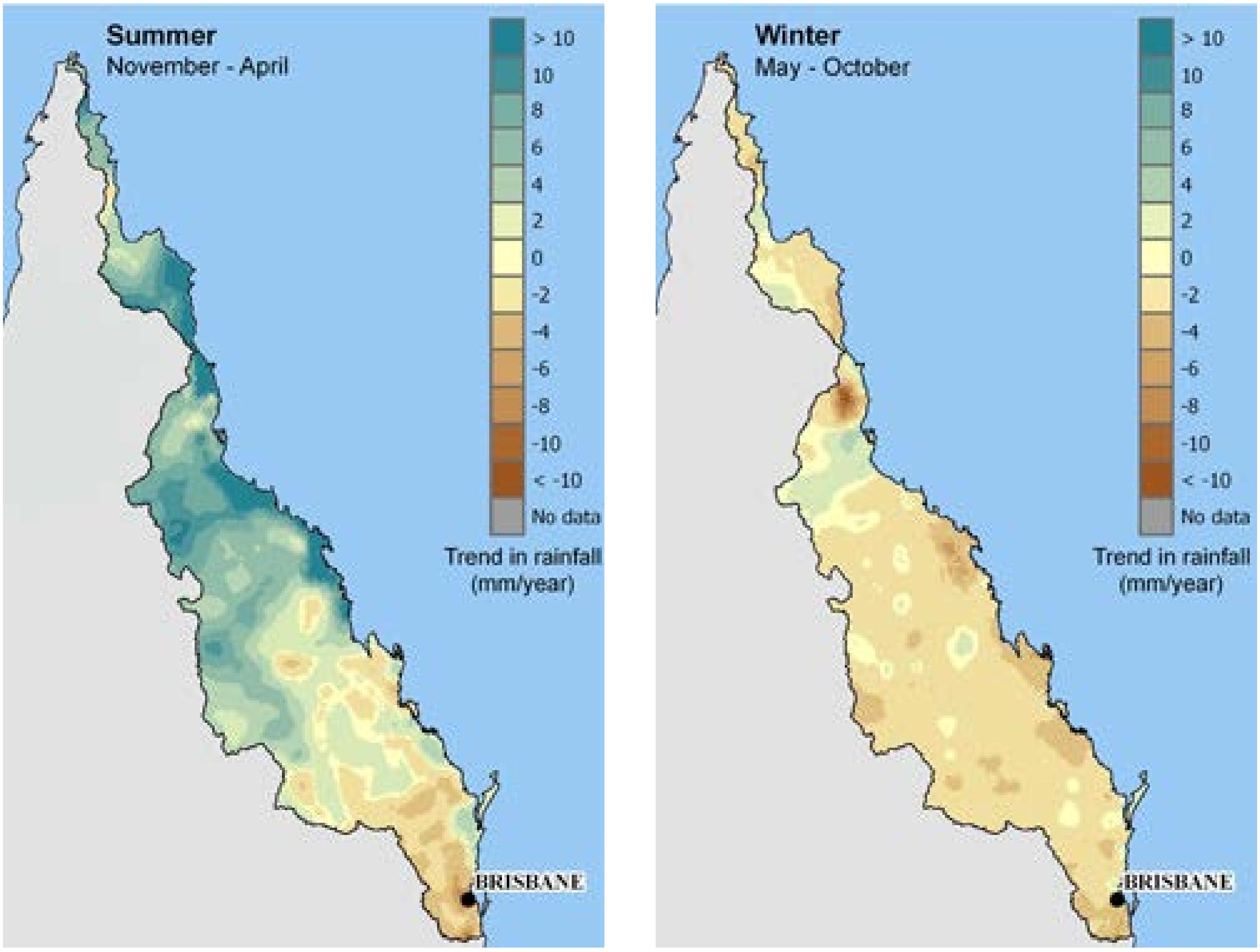


Figure 3-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the North East Coast region. The statistical significance of these trends is often very low

3.4.2 Evapotranspiration

Evapotranspiration for the North East Coast region for 2009–10 was estimated to be 675 mm, which is three per cent below the region's long-term (July 1911 to June 2010) annual average of 698 mm. The distribution of annual evapotranspiration across the region in 2009–10, shown in Figure 3-8 (a), is closely related to the distribution of annual rainfall (Figure 3-5 [a]). Evapotranspiration for the year was highest along the coastal areas and lowest across the west of the region.

Evapotranspiration deciles for 2009–10, shown in Figure 3-8 (b), indicate evapotranspiration was below average or very much below average across the southern areas of the region as well as in limited areas to the far north. Average values are observed across the centre of the region with above average evapotranspiration in the central west areas.

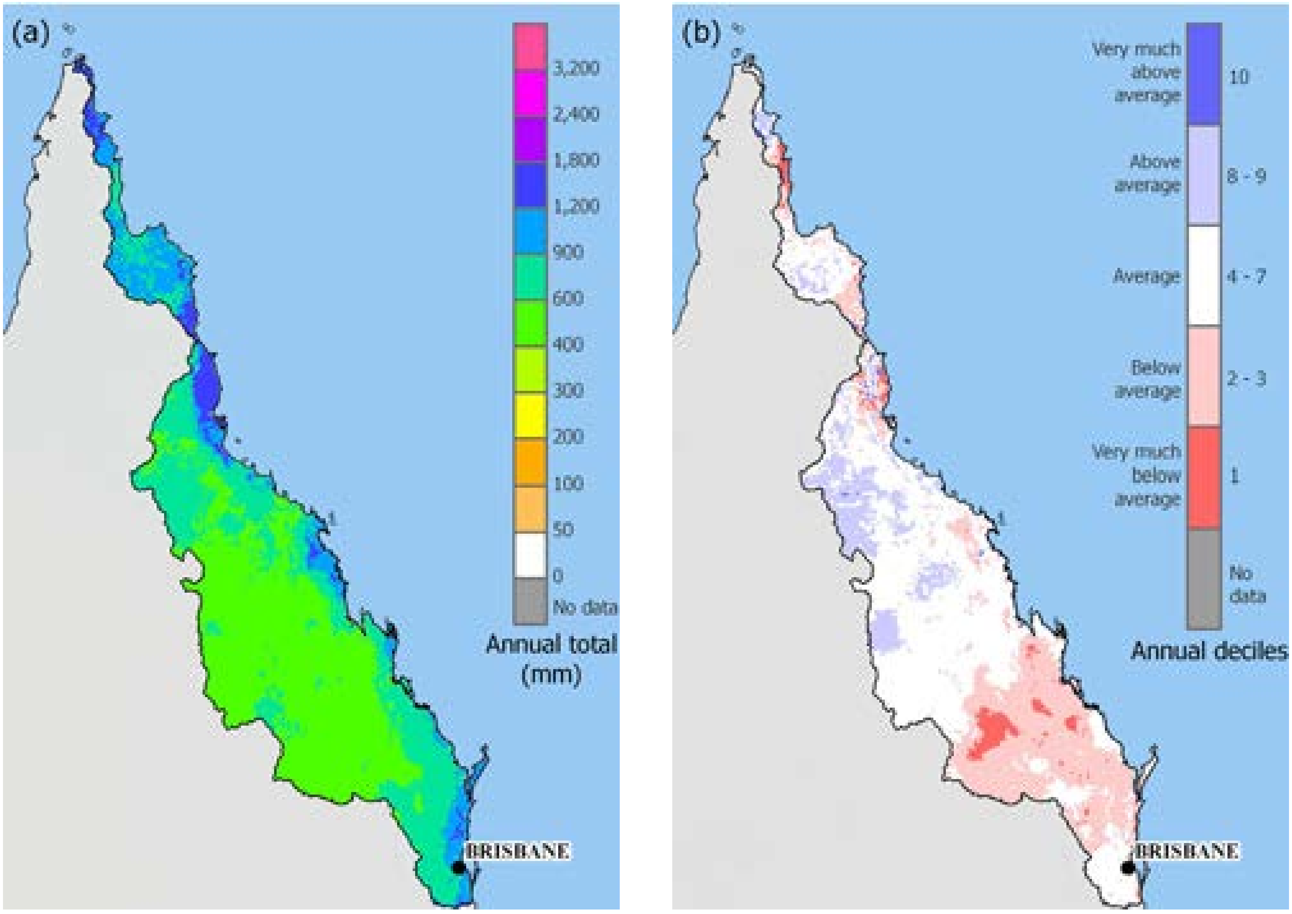
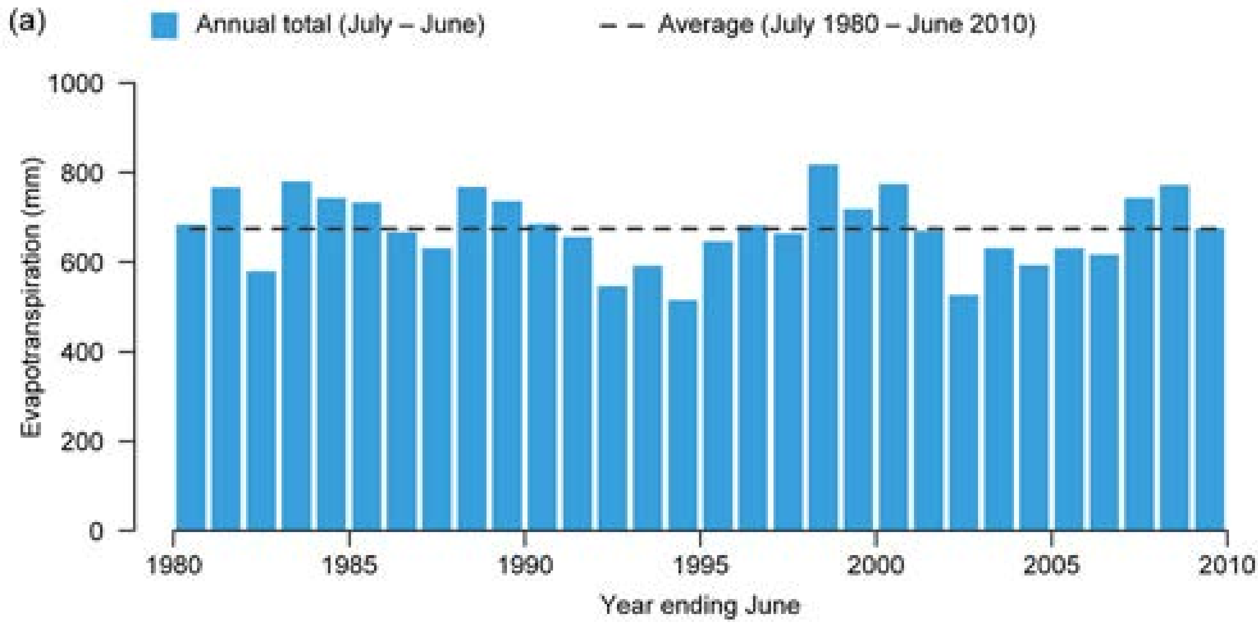


Figure 3-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North East Coast region



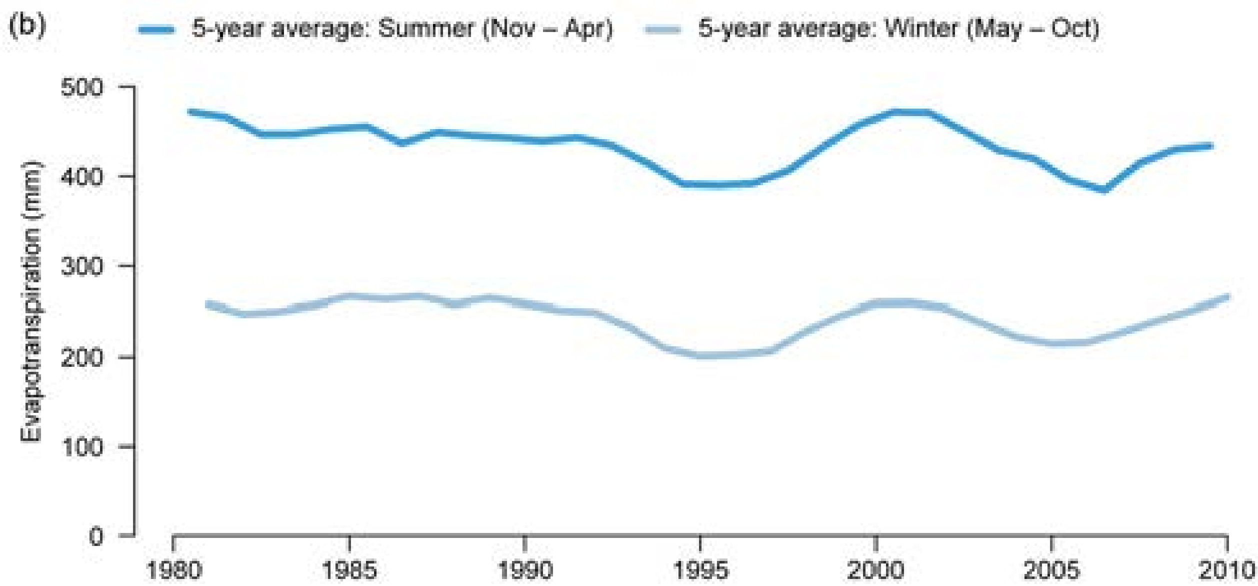


Figure 3-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the North East Coast region

3.4.2 Evapotranspiration (continued)

Figure 3-9 (a) shows annual evapotranspiration for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 515 mm (1994–95) to 821 mm (2008–09). The annual average for the period was 674 mm. The data show that the variability in annual evapotranspiration is closely linked to the variation between relatively wet and dry periods (Figure 3-6 [a]).

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) is presented using moving averages in Figure 3-9 (b). Consistent with rainfall, regional evapotranspiration for the summer period is consistently higher than during winter. The time-series of seasonal evapotranspiration averages reflect the cyclical patterns identified in the seasonal rainfall (Figure 3-6 [b]). This variability is particularly evident over the second half of the 30-year period.

Figure 3-10 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the modelled change in seasonal evapotranspiration over the 30 years.

In general, the spatial pattern indicates a slight decreasing trend in the south and slight increasing trends across much of the centre of the region for both summer and winter period evapotranspiration. The magnitudes of the trends, both positive and negative, are greatest for the higher evapotranspiration of the summer period.

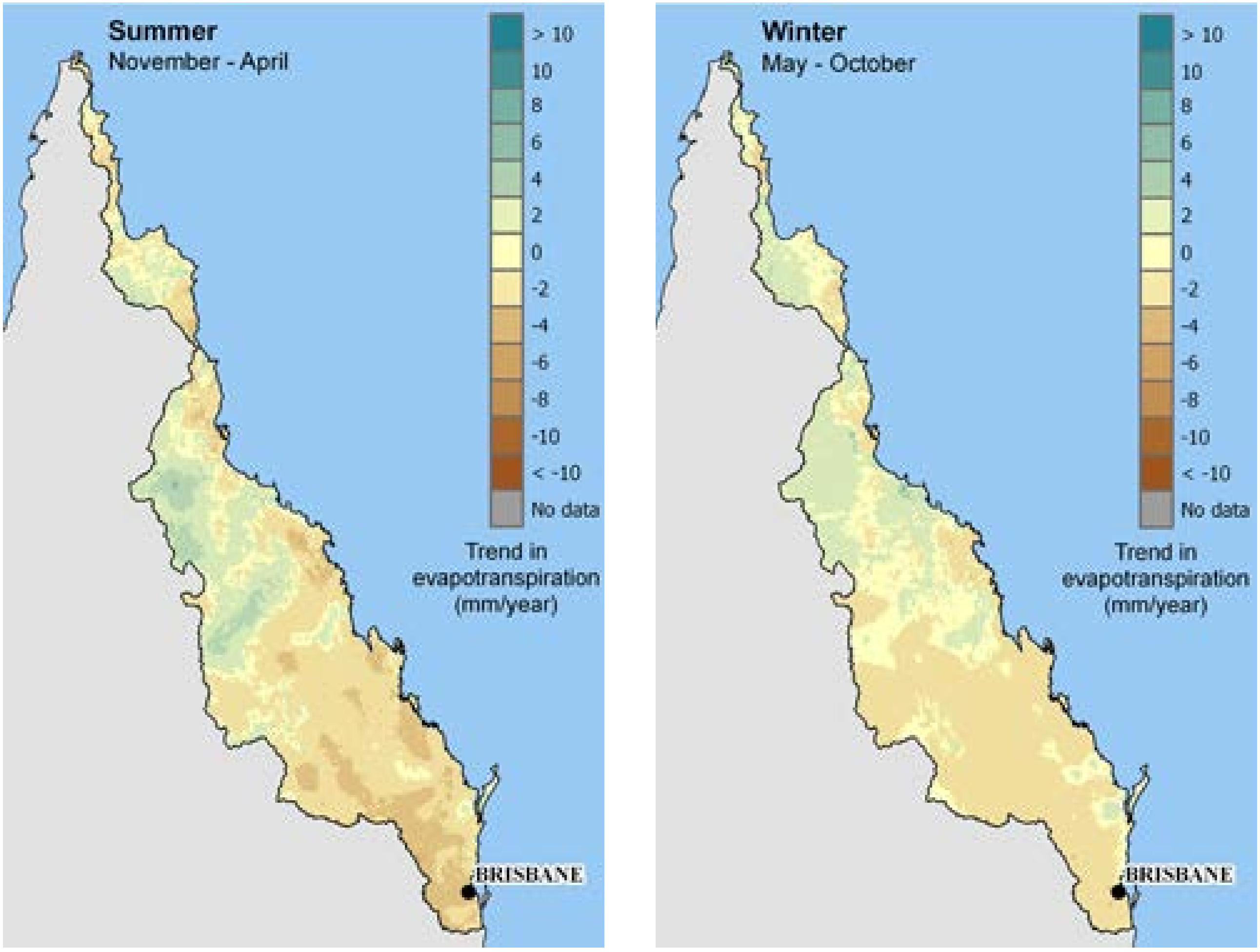


Figure 3-10. Linear trends modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the North East Coast region. The statistical significance of these trends is often very low

3.4.3 Landscape water yield

Landscape water yield for the North East Coast region for 2009–10 was estimated to be 172 mm, which is 25 per cent above the region's long-term annual average of 138 mm (July 1911 to June 2010). Figure 3-11 (a) shows landscape water yield for 2009–10 and reflects a similar pattern to the distribution of annual rainfall (Figure 3-5 [a]). Highest values are observed along the eastern coast with a sharply decreasing gradient to the west of the region. Landscape water yield deciles for 2009–10, shown in Figure 3-11 (b), indicate above average yield values across much of the west, along the southern coast and in areas to the north of the region. Average and below average values are identified through the centre of the region.

Figure 3-12 (a) shows annual landscape water yield for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 51 mm (1986–87) to 317 mm (1990–91). The annual average for the period was 134 mm.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 3-12 (b). The graph shows that water yield is consistently higher during the summer period compared to the winter period. The summer averages also exhibit a greater interannual and cyclical variability, reflecting the pattern observed in the region's rainfall (Figure 3-6 [b]).

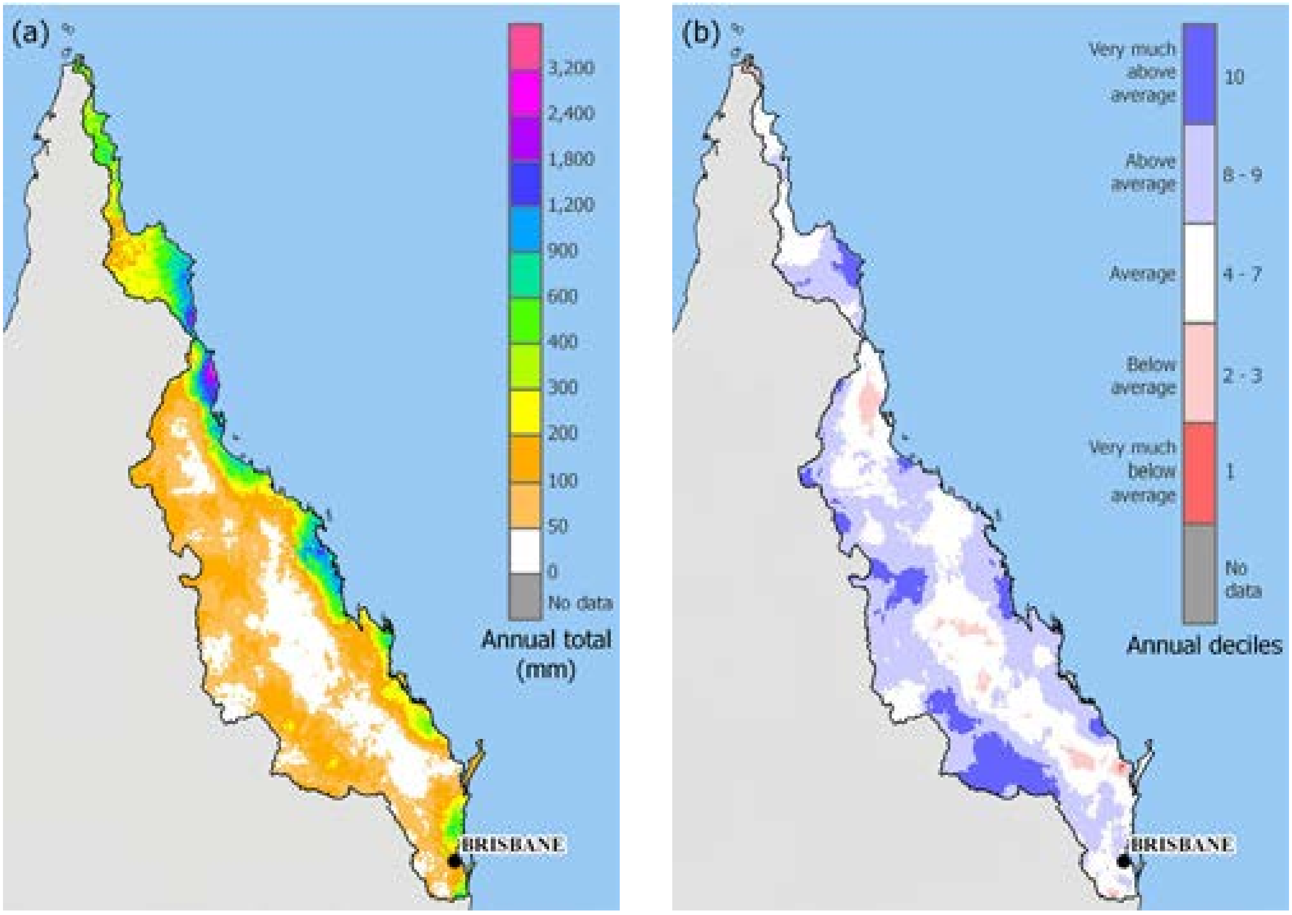


Figure 3-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North East Coast region

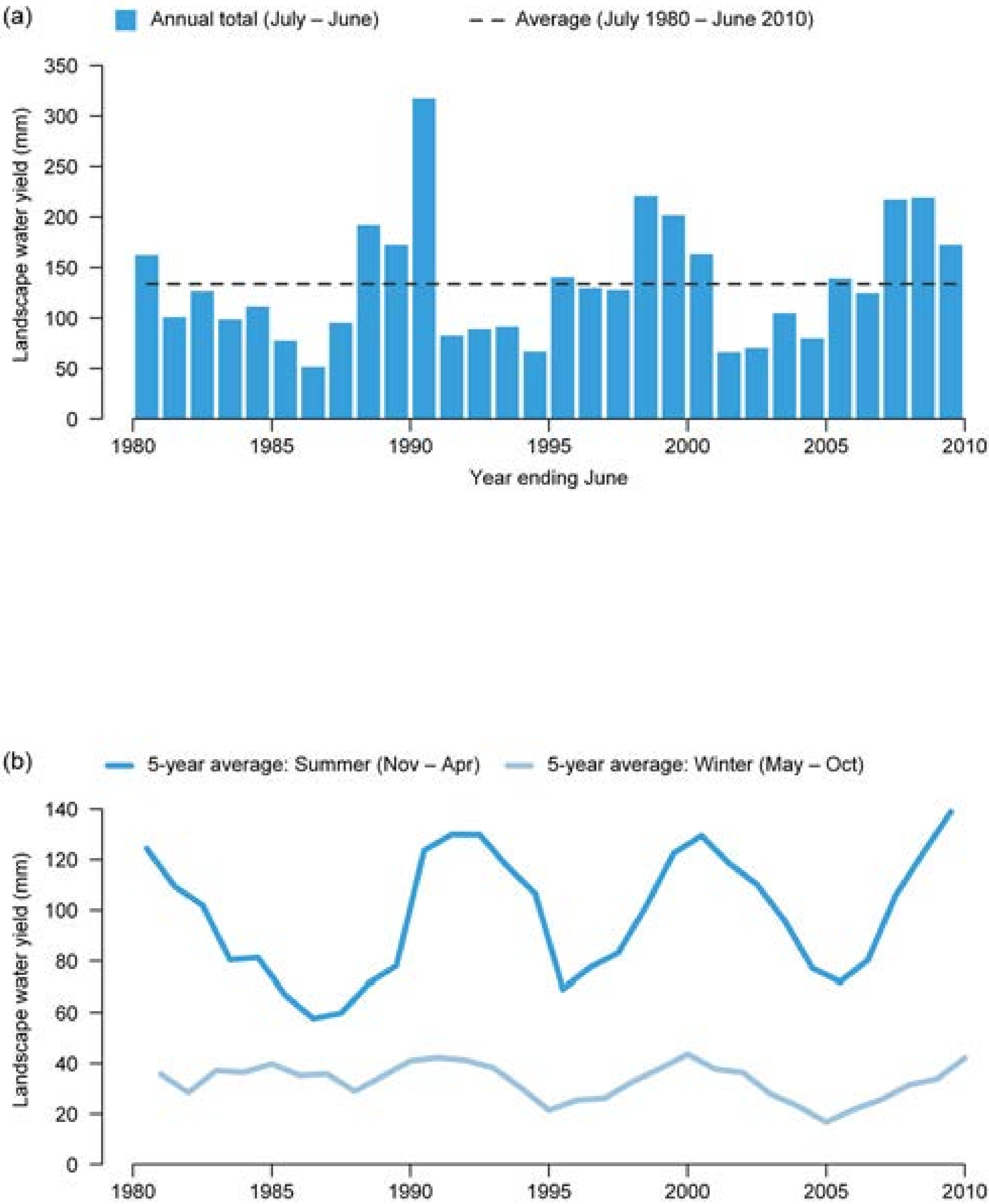


Figure 3-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the North East Coast region

3.4.3 Landscape water yield (continued)

Figure 3-13 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years. The pattern and distribution of landscape water yield trends across the region are closely related to those of rainfall (Figure 3-7).

Analysis of the summer period landscape water yield shows strongest positive trends in the northern and central areas, which are particularly strong along the northern coast. Over the 30-year period the magnitude of these increasing trends in the north of the region is high relative to average summer landscape water yield in these areas. Decreasing trends are identified in the far south of the region in the areas surrounding Brisbane.

The winter period analysis indicates slight negative trend in landscape water yield across much of the south of the region and slight positive trends in the far north of the region. The clearly defined area of strong decreasing trend is identified for a limited part of the central north and may be an artefact of errors in the underlying rainfall data. This anomaly can also be observed in the winter period rainfall trend analysis (Figure 3-7).

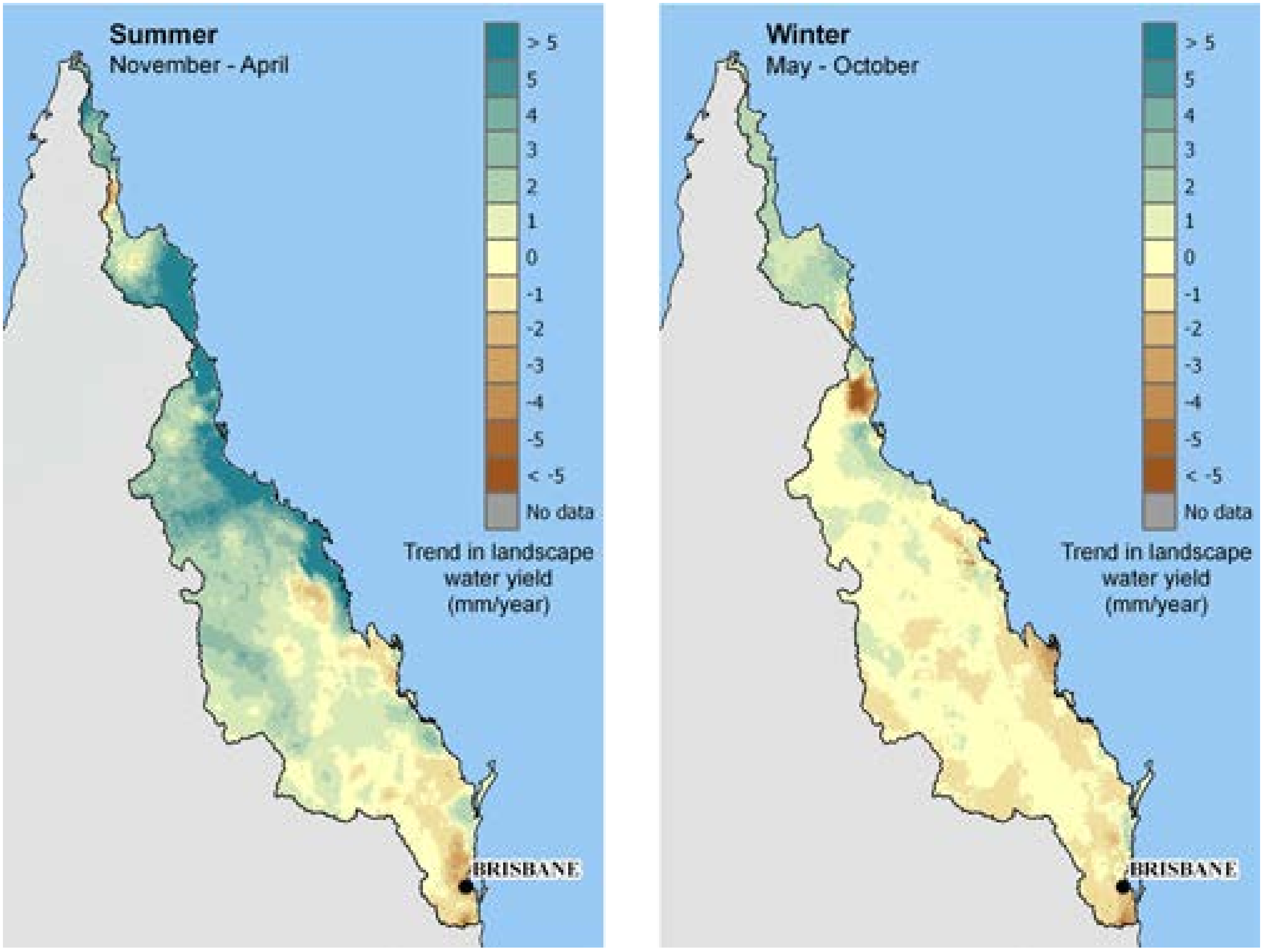


Figure 3.13 Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the North East Coast region. The statistical significance of these trends is often very low

3.5 Rivers, wetlands and groundwater

For examination of regional streamflow in this report, 48 stream gauges with relatively long records across 20 geographically representative river basins, were selected (Figure 3-14). Streamflow at these gauges in 2009–10 was analysed in relation to historical patterns of flow. Additionally, seven of these gauges were selected for analysis of patterns of wetland river inflows for the region.

The groundwater management units within the region are presented in Figure 3-15 (extracted from the Bureau's Interim Groundwater Geodatabase). Most of the groundwater management units are relatively small in area reflecting the limited groundwater use in the region.

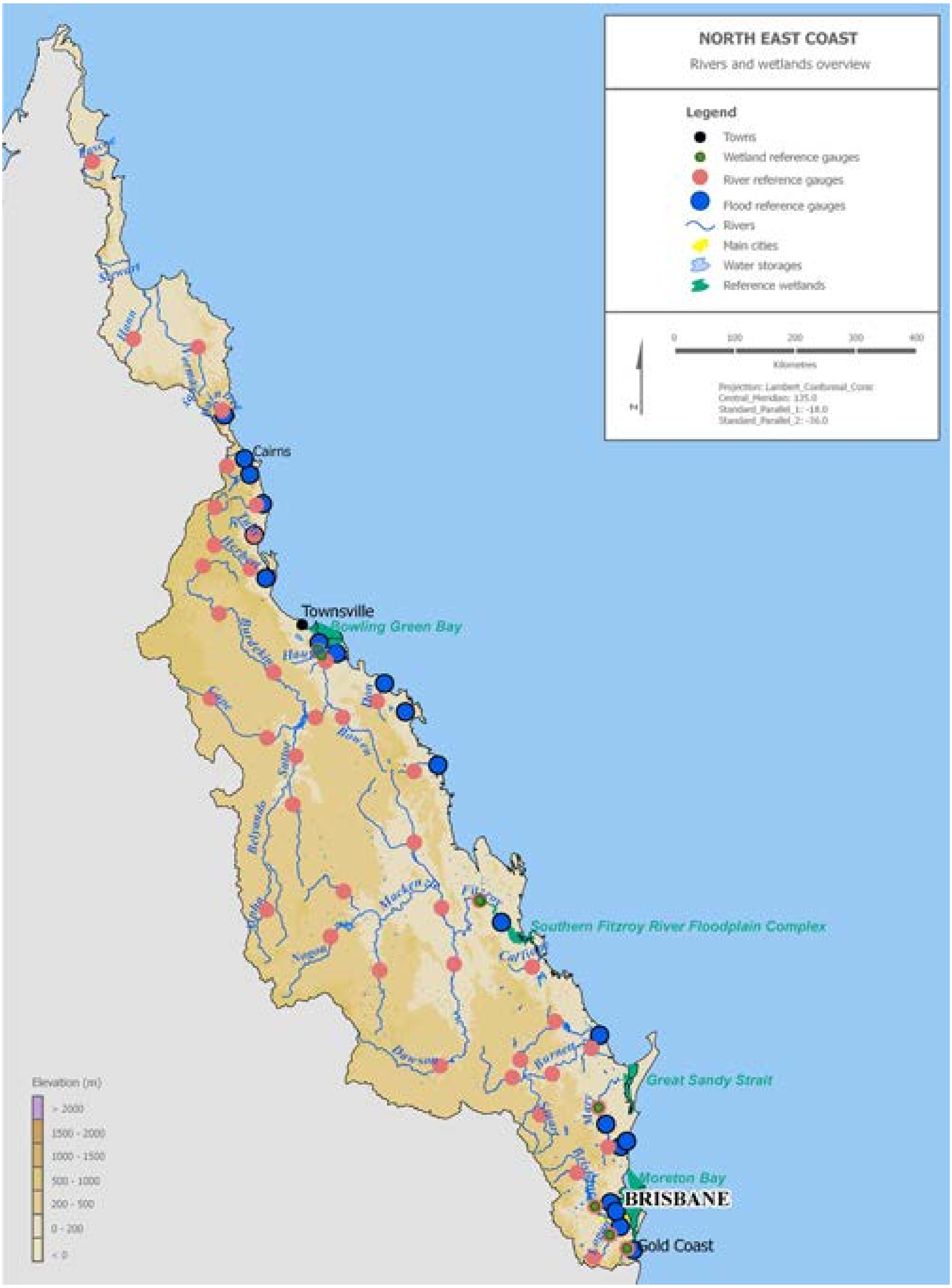


Figure 3-14. Stream gauges selected for analysis in the North East Coast region

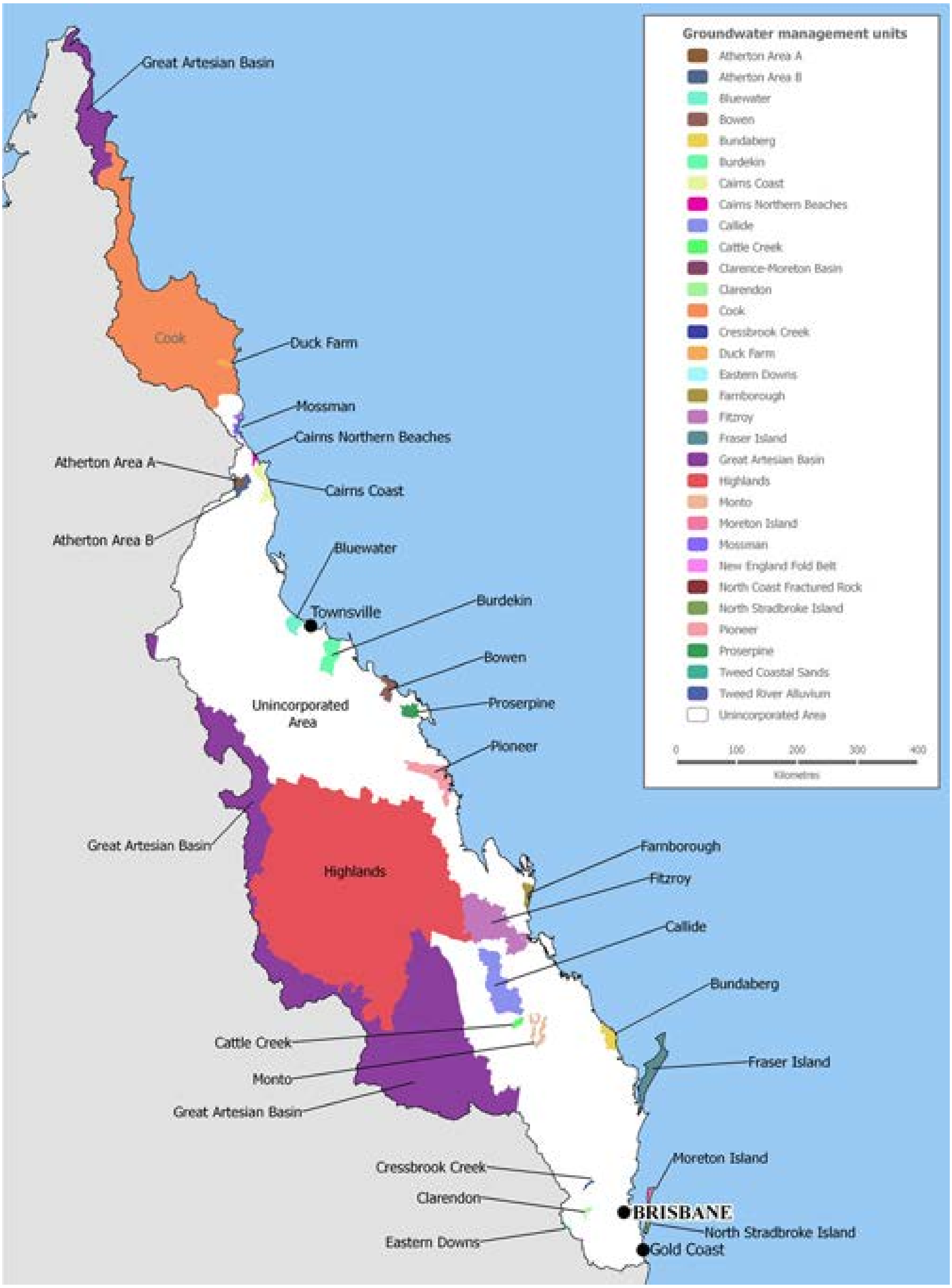


Figure 3-15. Major groundwater management units in the North East Coast region (Bureau of Meteorology 2011e)

3.5.1 Streamflow and flood report

Figure 3-16 presents an analysis of river flows over 2009–10 relative to annual flows for the last 30 years at 46 monitoring sites throughout the North East Coast region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for 2009–10 are colour-coded relative to the decile rank over the 1980 to 2010 period at each site.

With regard to total annual discharge for 2009–10, Figure 3-16 shows that observations from monitoring gauges in the region generally reflect the mostly average to above average modelled landscape water yield results shown in Figure 3-11. According to this Figure, most run-off was generated in the upstream reaches of the rivers, causing above average to very much above average total flows in many rivers in the centre of the region.

Broadly, Figure 3-16 shows:

- streamflow for 2009–10 was below average at only two of the 46 monitoring sites. These were on the Brisbane River below Lake Wivenhoe in the far south of the region and also in an upstream tributary to the Burdekin River in the north
- streamflow was average at 19 monitoring sites. These were on rivers in the far south of the region and among river basins in the central north
- above average streamflow was recorded at 46 monitoring sites. These are mainly located on rivers in the far north, centre and south of the region
- very much above average streamflow was recorded at five sites, located on rivers in the central south of the region.

Figure 3-16 shows a strong pattern of correlation between summer (November 2009 to April 2010) streamflow and total annual streamflow for 2009–10. This is to be expected given that the bulk of flows in the region, particularly in the north, occur over the summer months. It is apparent that while streamflow in the centre and south of the region was above average over 2009–10, flows in these river basins were even higher over the summer months compared with annual average conditions.

Through flood monitoring partnership arrangements, data were available for a number of flood gauges, allowing reporting on flood occurrence and severity at those sites. The two gauges selected as indicative stations for the North East Coast region are situated on rivers along the Queensland coast from Logan River in the south to the Daintree River in the north of the State (Figure 3-14). The stations were also selected on the basis of data quality and coverage for the 2009–10 period.

Rainfall associated with ex-tropical cyclone *Olga* was recorded in a wide area across Queensland during the first ten days of February 2010. Moderate to heavy rainfall produced fast stream rises over already saturated catchments. *Olga* crossed the coast, north of Cairns, initially on 24 January 2010 and reformed once in the Carpentaria Gulf. The cyclone crossed again around Normanton on 29 January. The system then weakened into a rain depression within hours of making landfall and tracked steadily southeast. The monsoon trough crossing the east coast was consequently dragged southward to the central coast region producing heavy rainfall and flooding in the Pioneer and Haughton river catchments. The Haughton River flood at Giru was the third highest on record.

Widespread shower and thunderstorm activity, spreading to rain over some areas, was recorded from 16–19 February 2010. The establishment of a ridge over Queensland, during 19 and 20 February, brought more stable conditions and confined rainfall to coastal and northern parts of the State. This moderate to heavy rainfall produced floods of varying severity in the Nogoa, Comet and Dawson rivers (all tributaries of the Fitzroy River). Flood levels at Rockhampton remained well below the minor flood level.

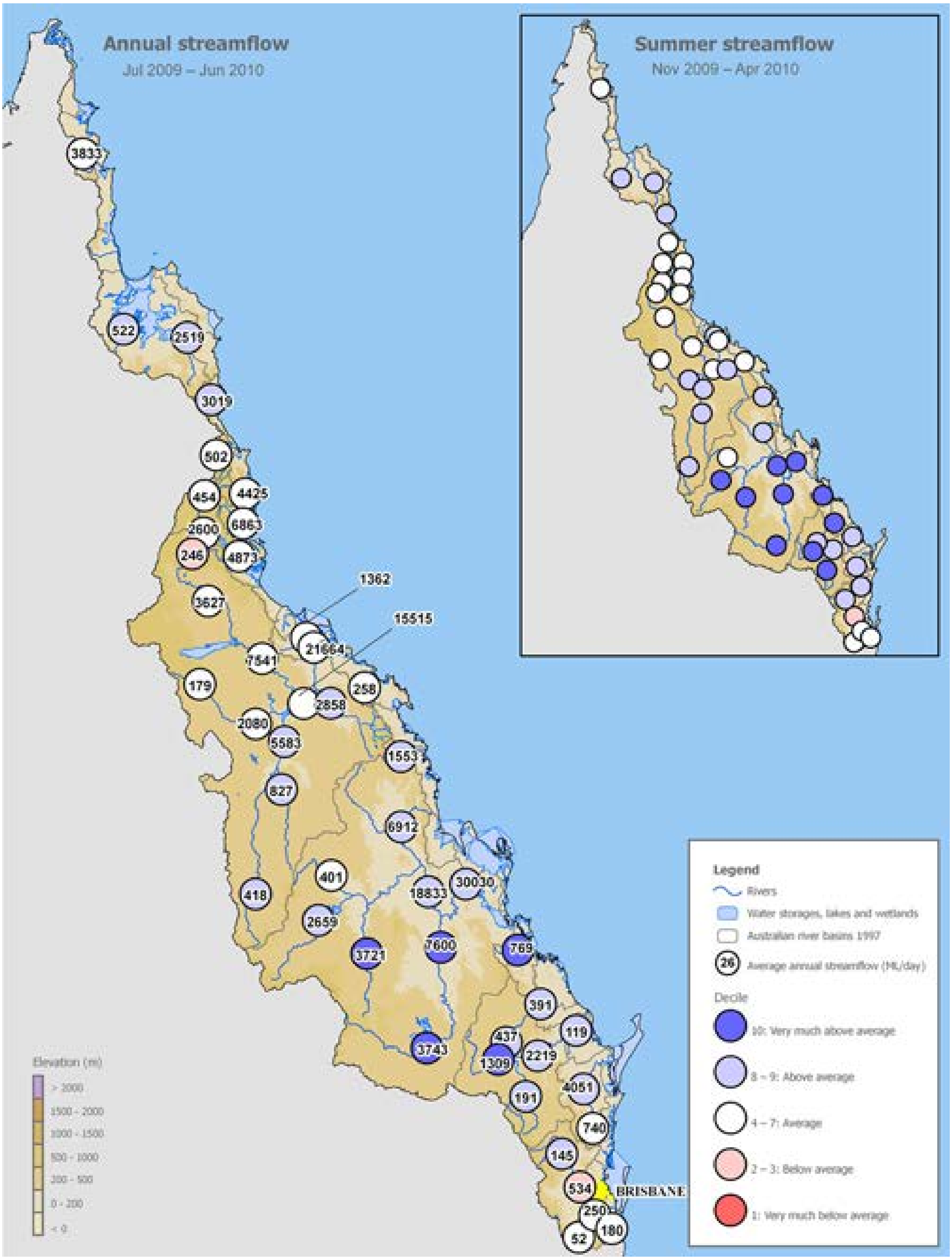
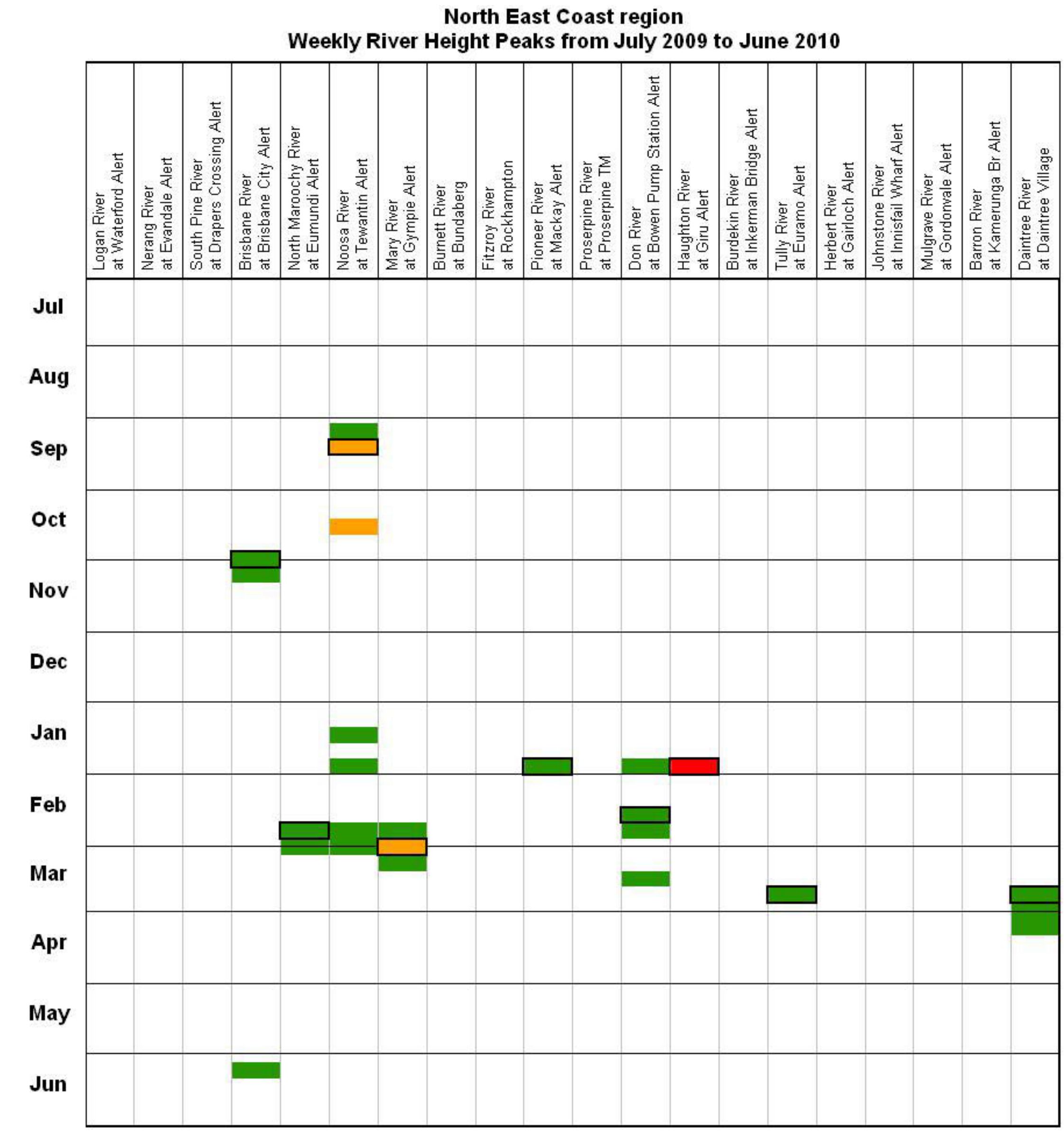


Figure 3-16 Annual and summer streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the North East Coast region

Table 3-3. Weekly flood classifications for key flood gauging sites within the region (flood classes are derived in consultation with emergency services and local agencies; the peak height for the year is also included)



Peak flood level (m)

	Logan River at Waterford Alert	Nerang River at Evandale Alert	South Pine River at Drapers Crossing Alert	Brisbane River at Brisbane City Alert	North Maroochy River at Eumundi Alert	Noosa River at Tewantin Alert	Mary River at Gympie Alert	Burnett River at Bundaberg	Fitzroy River at Rockhampton	Pioneer River at Mackay Alert	Proserpine River at Proserpine TM	Don River at Bowen Pump Station Alert	Haughton River at Giru Alert	Burdekin River at Inkerman Bridge Alert	Tully River at Euramo Alert	Herbert River at Gairloch Alert	Johnstone River at Innisfail Wharf Alert	Mulgrave River at Gordonvale Alert	Barron River at Kamerunga Br Alert	Daintree River at Daintree Village
Date	-	-	-	on 05/11/2009	on 02/03/2010	on 09/09/2009	on 03/03/2010	-	-	on 31/01/2010	-	on 18/02/2010	on 31/01/2010	-	on 28/03/2010	-	-	-	-	on 28/03/2010
Level	-	-	-	1.8	4.9	1.6	13.6	-	-	7.0	-	3.5	3.0	-	6.2	-	-	-	-	5.5

River height classes (m)

	Logan	Nerang	South Pine	Brisbane	North Maroochy	Noosa	Mary	Burnett	Fitzroy	Pioneer	Proserpine	Don	Haughton	Burdekin	Tully	Herbert	Johnstone	Mulgrave	Barron	Daintree
Major	9.0	2.5	6.0	3.5	6.0	1.8	17.0	7.0	8.5	9.0	9.0	5.5	2.5	12.0	9.0	11.5	6.0	14.0	8.0	9.0
Moderate	7.5	2.3	5.0	2.6	5.0	1.3	12.0	5.5	7.5	8.0	8.0	4.0	2.1	10.0	8.0	10.5	5.5	13.0	6.5	6.0
Minor	6.0	1.8	4.0	1.7	4.0	1.0	6.0	3.5	7.0	7.0	7.0	2.5	1.8	7.0	6.0	9.5	5.0	12.0	5.0	4.0

Colour codes:

- Below flood level
- Annual flood peak
- Major flooding
- Moderate flooding
- Minor flooding

3.5.2 Inflows to wetlands

This section looks at water flows into important wetlands in the region. Three internationally recognised Ramsar estuarine wetland sites (Bowling Green Bay, Great Sandy Straight and Moreton Bay) and a nationally important freshwater wetland site (the southern Fitzroy River floodplain complex) were selected for examination.

Seven wetland reference gauges were selected (Figure 3-14 and Figure 3-17) to enable an analysis of wetland river inflow patterns for the region. Figure 3-17 presents a comparison of 2009–10 monthly flows with monthly flows over the 30-year period 1980 to 2010 for each of the seven reference gauges.

While the seven selected reference gauges do not measure the total volumes of freshwater inflow to these wetlands, they do capture much of their temporal characteristics. In this regard, the following may be observed with respect to wetland water supply inflow in 2009–10 relative to the 30-year record:

- for the tropical north, above average summer flows in 2009–10 were balanced by average flows for the rest of the year
- for the southern Fitzroy River floodplain complex, the early summer inflows were around average; however, the bulk of summer wet season flows were very much above average
- for the Mary River feeding into the Great Sandy Strait in southern Queensland, the summer flow situation was similar to the above, with very much above average mid-summer season inflows
- for far southeast Queensland, river flows into Moreton Bay reflect substantially drier conditions in 2009–10, with the Brisbane, Logan and Nerang rivers presenting winter and summer flows which ranged from very much below average to average, except for average to above average flows in February–March 2010.

Figure 3-18 explores the pattern of changing wetland river inflows through the 30 years between 1980 and 2010. A five-year moving window was applied over daily streamflow data to produce the 10th, 50th and 90th flow percentiles for each of the seven reference gauges.

The 10th, 50th and 90th flow percentiles were selected to approximate patterns of low, median and high flows respectively. Low flows are associated with a base-level river flows needed to ensure a minimum level of ecological function during dry periods of the year. Median river flows sustain wetland hydrology and ecological function throughout most of the year. High flows are associated with the lateral movement of water into floodplains, and are necessary to sustain a high-level of wetland function.

Note that any variability in the flow percentiles of Figure 3-18 can be a result of changing climatic conditions as well as human interference. However, the purpose of the graphs is not to analyse the cause of the variability. In addition, the 10th percentiles (low flow) are sometimes estimated to be 0 ML/day and therefore are shown as the minimum plotted value for a gauge in Figure 3-18.

With respect to this 30-year period, the plots show:

- an overall ten-year cyclic high inflow pattern for all the reference sites similar to rainfall
- no obvious long-term trends in high inflow volumes except for the Brisbane River in the far southeast where decreasing trend is indicated
- increasing trends in median and low flow volumes for the rivers in the tropical north
- decreasing trends in low flow volumes in central Queensland on the Mary and Fitzroy rivers. From 1993 onwards the Fitzroy River has a markedly lower 10th percentile flow
- decreasing trends in median and low flow volumes at Logan River.

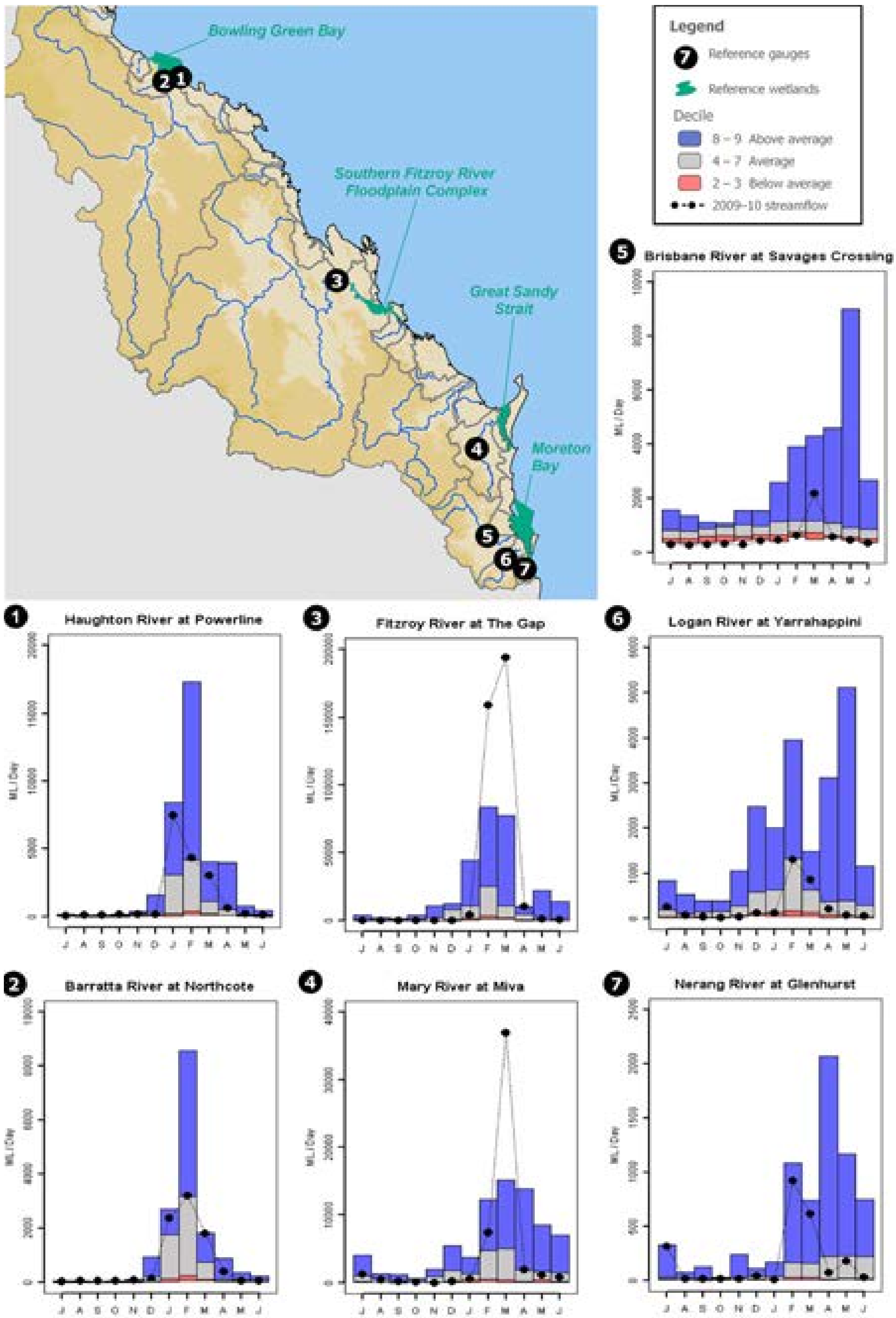


Figure 3-17. Monthly discharge hydrographs for 2009–10 compared with the period of 1980 to 2010 for reference gauges on rivers flowing into selected wetland sites of the North East Coast region

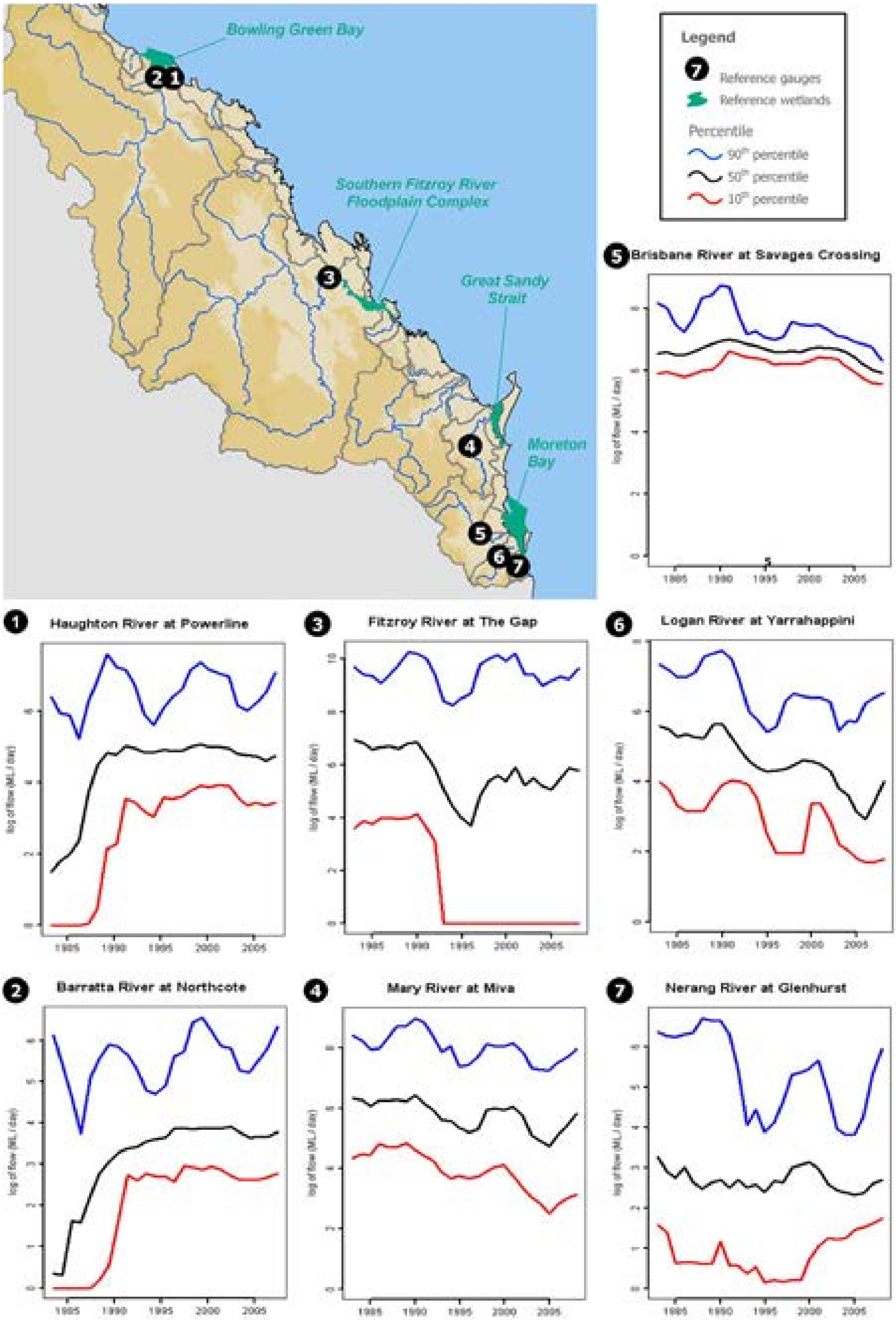


Figure 3-18. Daily flow percentiles extracted from a five-year moving window at reference gauges on rivers flowing into selected wetland sites of the North East Coast region

3.5.3 Groundwater status

Figure 3-19 shows the average watertable salinity (1990–2010) as total dissolved solids in milligrams per litre (mg/L), based on electrical conductivity measurements, at selected shallow groundwater bore sites across the North East Coast region. Generally, very fresh groundwater is present in the north of the region with the exception of the Lower Burdekin groundwater management unit where some salinity values are in excess of 3,000 mg/L (see Figure 3-15). Groundwater salinity in the lower part of the region is variable with some very high salinity values occurring in the Bundaberg groundwater management unit.

Figure 3-20 and Figure 3-21 show groundwater levels and salinity in selected bores across the region from 1990–2010. Caution is advised in interpreting single point measurements of groundwater level recorded in a groundwater bore. The groundwater conditions at a particular bore site are often atypical; for example local heterogeneity in the hydrogeology or groundwater extraction from neighbouring bores can have a significant effect on measured groundwater levels. The bores in Figure 3-20 and Figure 3-21 have been selected to try to avoid these issues and to provide a typical time-series of local groundwater conditions.

Figure 3-20 shows groundwater level and salinity measurements in the north of the North East Coast region, where there appears to be a rising trend in groundwater levels in bores two and three over the last 20 years. This reflects the rising trend in rainfall for the northern part of the region (Figure 3-7). The increasing irrigation in the Burdekin Irrigation Area over this period may also be affecting groundwater levels in bore two.

On the western edge of the region, bore five has a deep and steady groundwater level over the 20-year period. The two factors that are likely to be contributing to this behaviour are the lower rainfall in this area (resulting in slow steady recharge at depth) and the influence of a slow steady groundwater flow to the west in the Great Artesian Basin aquifers, which are present in the locality of the bore.

Figure 3-21 shows groundwater level and salinity measurements in the south of the North East Coast region. Bores one and five demonstrate a generally falling trend in groundwater level over the 20-year period, which is likely to be a response to the lower rainfall in the southern part of the region (Figure 3-7). The slightly rising trend in groundwater levels for bores two and three may be the result of the irrigation within the Bundaberg groundwater management unit.

In general, the variation in groundwater responses is an indication of differences in climatic conditions as well as soil and aquifer properties. The groundwater salinity values are typically relatively low (less than 3000 mg/L) and do not change greatly over the 20-year period. Further details of groundwater conditions in the Burdekin Irrigation Area are provided in Section 3.7.

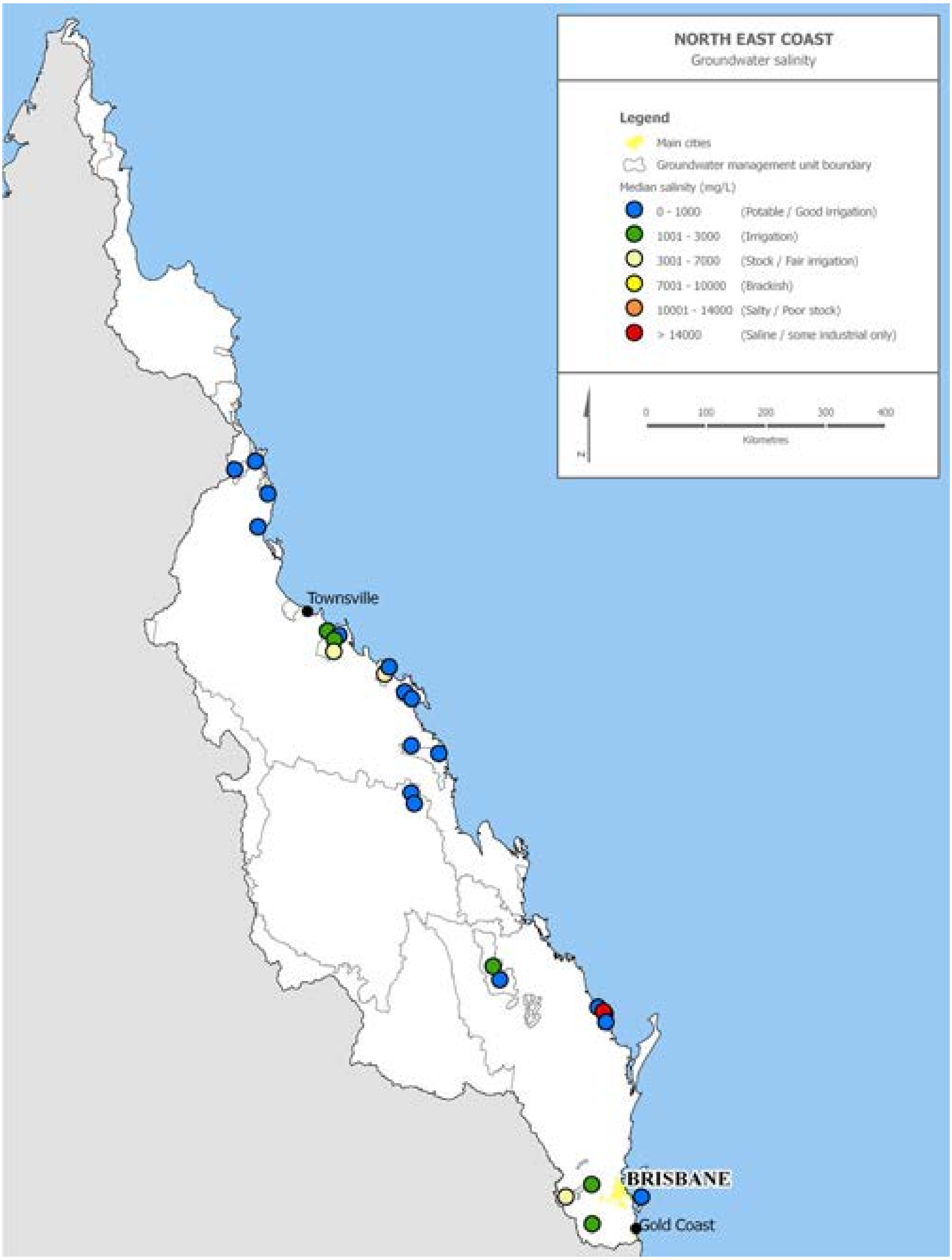


Figure 3-19. Median watertable salinity for the 1990–2010 period measured in selected shallow groundwater bores across the North East Coast region

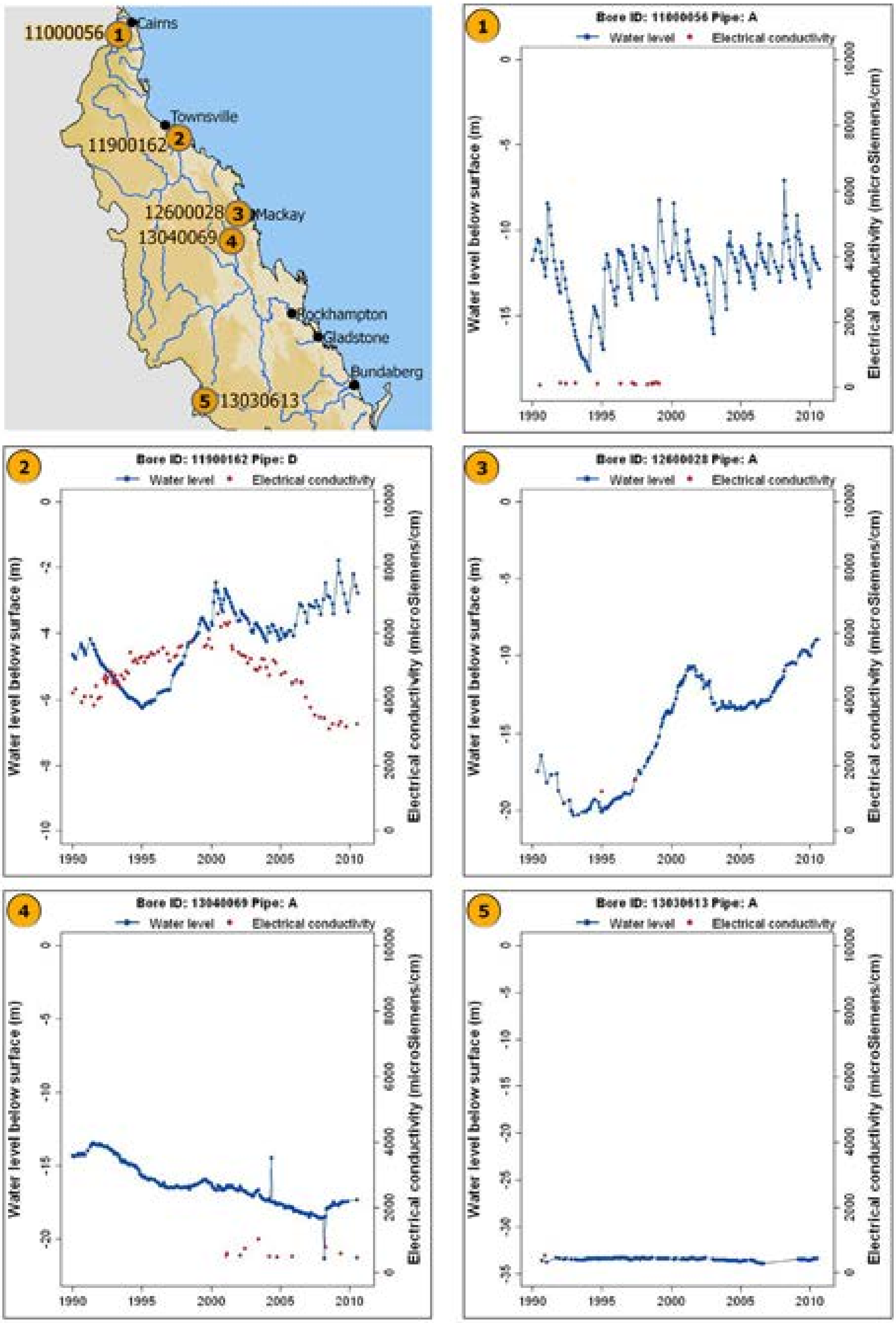


Figure 3-20. Groundwater levels and salinities from selected representative bores in the northern part of the North East Coast region

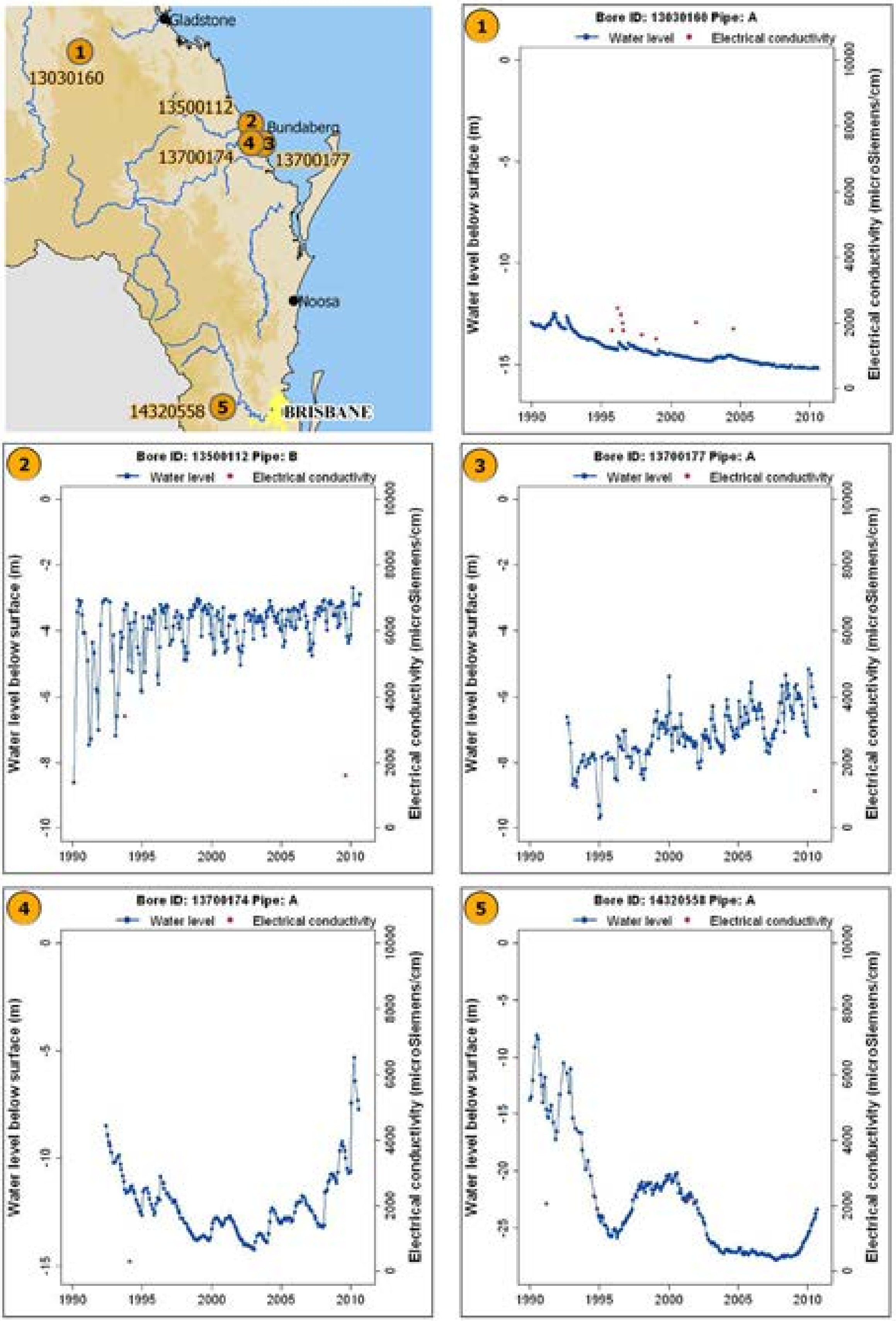


Figure 3-21. Groundwater levels and salinities from selected representative bores in the southern part of the North East Coast region

3.6 Water for cities and towns

3.6.1 Regional overview

The major urban areas in the North East Coast region are in the southeast. Across the region, urban areas account for 0.2 per cent of the total land area. On the South Coast, urban areas constitute greater than 15 per cent of the total area. In the north of the region, urban areas occupy four to seven per cent of the land surface.

The main urban centres with more than 25,000 people are located on the coastline. From south to north they are the Gold Coast, Brisbane, Sunshine Coast, Hervey Bay, Bundaberg, Gladstone, Rockhampton, Mackay, Townsville and Cairns. These cities, the river basins in which they are located and their storages are shown in Figure 3-22 and Table 3-2.

Variation in the volume of water held in storage over recent years and in 2009–10 for four of the cities in Table 3-2 is shown in Figure 3-23.

Table 3-2. Cities and their water supply storages in the North East Coast region

City	Population*	River basin	Major supply storages
Gold Coast	500,000	South Coast	Hinze Reservoir
Brisbane	1000,000	Brisbane River	Lake Wivenhoe, Lake Somerset and North Pine Reservoir
Sunshine Coast	320,000	Mary River	Lake MacDonald, Baroon Pocket, Ewen Maddock, Cooloolabin and Wappa reservoirs
Hervey Bay	59,000	Mary River	Lake Lenthall
Bundaberg	67,000	Burnett River	Ben Anderson Barrage, Ned Churchward Weir, Paradise and Fred Haigh reservoirs
Gladstone	50,000	Calliope River	Awoonga Reservoir
Rockhampton	77,000	Fitzroy River	Fitzroy River Barrage and Eden Bann Weir
Mackay	85,000	Pioneer River	Teemburra and Kinchant reservoirs
Townsville	104,000	Ross River	Ross River and Paluma reservoirs
Cairns	147,000	Mulgrave–Russell Rivers	Tinaroo Falls and Copperlode reservoirs

* Australian Bureau of Statistics (2010b)

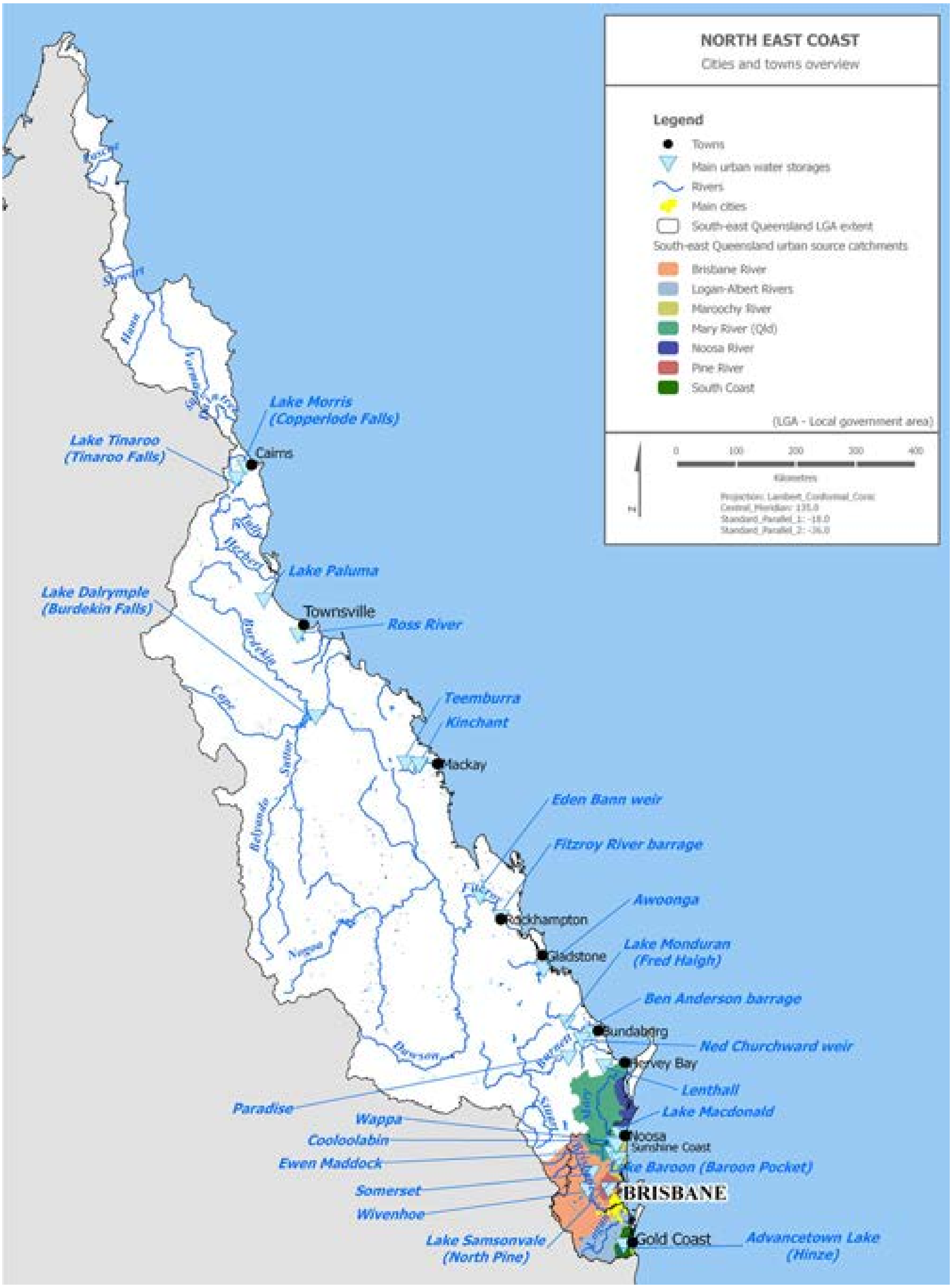
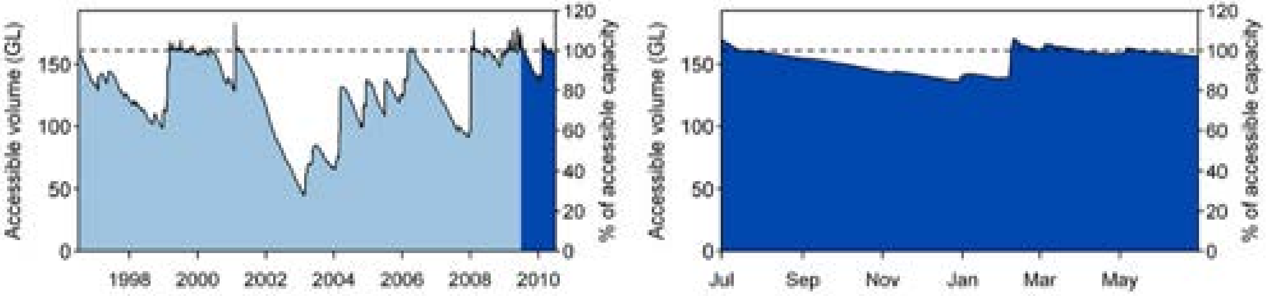
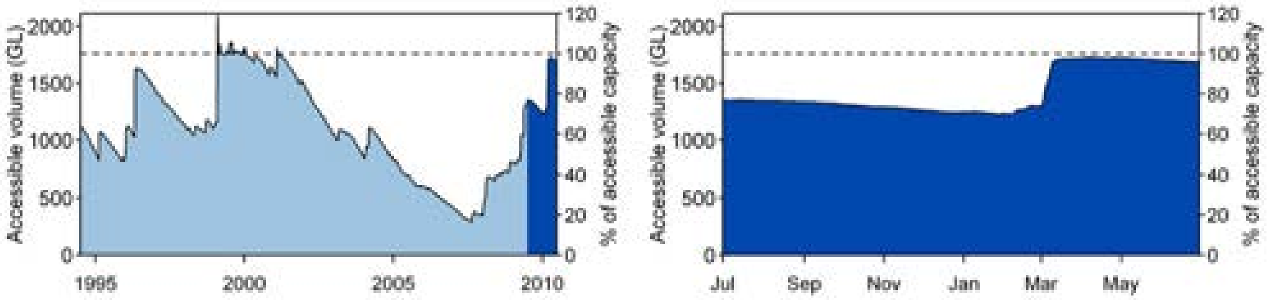


Figure 3-22. Urban areas and supply storages in the North East Coast region

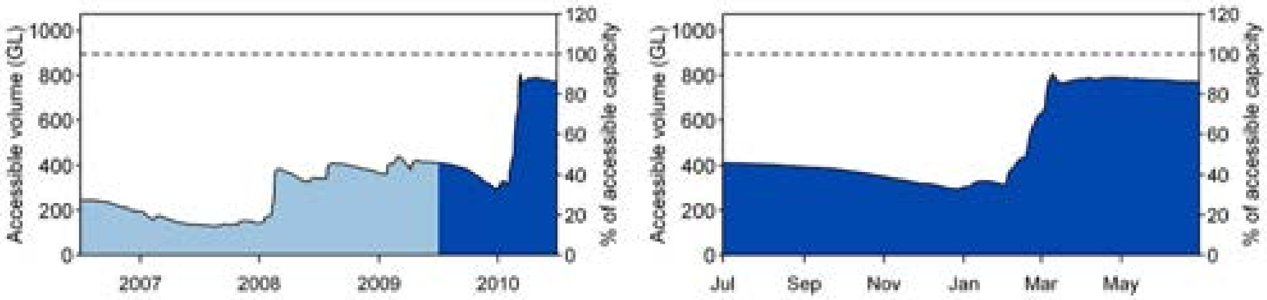
Gold Coast (Hinze Reservoir)



Brisbane (Lake Wivenhoe, Lake Somerset and North Pine Reservoir)



Bundaberg (Ben Anderson Barrage, Ned Churchward Weir, Paradise and Fred Haigh reservoirs)



Mackay (Teemburra and Kinchant reservoirs)

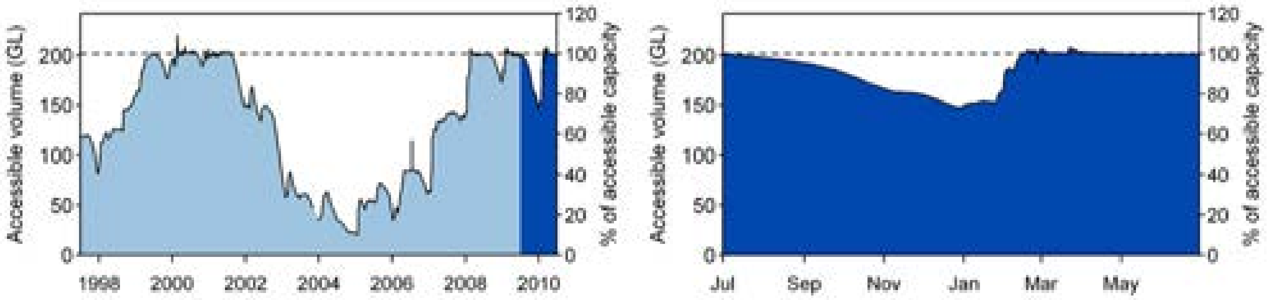


Figure 3-23. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for cities in the North East Coast region

3.6.2 Brisbane and the Gold Coast

Brisbane and the Gold Coast are located in southeast Queensland. The area consists of three water resources planning areas – Moreton, Logan and Gold Coast – and covers around 21,000 km^2. This is the most urbanised part of the region and provides an example of a relatively complex water supply system.

The Gold Coast water resources planning area is 1,300 km^2 and includes the Pimpama River, Coomera River, Nerang River, Tallebudgera Creek and Currumbin Creek catchments. Throughout the plan area, streamflows are used for irrigation and other agricultural purposes, while sub-artesian water is taken from local aquifers for agricultural and domestic uses. The highly developed and populated city of the Gold Coast and its surrounding districts rely primarily on Hinze Reservoir on the Nerang River and Little Nerang Reservoir on Little Nerang Creek. Urban water use accounts for 70 per cent of total water use within the plan area, with the remainder used for industrial (15 per cent) and rural (15 per cent) purposes (Department of Natural Resources and Water 2009).

The Logan basin water resources planning area is 4,200 km^2 and includes the Logan and Albert rivers and the Redlands sub-catchments. Nearly two-thirds of water supplied in the area is for irrigated agriculture, including fodder, cereal and horticulture crops. Water in the Logan River water supply system is supplemented from Bromelton Weir and Cedar Grove Weir on the Logan River, and Lake Maroon on Burnett Creek. Irrigated agriculture is centred on the Logan River water supply system, with water for irrigation also taken from local creeks. Town water for Beaudesert, Rathdowney, Kooralbyn, South Maclean and Cedar Grove is taken directly from the Logan River (Beaudesert also draws water from the Albert River). Canungra draws its supplies from Canungra Creek, while some water for the Redland City Council area is drawn from Tingalpa Creek.

The Moreton water resources planning area is 15,600 km^2 and includes the catchments of the Brisbane River, Pine Rivers, Caboolture River, Cabbage Tree Creek and Pumicestone Creek. Three large reservoirs (Lake Wivenhoe, Lake Somerset and North Pine Reservoir) hold 83 per cent of the stored water in the area. Approximately three-quarters of allocated water is for urban and industrial purposes. The upper, central and lower Brisbane River are the sources of water supply for many towns, including Brisbane City. Water for Toowoomba is taken directly from Cressbrook and Perseverance reservoirs and from Lake Wivenhoe in times of shortage. A number of small reservoirs are used to supply many of the other towns within the plan area. About eight per cent of the total allocated water is used for irrigated agriculture (including fodder, cereal and horticulture crops).

In the rest of this section, the data is presented for Brisbane, Logan and Gold Coast city councils only.

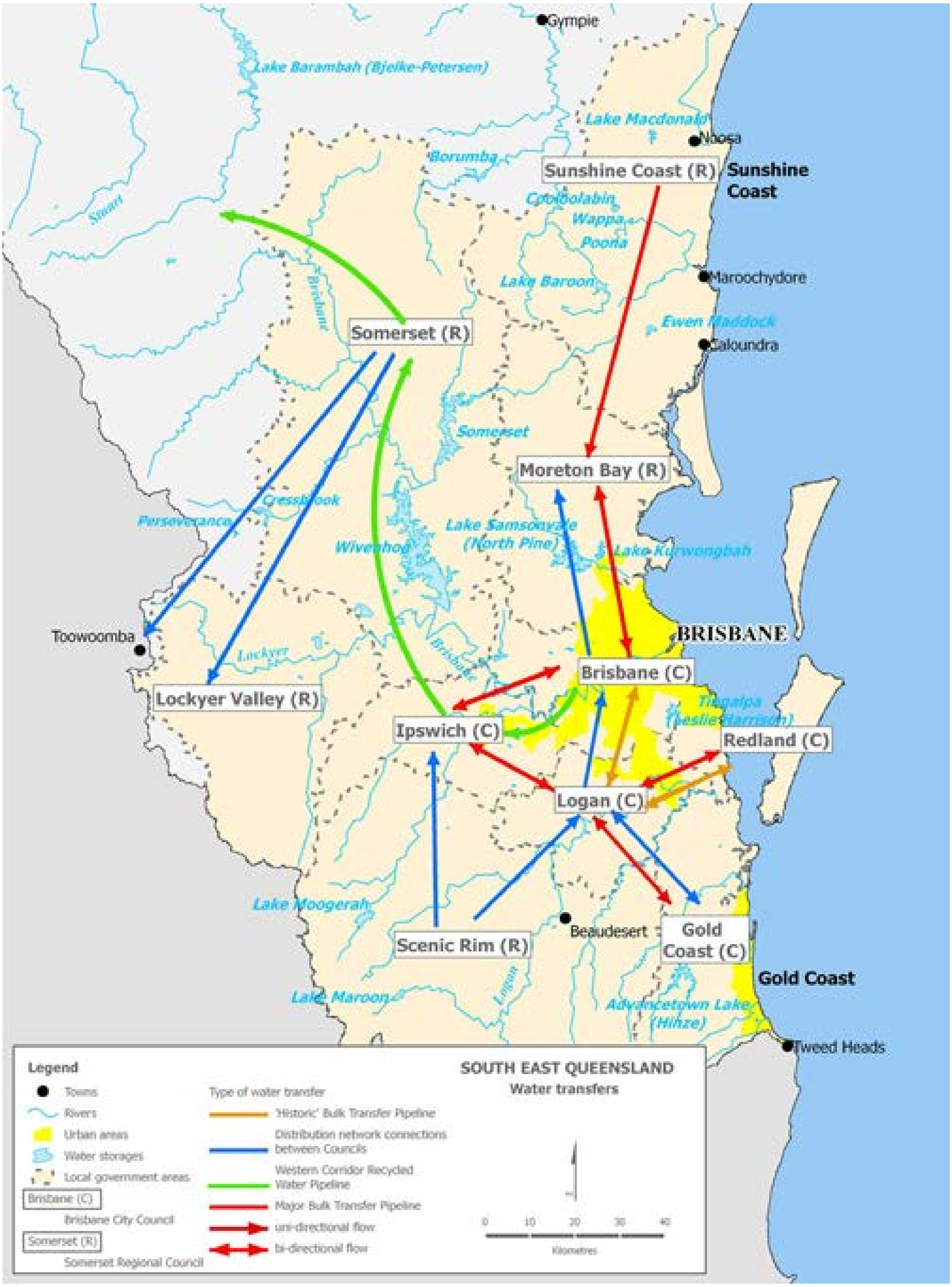


Figure 3-24. Water supply schematic for Brisbane and the Gold Coast

Urban water infrastructure and management in southeast Queensland

Figure 3-24 shows the major water infrastructure supporting Brisbane and the Gold Coast, including the southeast Queensland Water Grid, and illustrates urban flow pathways among water utilities and major customers. The water grid is an integrated system that manages southeast Queensland's water supplies. The southeast Queensland Water Grid comprises an infrastructure network of treatment facilities and two-way pipes that move water between new and existing sources across the region. It provides southeast Queensland with more water sources, both dependent on climatic conditions (surface water reservoirs and rainfall) and resilient to climatic conditions (desalination and purified recycled water), managed with a conservation focus. The network includes about 450 kilometres of pipelines to move water from areas of surplus to areas of shortfall. Key components include 25 reservoirs, 47 weirs, 46 water treatment plants and 14 groundwater bore fields. The network allows the coordinated use of all major bulk water sources in the region. Some water is exported to adjacent regions, the largest being Toowoomba.

Water sources that are not greatly affected by climatic conditions include the Gold Coast Desalination works and the Western Corridor Recycled Water works. The former is located at Tugun and can provide up to 133 ML of new drinking water a day to the grid. The latter includes more than 200 kilometres of pipelines and three advanced water treatment plants at Bundamba, Gibson Island and Luggage Point. It can provide purified recycled water to power stations, future industrial customers and, potentially, agricultural users. It can also supplement the region's drinking water supply through supplying Lake Wivenhoe when reservoir levels fall to 40 per cent and below.

The southeast Queensland Water Grid Manager is a Queensland Government-owned statutory body that is responsible for managing the strategic operation of the southeast Queensland water supply network. During 2009–10 it delivered bulk and purified recycled water to ten councils (Brisbane, Gold Coast, Ipswich, Lockyer Valley, Logan, Moreton Bay, Redland, Scenic Rim, Somerset and Sunshine Coast) and business customers (including the Swanbank, Tarong and Tarong North power stations). Local government-owned retailers took responsibility for the retail sale of water supply and sewage disposal services to households and businesses through their water distribution networks. This arrangement changed in July 2010 when utilities were created to take over the roles of bulk supply and the provision of water and wastewater services to customers. These utilities will take a leading role in the future provision of water in southeast Queensland.

About 20,000 southeast Queensland residents live in communities that have drinking water supplies not directly connected to the southeast Queensland Water Grid. These communities obtain water from a range of sources with varying levels of security.

Surface storage inflows in 2009–10

Figure 3-25 illustrates the combined inflows to the main water supply reservoirs for southeast Queensland (Wivenhoe, Somerset and North Pine) in 2009–10. These are compared with monthly inflows since January 2000, shown as decile bands on the same graph. Reservoirs received significant inflows during the February to April 2010 period, which resulted in an increase in combined storage levels (Figure 3-26). Inflows in March 2010 were the highest monthly inflows of the last decade. Inflows were below average in most months of 2009–10 except for July 2009 and the January–April 2010 period.

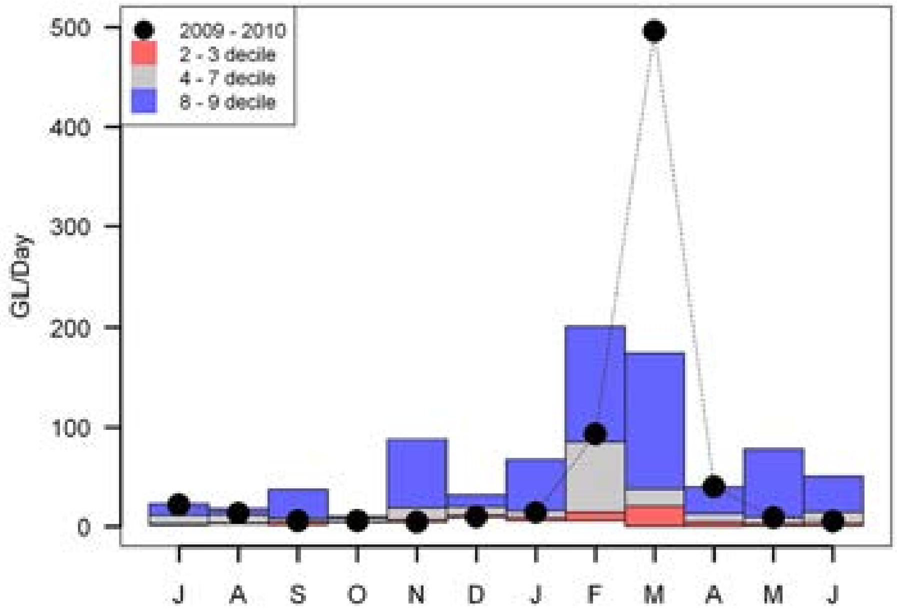


Figure 3-25. Combined inflows to Lake Wivenhoe, Lake Somerset and North Pine reservoirs for 2009–10

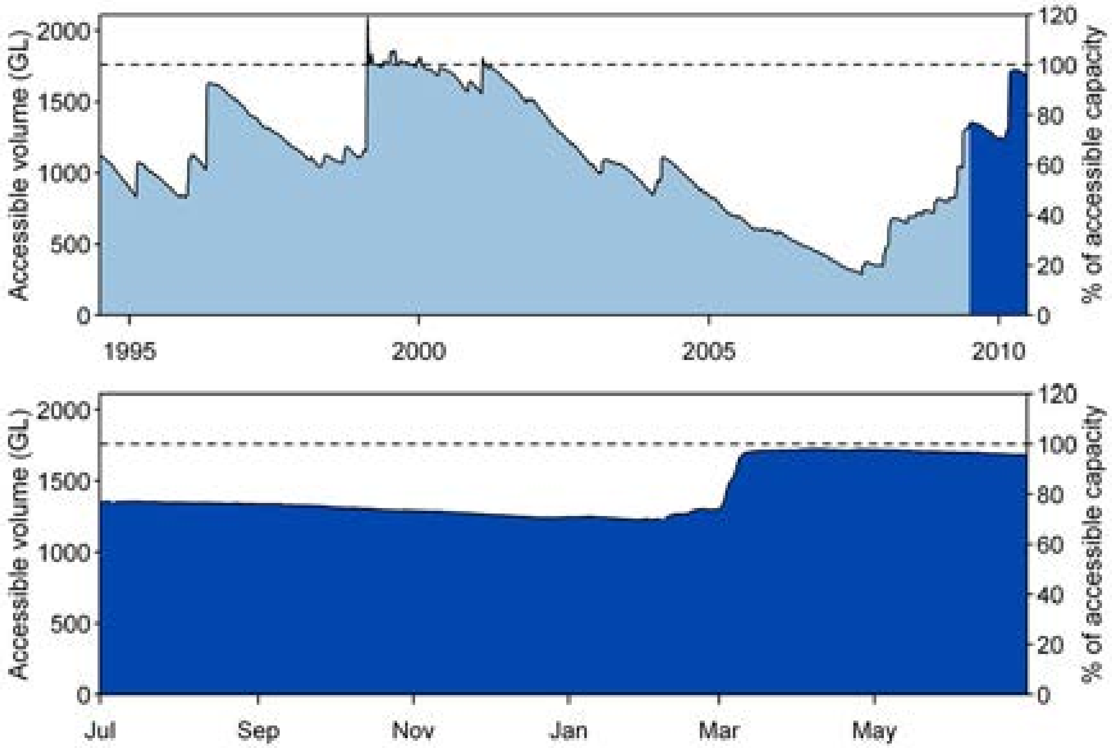


Figure 3-26. Combined surface water storage volumes for Lake Wivenhoe, Lake Somerset and North Pine Reservoir since January 1994 (top) and during 2009–10 (bottom)

3.6.2 Brisbane and the Gold Coast (continued)

Surface storage levels and volumes in recent years

From 2001–09, southeast Queensland experienced the lowest levels of rainfall over an eight-year period in the region's recorded rainfall history, which resulted in both reductions in run-off and increases in the length of period of below average flows (Queensland Water Commission 2010a).

Reservoir levels reached 60 per cent of their combined capacity in May 2009. Following further rainfall in June 2009, the combined reservoir levels reached 77 per cent capacity at the start of the 2009–10 year. They dropped to 70 per cent by January 2010 and rose again to 98 per cent by March. Combined reservoir levels were over 95 per cent for the remainder of 2009–10.

Over the past 16 years, the combined reservoir levels reached 100 per cent twice. The first time occurred in May 1999 and lasted for almost eight months. The reservoirs again reached full capacity in February 2001. Since then storage volumes continually dropped, except for a few small rises, and eventually reached an historic low of 16.4 per cent of capacity in August 2007. The combined water storage volumes were below 20 per cent capacity for six months from April 2007 to September 2007 and only reached 40 per cent of their combined capacity by July 2008. Since then volumes have gradually increased.

Water restrictions in recent years

The Queensland Government's drought response, which began in 2005, included increasing the number of sources for water supply through the building of reservoirs, a desalination plant and purified recycled water plants. Water use was also reduced through the demand management program of the Queensland Water Commission which focused on both residential and non-residential sectors.

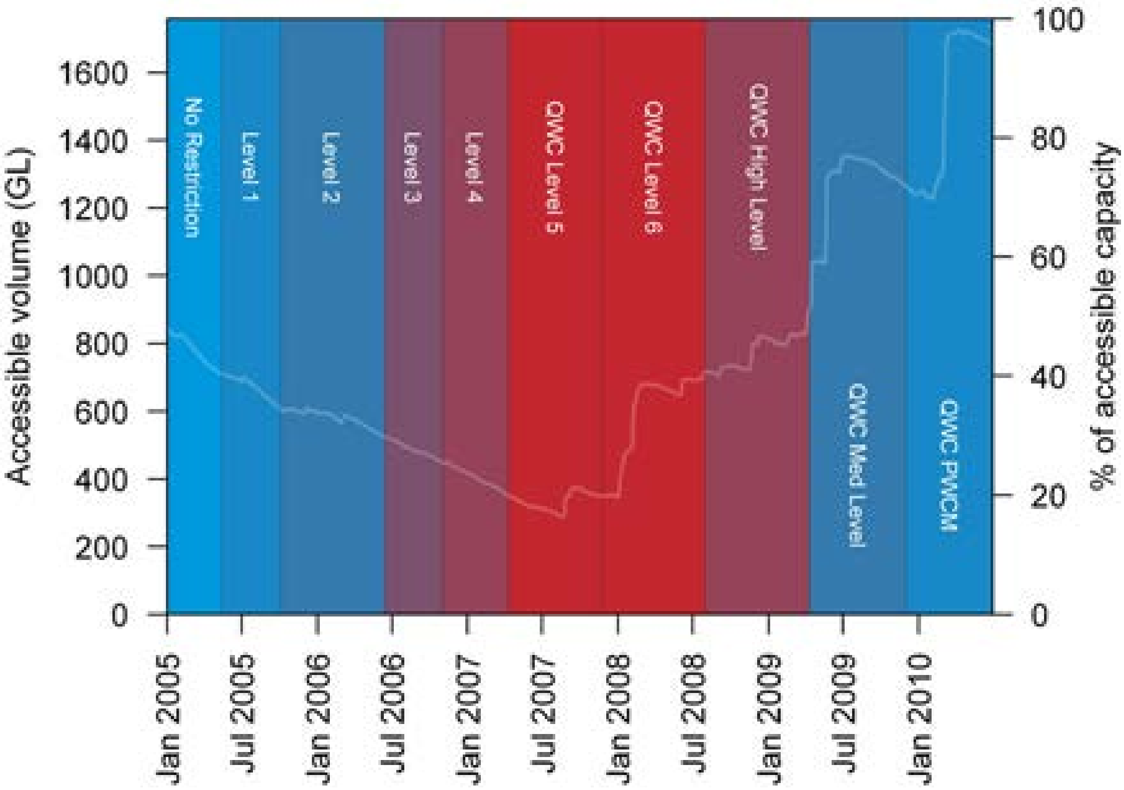


Figure 3-27. Urban water restriction levels and permanent water conservation measures (PWCM) across southeast Queensland since 2005 shown against the combined accessible water volume of Lake Wivenhoe, Lake Somerset and North Pine Reservoir

3.6.2 Brisbane and the Gold Coast (continued)

The Queensland Water Commission manages decisions about water restrictions and these have been in place across southeast Queensland since 2005. Restrictions in force throughout southeast Queensland (excluding Redland, Sunshine Coast Council and Toowoomba) are shown against combined storage levels in Figure 3-27. A description of the restrictions can be found on the website of Queensland Water Commission (2010b).

Major rainfall events in 2009, particularly in April and May, and the completion of major infrastructure projects contributed to increased water storage levels and supply capacity. With storage volumes reaching 50 per cent of capacity in April 2009, restrictions were eased from High Level to Medium Level with a use target of 200 litres per person per day. As rainfall continued, the combined reservoir volumes rose to 77 per cent in July 2009.

Permanent water conservation measures, however, were introduced in December 2009 across southeast Queensland including the Sunshine Coast. These measures encouraged the use of a maximum of 200 litres per person per day. This resulted in regionally consistent water restrictions for all southeast Queensland local government areas.

Source and supply of urban water in recent years

Figure 3-28 shows total volume of water sourced from surface water, groundwater, recycling, and received from bulk suppliers for Brisbane, Gold Coast and Logan city council areas (National Water Commission 2011a). The volume of surface water and groundwater shown in Figure 3-28 refers to water taken locally by water retailers. In addition, water retailers are responsible for sourcing and distribution of recycled water (Figure 3-28). Bulk water is the water supplied by the SEQ water grid, which was originally sourced from surface water (dams and reservoirs) and the Gold Coast Desalination works. For the Brisbane, Gold Coast and Logan city council areas, the total volume of water sourced in 2009–10 was 221 GL. Over the past five years, the highest volume of water sourced for these council areas was in 2005–06. During 2005–06, water restriction levels were at Level 1 and 2 and water storage volumes dropped. Over the next three years, the volume of water sourced fell as a result of demand management reflected in water restrictions. The lowest volume of water sourced over the past five years was in 2008–09. The main sources of water supply were from bulk suppliers and recycled water systems (Figure 3-28).

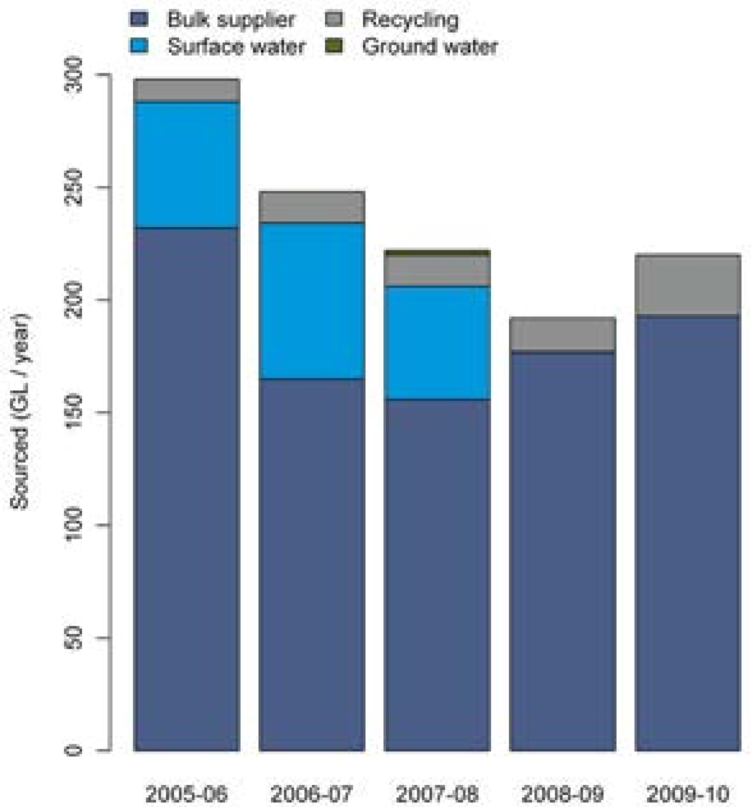


Figure 3-28. Total urban water sourced for southeast Queensland from 2005–06 to 2009–10. See text for description of water sources

3.6.2 Brisbane and the Gold Coast (continued)

Groundwater makes a small yet important contribution to local water supplies in this area. The limited size of groundwater resources in southeast Queensland means that groundwater will not comprise a sizable component of the region's water supply.

Groundwater currently constitutes about six per cent of the total water use in the region. At present, the Redland City Council extracts groundwater from North Stradbroke Island while the Moreton Bay Regional Council extracts groundwater from Bribie Island.

Figure 3-29 shows the total volume of water delivered to residential, commercial, municipal and industrial consumers in Brisbane, Gold Coast and Logan city council areas (National Water Commission 2011a). Total water supplied was 220 GL in 2005–06 and decreased for two consecutive years due to water restrictions. Total water supplied then increased slightly due to the fact that water restrictions were eased, including the reintroduction of outdoor watering. Total volume of water supplied to urban customers in 2009–10 was 176 GL. The recent water use is low compared to historical levels of water use.

Using population numbers and total water supplied data from National Performance Reports, the average total water consumption across southeast Queensland in 2009–10 was 634 ML/d or 255 litres per person per day (L/p/d), well below the southeast Queensland Water Strategy planning assumption of 375 L/p/d. The residential sector accounted for 74 per cent of potable water consumption (similar to the previous year when residential consumption was estimated to be 73 per cent). Average residential consumption for southeast Queensland was 163 L/p/d. The lowest water consumption was from the central part of southeast Queensland (141 L/p/d) and the highest was from Sunshine Coast (230 L/p/d). The non-residential sector accounted for 26 per cent of potable urban water consumption.

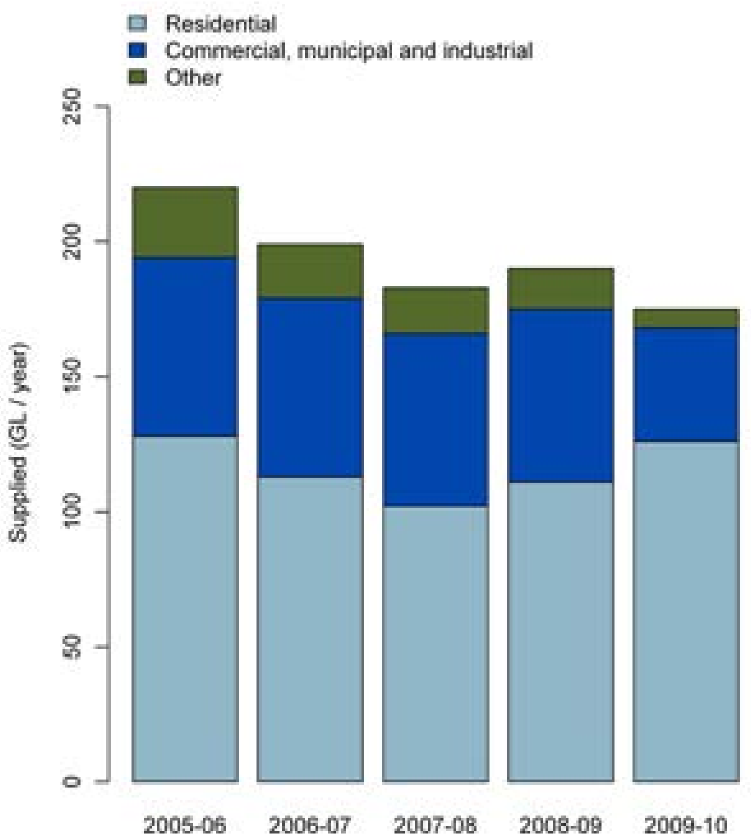


Figure 3-29. Total urban water supplied to southeast Queensland from 2005–06 to 2009–10

3.7 Water for agriculture

Most of the North East Coast region is relatively undeveloped and much of this is used for grazing. In the north, grazing occurs on native rangelands with fewer management inputs and less pasture improvement than in the south. Dryland and irrigated agriculture account for approximately 0.4 per cent of the land use of the area. Intensive land uses such as urban areas account for 0.2 per cent.

The greatest area of dryland agriculture (1.8 million hectares) is located in the Fitzroy River basin. Other river basins dominated by dryland agriculture are located in central and northern Queensland. Forestry generally occurs in upper catchment areas and is relatively evenly distributed across higher rainfall river basins with the largest extents occurring in southern basins (e.g. Fitzroy, Burnett and Mary rivers).

3.7.1 Soil moisture

Upper soil moisture content during the summer of 2009–10 (November–April) was average to well above average for the season, particularly in pastoral and cropping regions to the west of Emerald, Moranbah and Charters Towers (Figure 3-30).

Soil moisture increased to very much above average levels across most dryland agricultural areas during the winter (May–October) of 2010 (Figure 3-30). These increases were largely a consequence of high rainfall in August, September and October 2010, after the 2009–10 year.

3.7.2 Irrigation areas

Irrigated agriculture occupies only a small proportion of the region. The larger of these areas are located in the Brisbane, Mary, Burnett, Burrum and Kolan river basins in the south; the Fitzroy, Plane Creek and Pioneer river basins in the centre of the region and the Haughton and Burdekin river basins in the north (Figure 3-31).

A comparison of water use in irrigated catchments of the region over the period 2005–06 to 2009–10 is shown in Figure 3-32 and Figure 3-33 by natural resource management region. Data were sourced from the *Water Use of Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011). The Burdekin Irrigation Area is used as an example of resource condition and water use for irrigated agriculture in 2009–10 (see section 3.7.3).

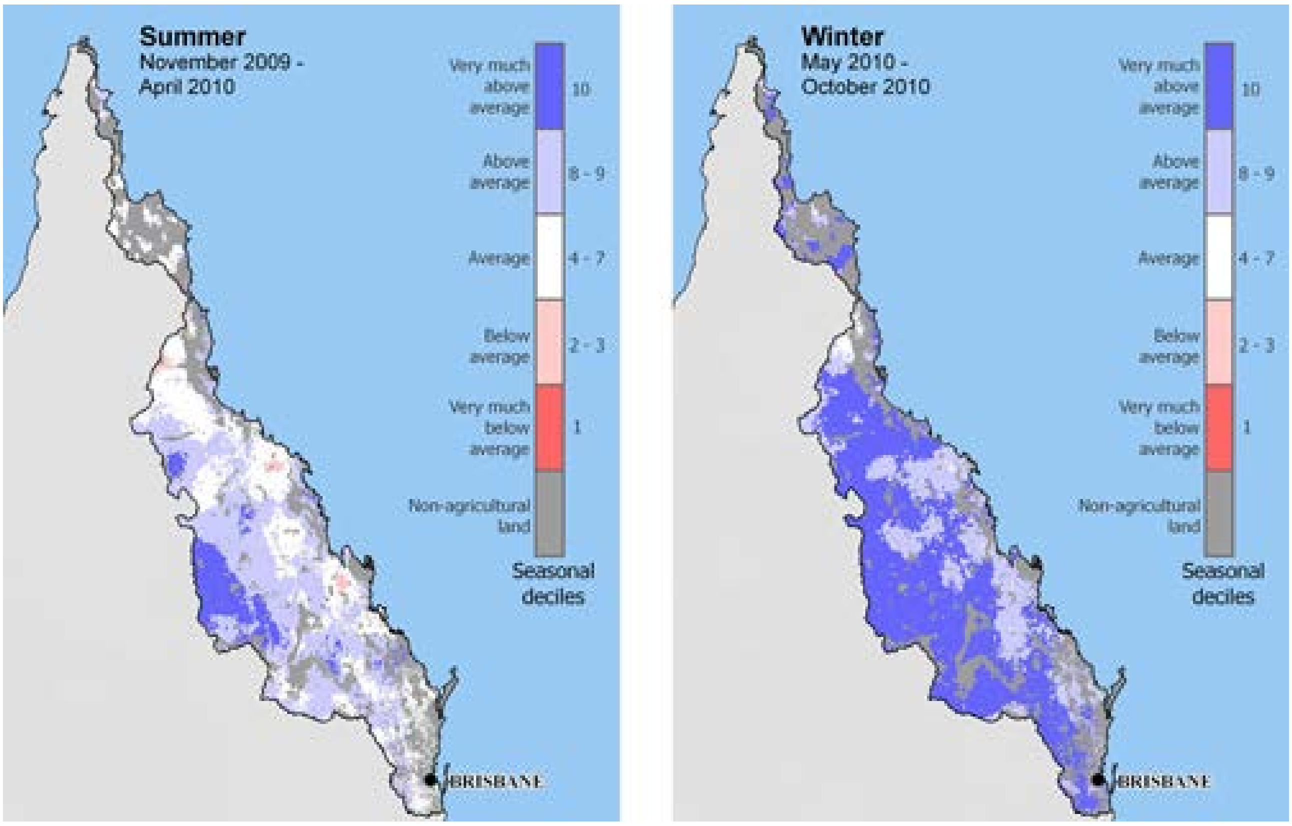


Figure 3-30. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the North East Coast region

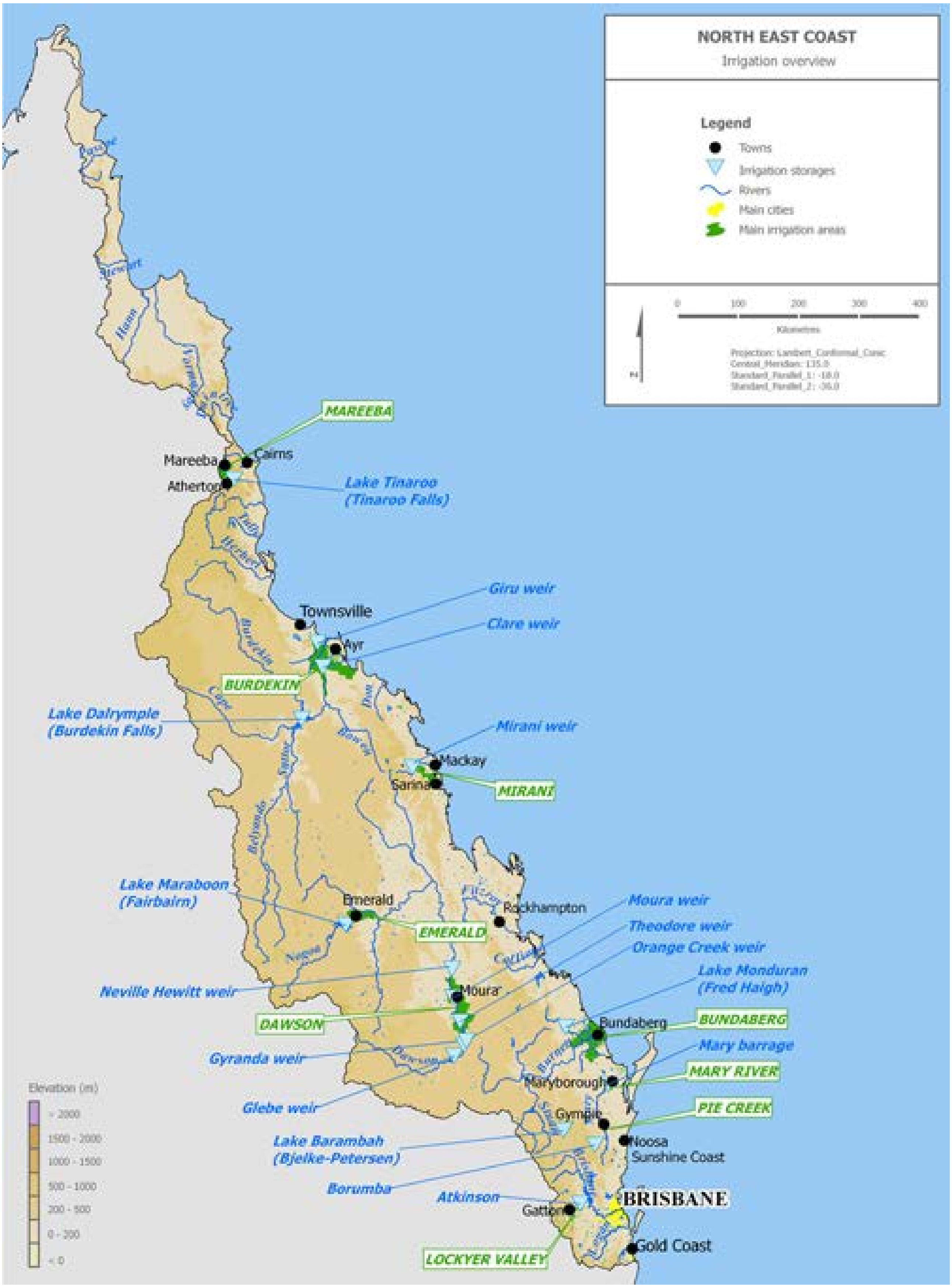


Figure 3-31. Map of irrigation areas and infrastructure in the North East Coast region

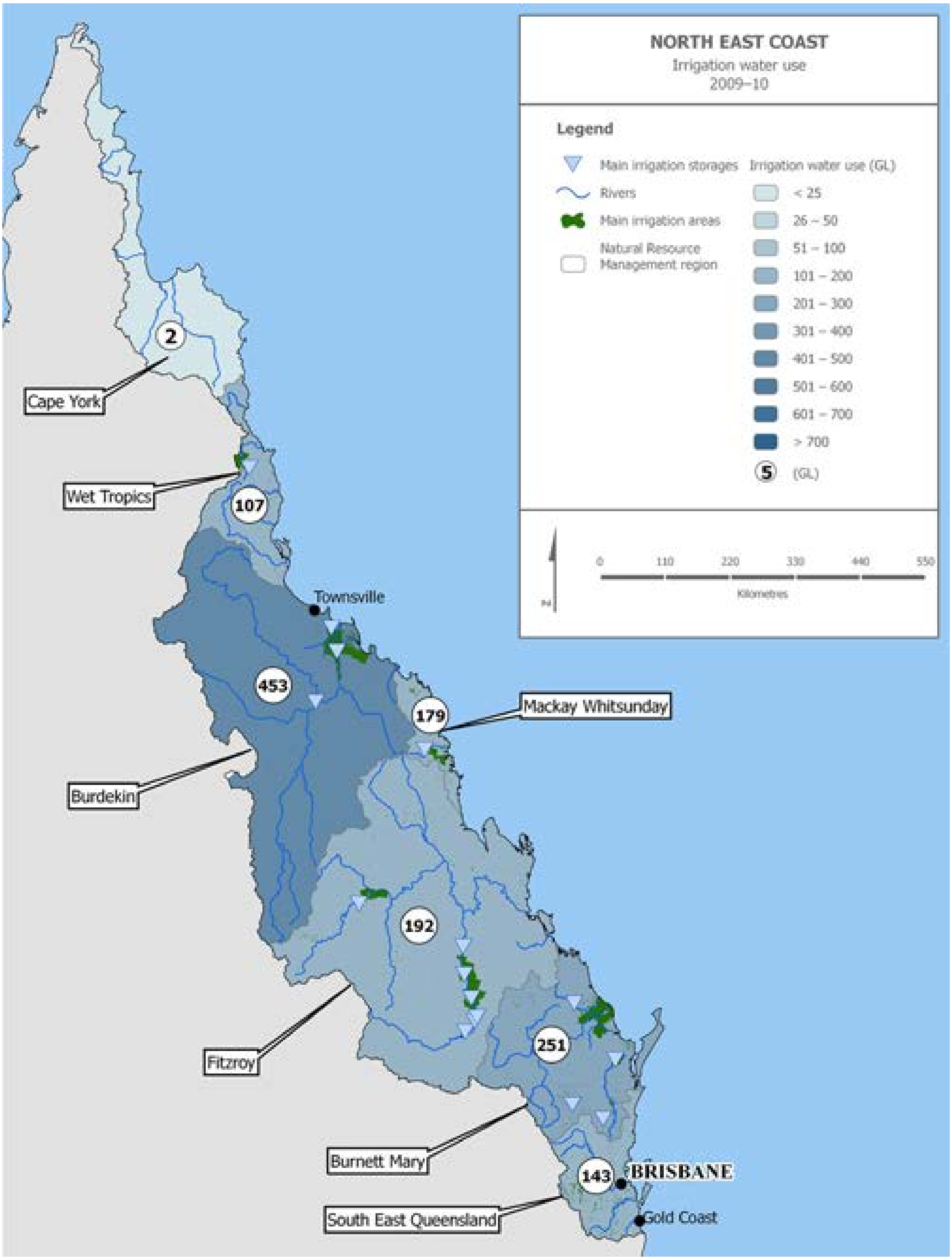


Figure 3-32. Annual irrigation water use (GL) per natural resource management region for 2009–10 in the North East Coast region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

3.7.3 Burdekin Irrigation Area

The Burdekin River basin is located in the dry tropics on the northeastern coast of Queensland, covering a total catchment area of approximately 133,000 km^2. This region of Queensland can receive more than 300 days of sunshine each year, which is a primary reason for the highly productive agricultural industry. This can be tempered, however, by the traditional wet season, which runs from November to March each year with the wettest months typically being January and February.

The lower Burdekin area is one of Queensland's premier irrigation zones and has a reputation for producing some of the highest yields and highest quality sugarcane in Australia. Although sugarcane is the dominant crop, approximately one-third of the national mango harvest is produced in the region. Additionally, the region's horticultural sector produces a wide variety of fruit and vegetable crops, including out-of-season winter crops, such as capsicums, eggplant, bananas, plums, tomatoes, rockmelons, watermelons, chillies, beans and sweet corn (SunWater 2010).

The Burdekin Irrigation Area was established in the early 1950s and consisted of approximately 7,500 ha of land at Claire, Millaroo and Dalbeg located on the levee soils of the lower Burdekin River floodplain. At this time, water supplies for these irrigation areas were sourced from the Gorge Weir and Blue Valley Weir. In the 1970s these supplies were supplemented by (transferred) water from the Eungella reservoir on the Broken River. In 1984, construction of the Burdekin Falls Reservoir commenced. It is one of the largest surface water storages in Queensland covering an area of 22,400 ha and impounds water up to 50 km up the Burdekin River forming Lake Dalrymple. The construction of the dam was completed in 1987 and it filled during the following wet season in 1988. Following dam construction, the Queensland Government developed a further 32,500 ha of irrigation areas on the left and right banks of the Burdekin River, approximately 150 km below the storage.

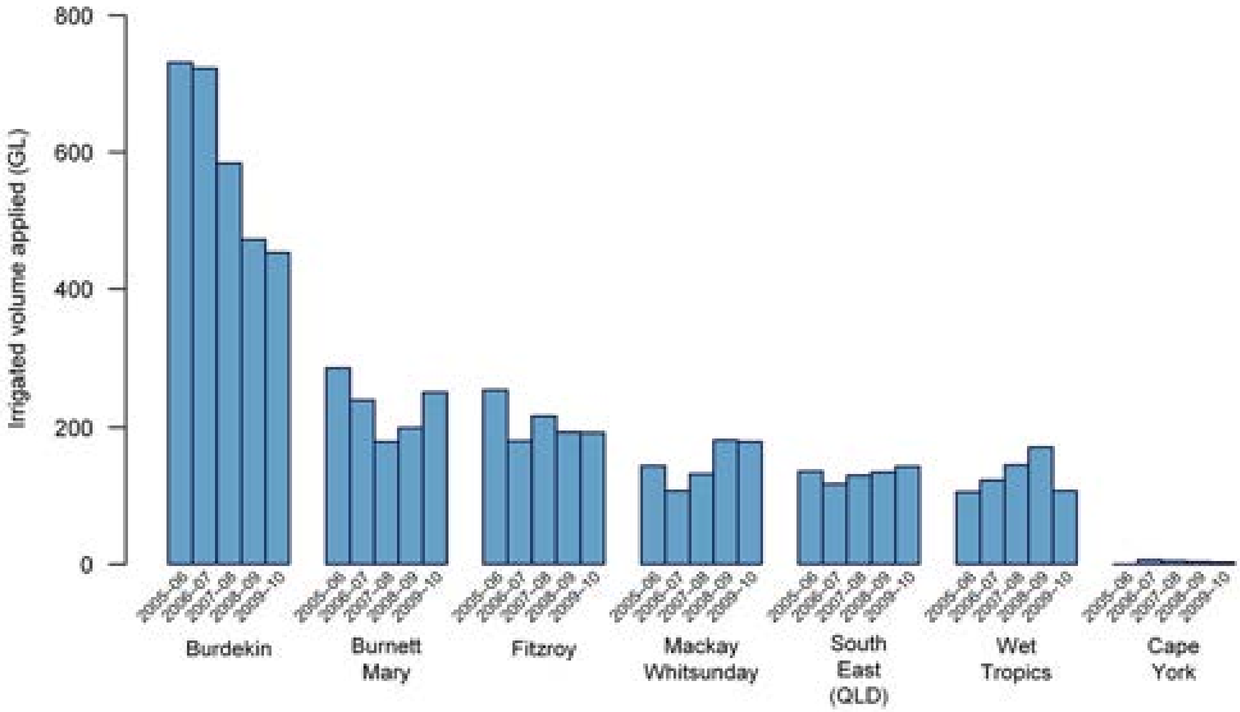


Figure 3-33. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the North East Coast region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

3.7.3 Burdekin Irrigation Area (continued)

The Burdekin–Haughton Water Supply Scheme is a surface water-dominated irrigation system and is mainly located to the north and west of the Burdekin River. The supply system receives significant volumes of water from Burdekin Falls Reservoir. Irrigation is supplemented by groundwater supplies. The Burdekin Irrigation Area is underlain to a significant extent by relatively shallow groundwater systems (Bristow 2009).

Most of the remaining irrigated area is located downstream in the Burdekin River delta area and is a groundwater-dominated irrigation system. Lower Burdekin Water, formed to manage this area, is a joint venture of the North Burdekin Water Board and the South Burdekin Water Board (autonomous Boards funded by irrigators). A primary role of Lower Burdekin Water is the management of groundwater recharge to prevent seawater intrusion to the aquifer (Bristow & Stubbs 2010).

Surface water management and supply to the Burdekin Irrigation Area

The tropics of northern Australia are renowned for highly variable seasonal and annual rainfall events that are linked to the El Niño Southern Oscillation, tropical lows/cyclones and monsoonal activity (Lough 2001). The extreme seasonality is clearly highlighted in the historical streamflow discharge records of gauging stations on the Burdekin River at Sellheim (120002C), Cape River at Taemas (120302B) and Suttor River at St Anns (120303A). Approximately, 85–90 per cent of the recorded discharge in three catchments upstream of the Burdekin Falls Reservoir for the period 1990–2010 occurred during the wet season, in the months of December through to the end of March (see Figure 3-34).

The total accessible storage capacity of the Burdekin Falls Reservoir is 1,860 GL. The reservoir is supplied by an upstream catchment area of approximately 120,000 km^2. The upstream catchment extends north to the Seaview Range west of Ingham, south to the Drummond Range near Alpha through the Suttor and Belyando Rivers, southeast to the coastal ranges west of Mackay, and west beyond Charters Towers to the Lolworth, Montgomery and Stopem Blockem Ranges through the Clarke River. In spite of the large capacity of the Burdekin Falls Reservoir, the considerable size of the inflowing upstream catchment area combined with the significant seasonal discharge from these contributing catchments has resulted in the dam spilling almost every wet season since construction (Faithful & Griffiths 2000).

That both high priority and medium priority customers in the Burdekin Irrigation Area received full water allocations for the past seven years highlights the reliability of storage recovery of this reservoir as a result of high inflow volumes relative to total surface storage capacity. A minimum accessible storage volume of 54 per cent (1,000 GL) was recorded on 13 January 2006 but recovery to a full level occurred in the following 94 days during the wet season (Figure 3-35). This is equivalent to a change in storage of 846,000 ML during the refill period, which equates to an average daily increase in storage of approximately 9,000 ML over almost three-months.

3.7.3 Burdekin Irrigation Area (continued)

Groundwater occurrence in the Burdekin Irrigation Area

Irrigation in the Burdekin River delta area (Figure 3-36) is underlain by relatively shallow groundwater systems (Bristow 2009). A groundwater-dominated irrigation system is managed by Lower Burdekin Water in the area, downstream and east of Mount Kelly (Lenahan & Bristow 2010). Currently more than 1400 groundwater pumps are in operation applying 10–40 ML/ha/yr (McMahon et al. 2002). This is equivalent to 1,000–4,000 mm/year. The water source used for irrigation (groundwater or surface water) depends on proximity to the river or irrigation channels and on groundwater salinity and yield.

The coastal floodplain groundwater system is mostly unconfined. The shallow groundwater is in direct hydraulic connection with the Burdekin River. Typically, during the dry season, groundwater elevation is higher than surface water levels in the river upstream of The Rocks (see Figure 3-36 for location) allowing groundwater discharge into the river. During occasional high flow events in the wet season, the direction of flow is reversed allowing surface water to recharge groundwater (Lenahan & Bristow 2010). This activity indicates a high connectivity between surface water and groundwater. Generally, lateral groundwater flow is northerly towards the coast; however, groundwater pumping causes large fluctuations in groundwater levels that complicate groundwater flow paths.

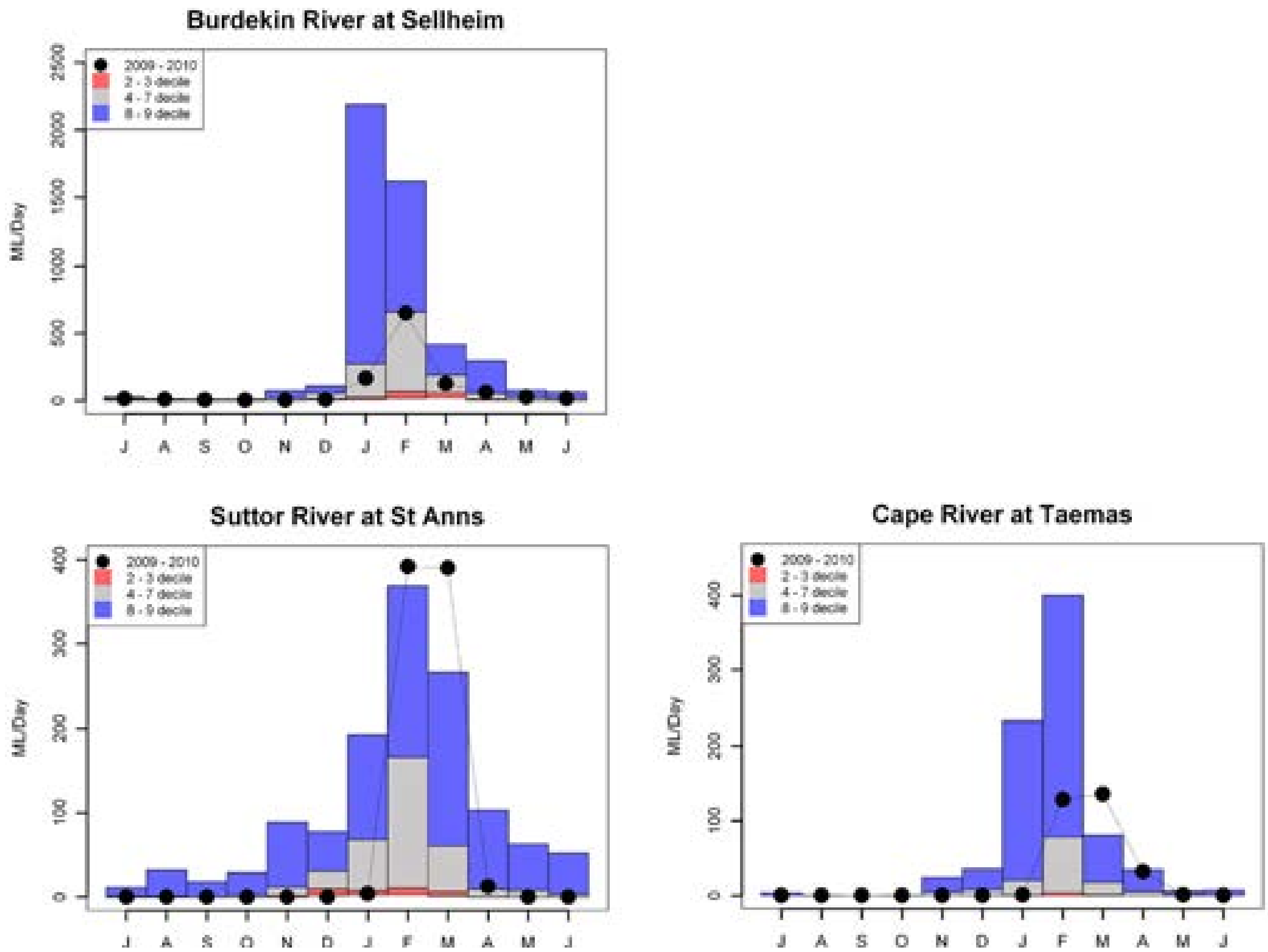


Figure 3-34. Monthly discharge hydrographs compared to discharge deciles at reference gauges for inflows to the Burdekin Falls Reservoir

3.7.3 Burdekin Irrigation Area (continued)

Fluctuations in shallow groundwater levels at selected sites are shown in Figure 3-37. From 1995 to 2010, groundwater levels show a rising trend with only a short cycle of falling levels visible between 2000 and 2003.

Figure 3-37 allows the comparison of the shallow groundwater levels to the cumulative rainfall residual mass at Ayr (location shown in Figure 3-36) and to the monthly discharge of the Burdekin River at Clare from 1990 to 2010.

There are periods for which the rainfall residual mass rises, indicating wetter-than-average conditions while periods with a falling trend indicate drier-than-average conditions. As shown, rainfall and streamflow appear to be well correlated with groundwater levels. Peaks in streamflow and in the rainfall residual mass curve correspond to peaks in groundwater. However, there are some inconsistencies between the rainfall and groundwater level cycles. For example, groundwater levels start rising in 1995 and 2003 even though the rainfall residual mass curve is still falling. It is possible that groundwater recharge from the river is contributing to level rises at these times.

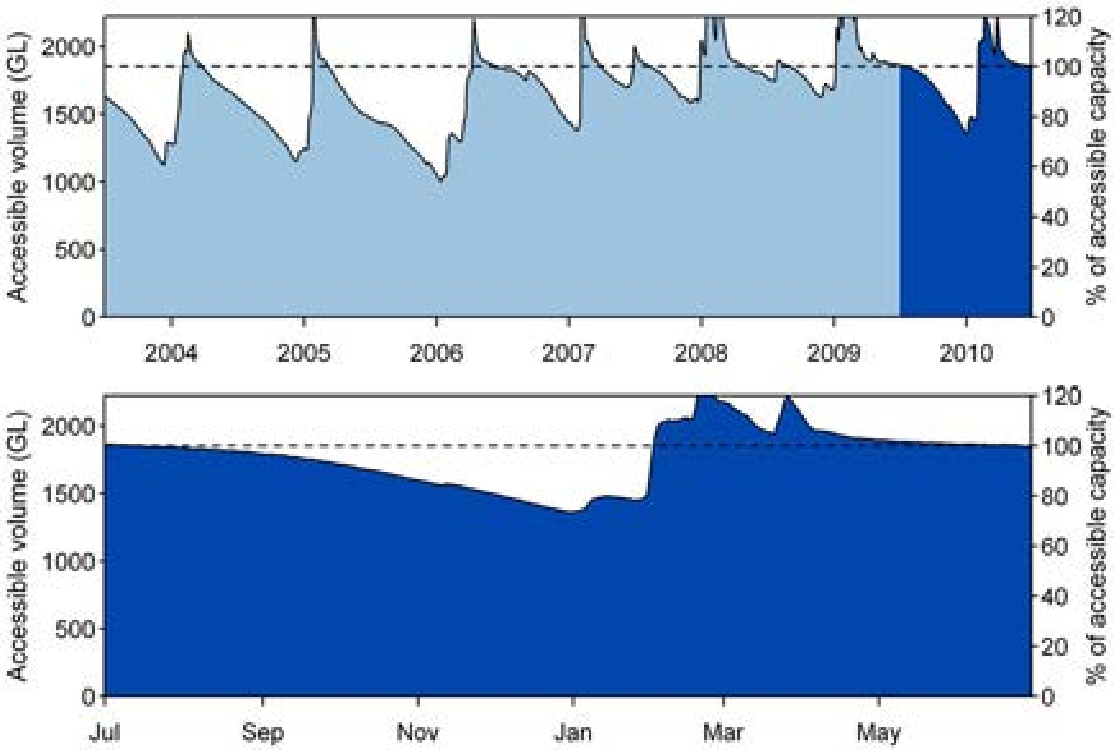


Figure 3-35. Water storage volumes available for irrigation at the Burdekin Falls Reservoir since 2003 (left) and during 2009–10 (right)

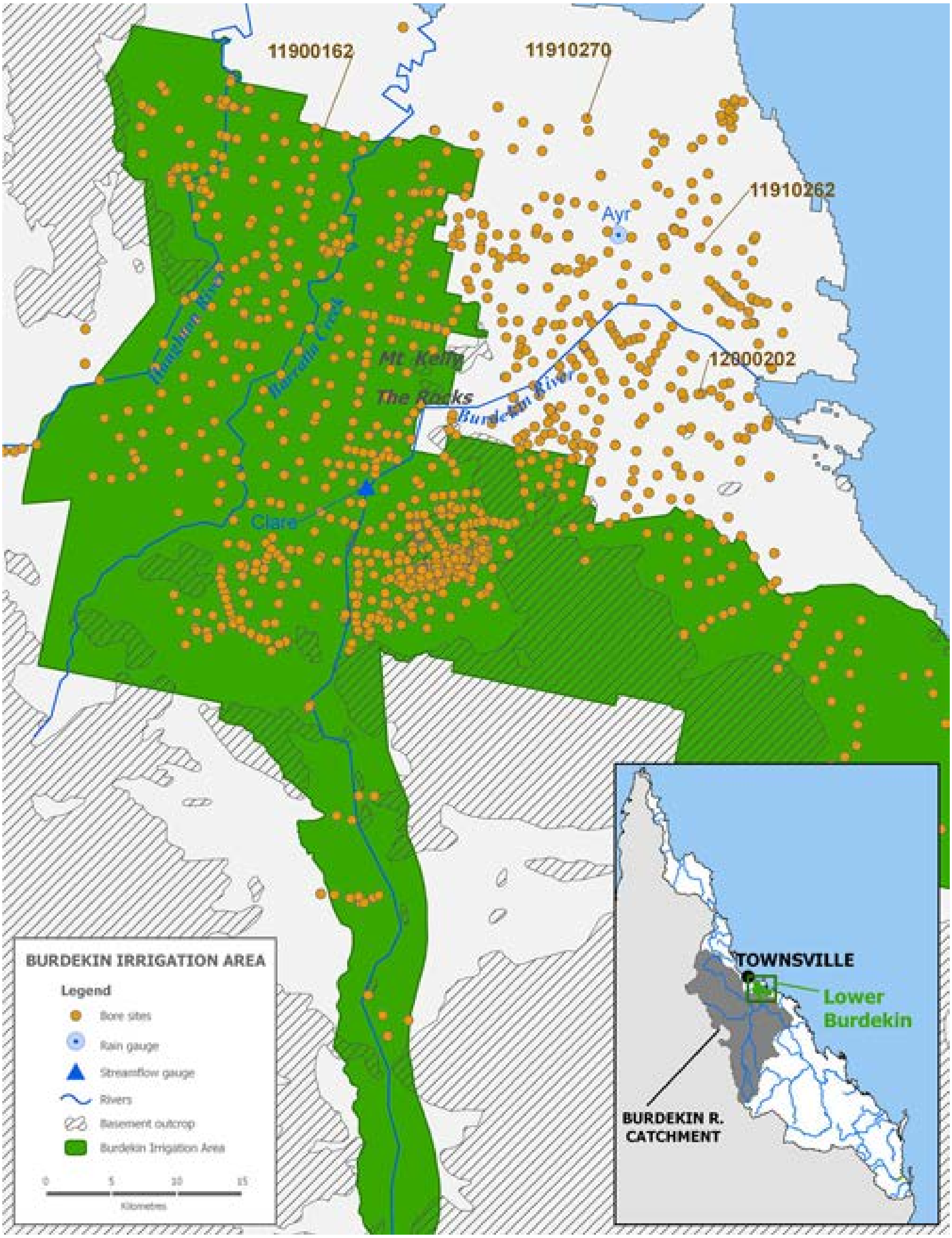


Figure 3-36. The Burdekin Irrigation Area with groundwater bore sites, river gauge (Claire station no 120006B) and rain gauge (Ayr station no 33002) locations, including location map of the lower Burdekin River catchment within the North East Coast region

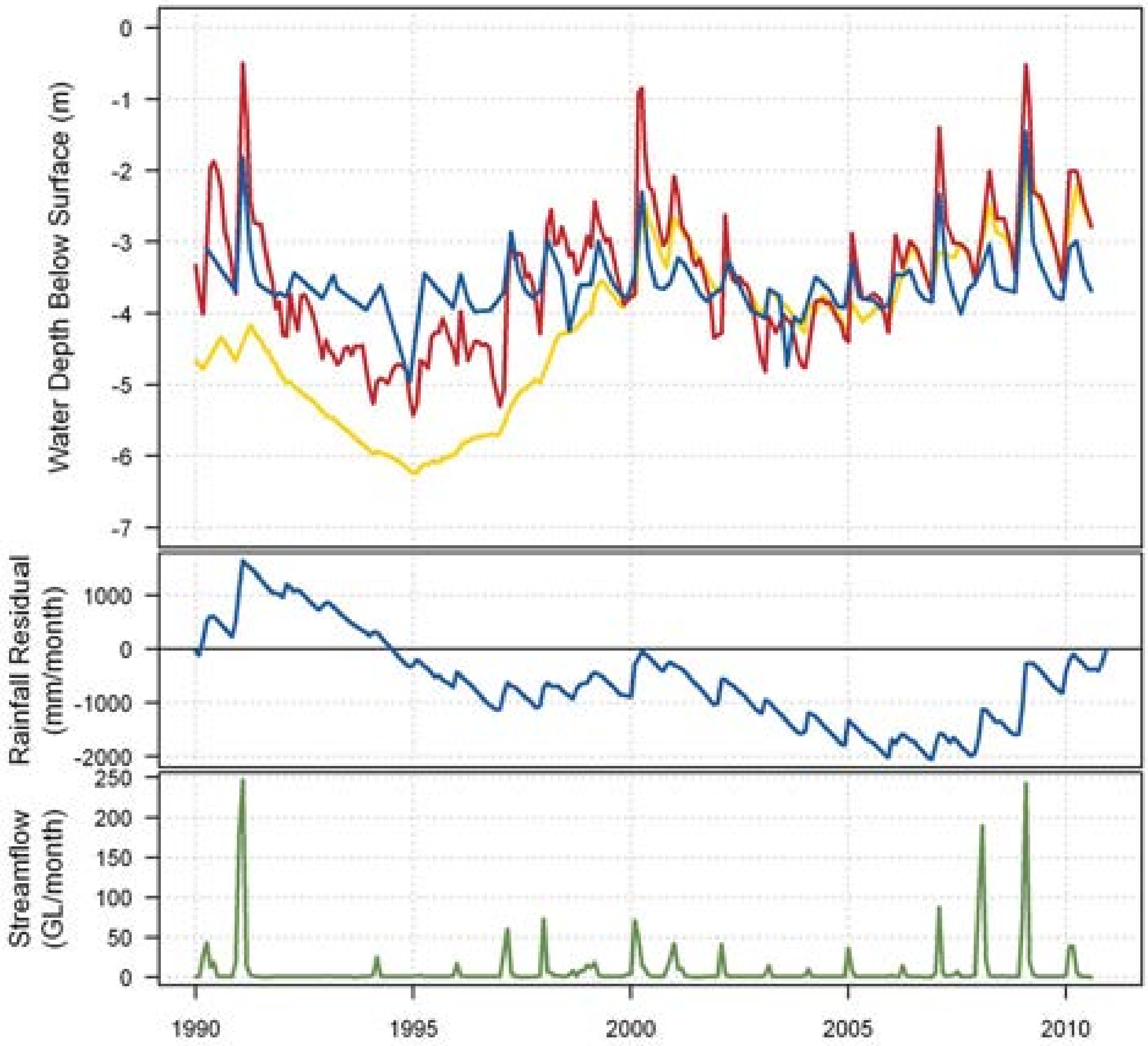


Figure 3-37. Shallow groundwater levels between 1990 and 2010 recorded at nested bore sites. Top panel: bore 11910262 pipe D (red), bore 12000202 pipe D (blue), bore 11900162 pipe D (yellow) in the Lower Burdekin area. Middle panel: cumulative rainfall residual mass at Ayr station no 33002. Lower panel: Burdekin River discharge at Clare – station no 120006B. Groundwater bore, rain gauge and river gauge locations are shown in Figure 3-36.

Groundwater level status

Groundwater level measurements are an important source of information about hydrological and anthropological influences on the groundwater in an area, including recharge. Figure 3-38 presents groundwater levels recorded in bores of different depth at the same site (a nested bore site) in the Lower Burdekin area. Groundwater level fluctuations are similar at all depths indicating that deeper groundwater is hydraulically connected to the shallower groundwater. Hydraulic gradients indicated that groundwater flow is predominantly downward.

Figure 3-39 shows ranges of groundwater depth in the shallow and deeper groundwater bores in the Lower Burdekin area, and the ranking of 2009–10 median groundwater levels compared to annual median groundwater levels in the last 20 years (1990–2010). In general, in the shallow bores, groundwater levels vary from quite shallow near the coast to greater than ten metres deep further inland. Median groundwater depth in 2009–10 is mostly in the upper ten per cent of recorded levels, indicating that groundwater levels are on average the shallowest of the last 20 years in both deep and shallow bores. This is consistent with the trend in groundwater levels shown in Figure 3-38.

Groundwater salinity status

Since the 1960s, when the Queensland Government commenced regular monitoring of groundwater quality, an increase in salinity has been reported at many sites. Two main issues linked to degrading groundwater quality were highlighted: the increase in groundwater salinity beyond irrigated crop tolerance level and ecosystems decline due to greater influx of solutes from the aquifers into the surface water and ultimately into the Great Barrier Reef (Lenahan & Bristow 2010).

A decline in groundwater quality at some locations was connected to:

(a) land clearing and irrigation, that mobilised subsurface solute stores

(b) increases in groundwater pumping that caused upward leakage of relict deeper salty groundwater or seawater intrusion.

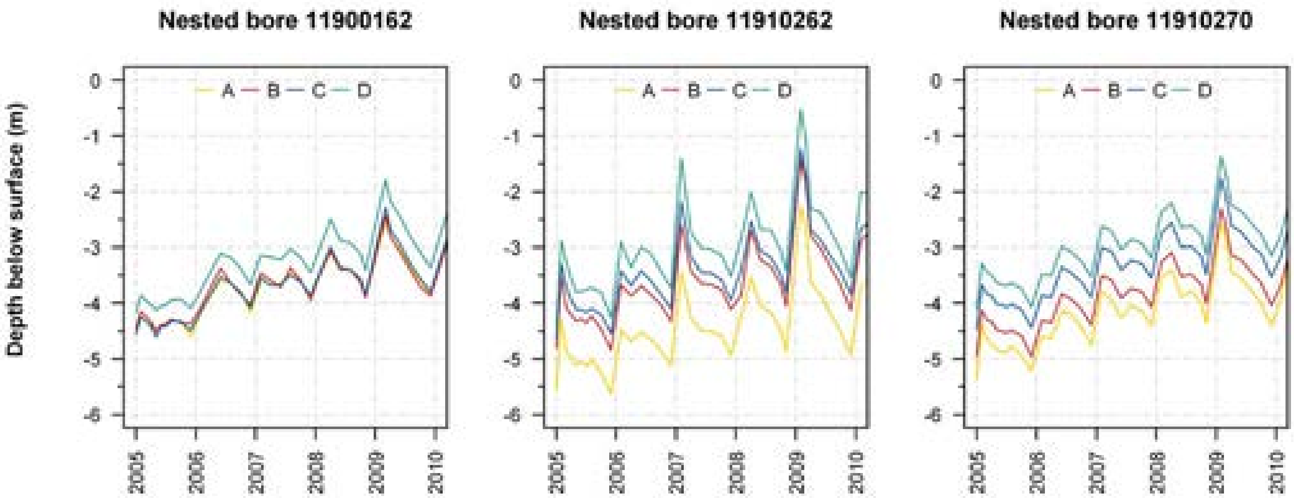


Figure 3-38 Groundwater levels between 2005 and 2010 recorded at selected nested bore sites in the lower Burdekin areas. Depth of screen interval increases from pipe D (shallow, light blue), pipe C (blue), pipe B (red) to pipe A (deep, yellow). Groundwater bore locations are shown in Figure 3-36.

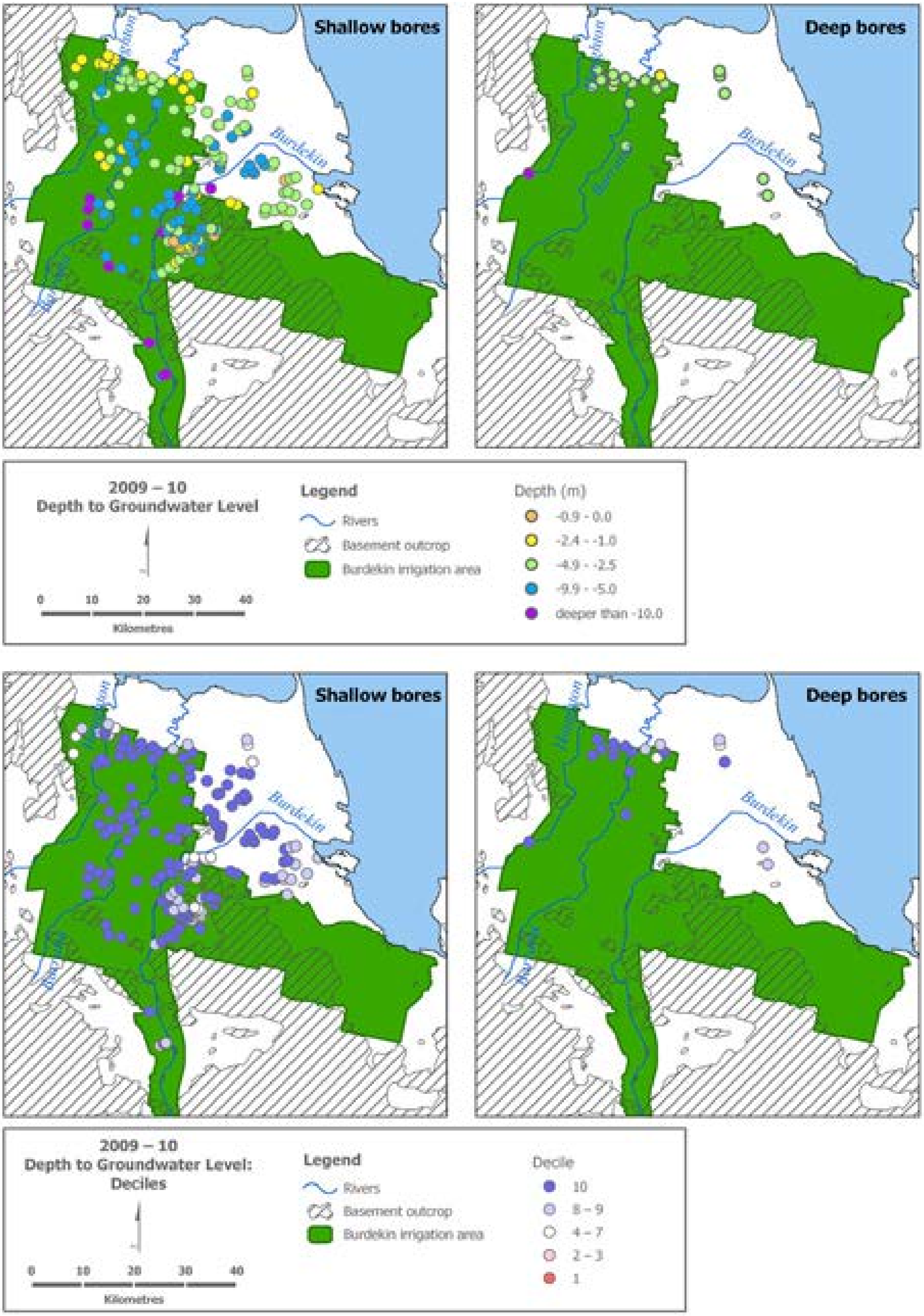


Figure 3-39. Median groundwater depth for the Lower Burdekin area in 2009–10 (top maps) and decile rank of depth in 2009–10 compared to the 1990–2010 period (lower maps). Groundwater depths are shown for shallow bores (bottom of bore casing screen less than 20 m) on the left and deep bores (top of screen greater than 40 m) on the right

3.7.3 Burdekin Irrigation Area (continued)

Figure 3-40 shows groundwater salinity (expressed in units of electrical conductivity) at four depths for each of three nested bore sites in the Lower Burdekin area. Groundwater salinity in the deep bores is usually very high compared to the shallow bores. At these nested sites, the shallow groundwater salinity is more than an order of magnitude lower than salinity in deeper bores. Figure 3-40 also shows that for the shallow bores, groundwater salinity has been declining since 2005.

Figure 3-41 shows median groundwater salinity in shallow and deep groundwater bores in 2009–10 and also the salinity in 2009–10 compared to the 20-year annual average of the period 1990–2010. Note that in general, groundwater salinity is slow to change.

In the Burdekin Irrigation Area, shallow groundwater is saltier in the north and in the south of the area, with saline groundwater near the coast and near the bedrock outcrop. In deep bores, salty groundwater appears to define the distance from the coast where sea water intrusion may have occurred. Lenahan and Bristow (2010) note that groundwater salinity in the aquifer is highly variable depending on proximity to the Burdekin River, palaeochannels and the presence of sediments with relict transpired sea water or sea water intrusion. Fresh groundwater is linked to lateral discharge from the river or vertical infiltration of irrigation water or rainfall in coarse palaeochannel sediments.

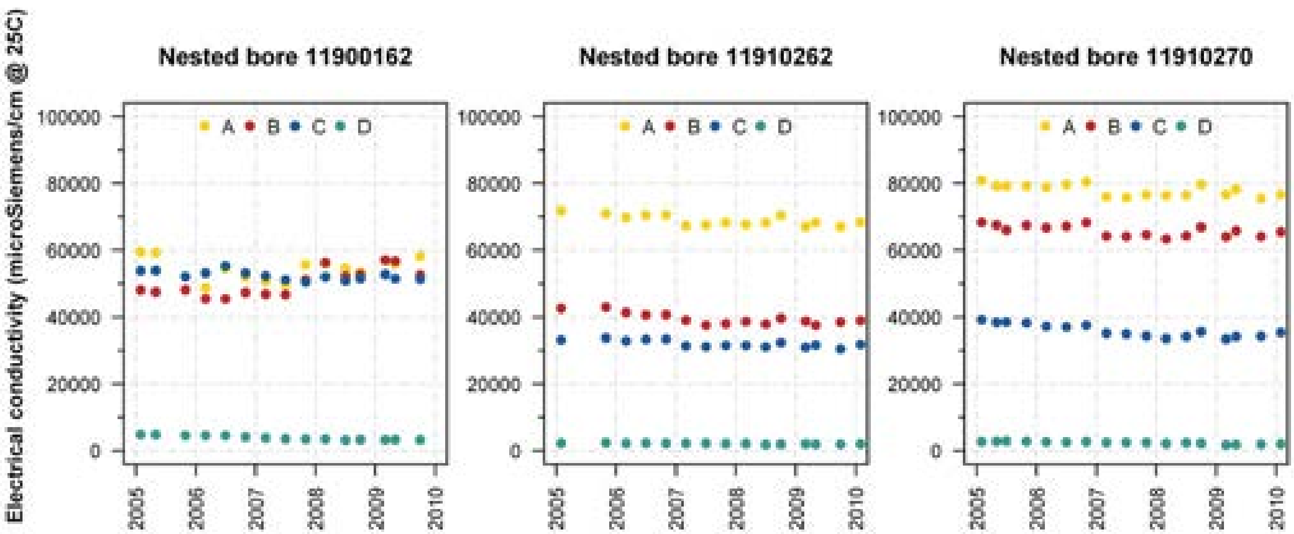


Figure 3-40 Groundwater salinity recorded at selected nested bore sites in the Lower Burdekin area between 2005 and 2010. Depth of screen interval increases from pipe D (shallow, light blue), pipe C (blue), pipe B (red) to pipe A (deep, yellow). Groundwater bore locations is shown in Figure 3-36.

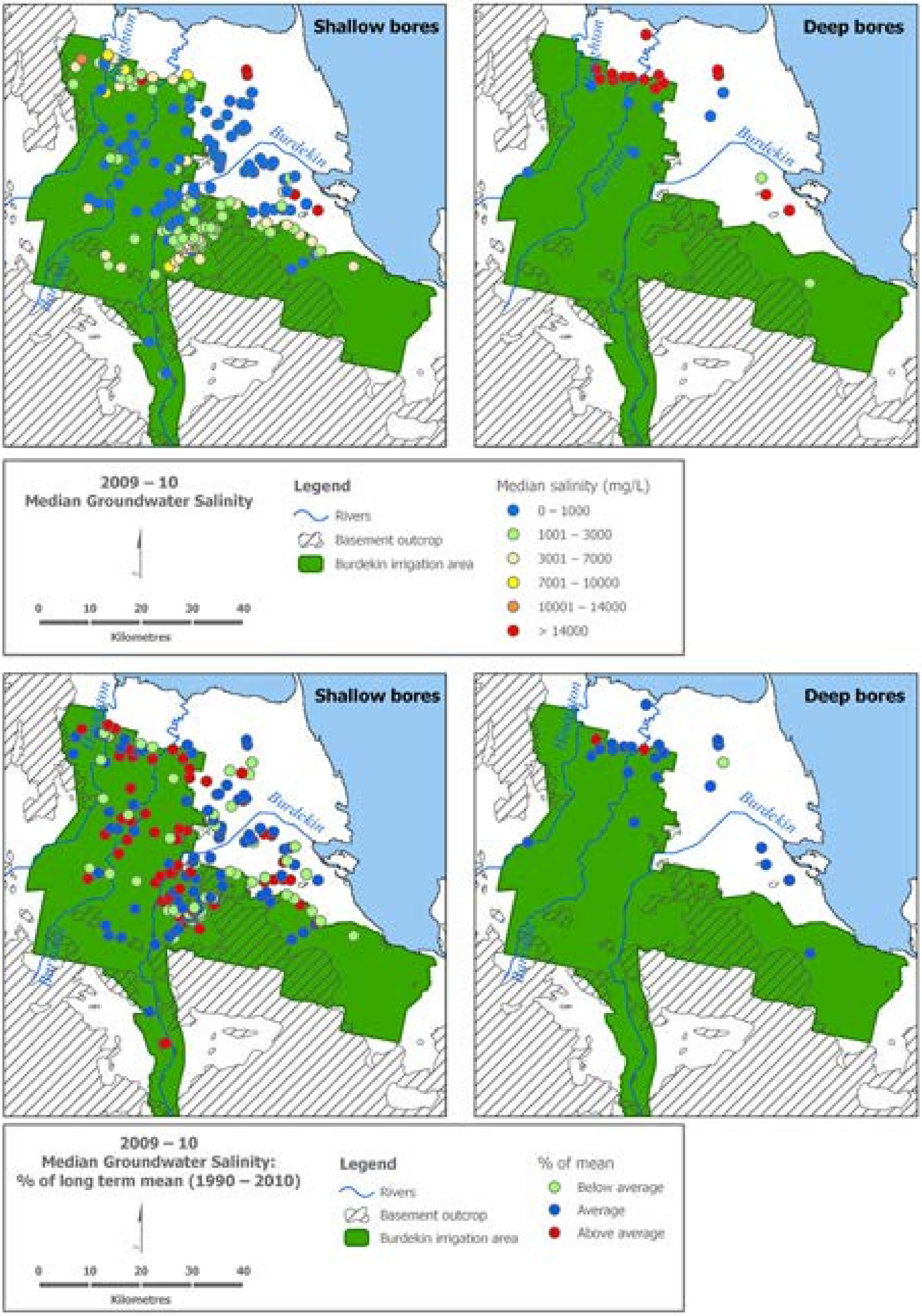


Figure 3-41. Median groundwater salinity for the Lower Burdekin area in 2009–10 (top maps) and groundwater salinity in 2009–10 compared to the 1990–2010 period (lower maps). Groundwater salinity is shown for shallow bores (bottom of bore casing screen less than 20 m, left) and deep bores (top of screen greater than 40 m, right)

4. 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 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers. Information on water use is provided for selected urban centres and irrigation areas.
The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a description of the region.

Surface water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

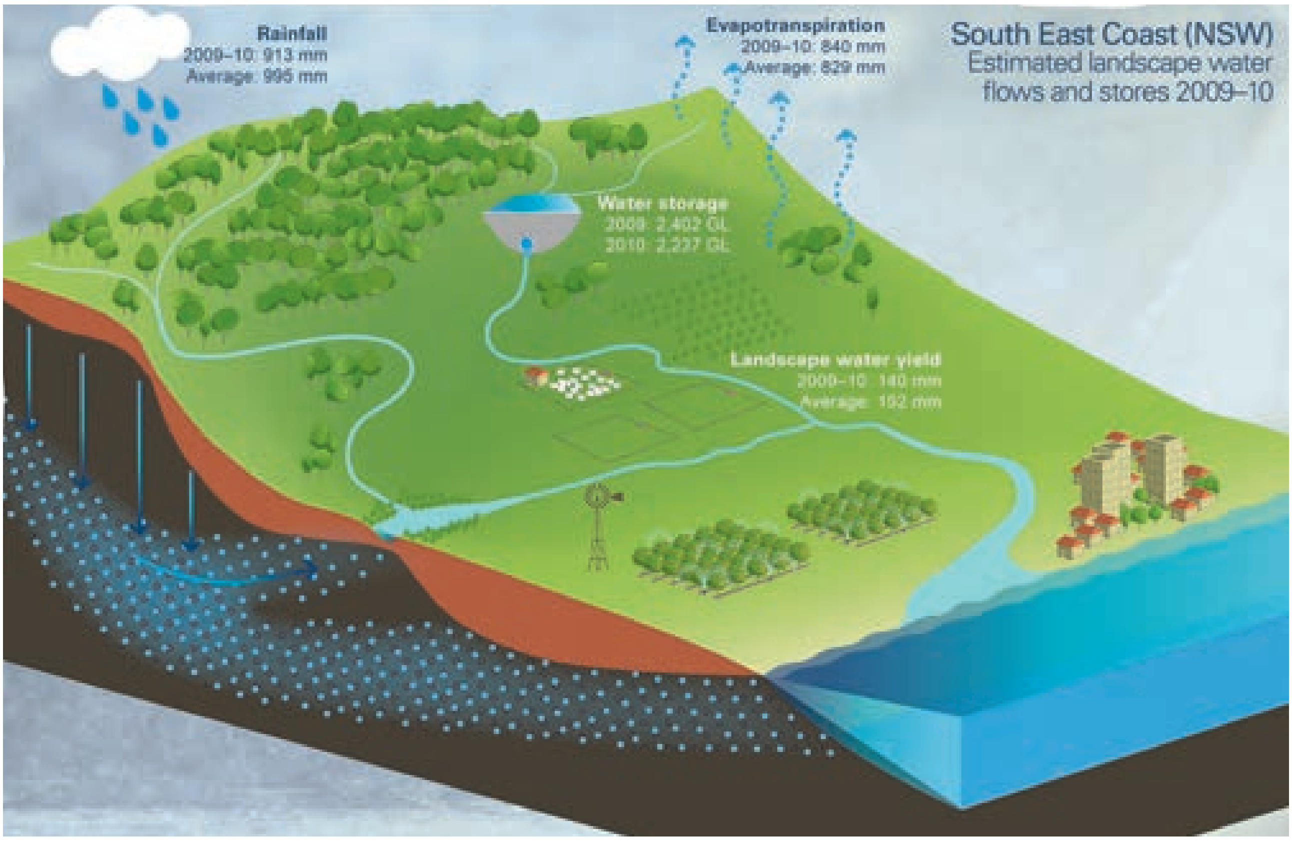


Figure 4-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the South East Coast (NSW) region

4.2 Key data and information

Figure 4-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the South East Coast (NSW) region. Despite the relatively low rainfall amount, the landscape water yield[1] total was still close to the long-term average, mainly due to the internal regional spatial distribution of both rainfall and landscape water yield. The surface water storage change did reflect the lower rainfall amounts as most water storages are located in the lower rainfall areas.

Table 4.1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 4-1. Key information on water flows, stores and use in the South East Coast (NSW) region[2]

Landscape water balance

	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	913 mm	-8%	39	1,491 mm (1988–89)	755 mm (2002–03)
Evapotranspiration	840 mm	+1%	55	923 mm (1988–89)	696 mm (1980–81)
Landscape water yield	140 mm	-8%	53	376 mm (1988–89)	62 mm (1997–98)

Surface water storage (comprising approximately 82% of the region's total surface water storage)

Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
3,679 GL	2,402 GL	65.3%	2,237 GL	60.8%	-4.5%

Measured streamflow in 2009–10

Far and mid-north coast rivers	Central coast rivers	South coast rivers
Average to above average	Below normal to exceptionally low	Below average to above average

Urban water use (Greater Sydney)

Water supplied 2009–10	Trend in recent years	Restrictions
506 GL	Steady	Eased from mandatory level 3 to Water Wise Rules

Annual irrigation water use in 2009–10 for natural resource management regions

Hunter–Central Rivers	Northern Rivers	Hawkesbury-Nepean	Southern Rivers	Sydney Metro
81 GL	34 GL	52 GL	13 GL	2 GL

Soil moisture for dryland agriculture

Summer 2009–10 (November–April)	Winter 2010 (May–October)
Average in most areas, above average in some central parts of the region	Above average and very much above average in the north and northwest, average in most other areas

*A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

4.3 Description of region

The South East Coast (NSW) region is part of the long, narrow area of eastern Australia between the Great Dividing Range and the sea. The western and eastern boundaries of the region are clearly defined by geography (top of the Great Dividing Range to 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 region covers all of coastal New South Wales, and has a total area of 129,500 km².

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.

There are seven river basins in the north of the region incorporating the following rivers: Tweed, Brunswick, Bellinger, Richmond, Clarence, Macleay and Hastings–Camden Haven. The Clarence River is the largest in the South East Coast (NSW) region in terms of annual discharge into the sea. The river basin has diverse vegetation and wildlife habitats, national parks and reserves with remnant forests.

Major river basins in the mid-coast area contain the Manning, Karuah, Hunter and Hawkesbury rivers. The Hawkesbury and Hunter rivers are two important systems in the region in terms of urban and irrigation water supply.

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.

The region has a population of over 4.7 million (Australian Bureau of Statistics 2006) including the most populous city in Australia, Sydney, which is surrounded by heavily urbanised and industrialised areas. The largest population centres of the region – Sydney, Newcastle, Central Coast and Wollongong (with a combined population of nearly 4.5 million) – lie near the centre of the region in a narrow coastal strip. Other urban centres in the region (with more than 25,000 people) are Maitland, Richmond–Windsor, Nowra–Bomaderry, Lismore and coastal towns Port Macquarie and Coffs Harbour. Water supply to Sydney, Richmond–Windsor and Wollongong is discussed in Section 4.6.

Land use in the region is illustrated in Figure 4-2. Nature conservation is the main feature of South East Coast (NSW) region (44 per cent) followed by dryland pasture (37 per cent). 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 is mainly of wine grapes and dairy pasture. In the south of the region, irrigation of broad-acre and dairy farming enterprises occurs in the Hawkesbury–Nepean and Bega river basins.

The hydrogeology of the 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. Typically, use of groundwater in the region is limited.

The major watertable aquifers in the region are shown in Figure 4-3. Groundwater systems in the region that generally provide more potential for extraction include:

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

Figure 4-4 shows a classification of the watertable aquifer as either fresh or saline according to salinity levels. As shown in the figure, quality assured salinity data are not available for most of the region. Generally, fresh groundwater is present in the central parts of the South East Coast (NSW) region southwest, west and northwest of Sydney. Areas with known high salinity values in the region are relatively small.

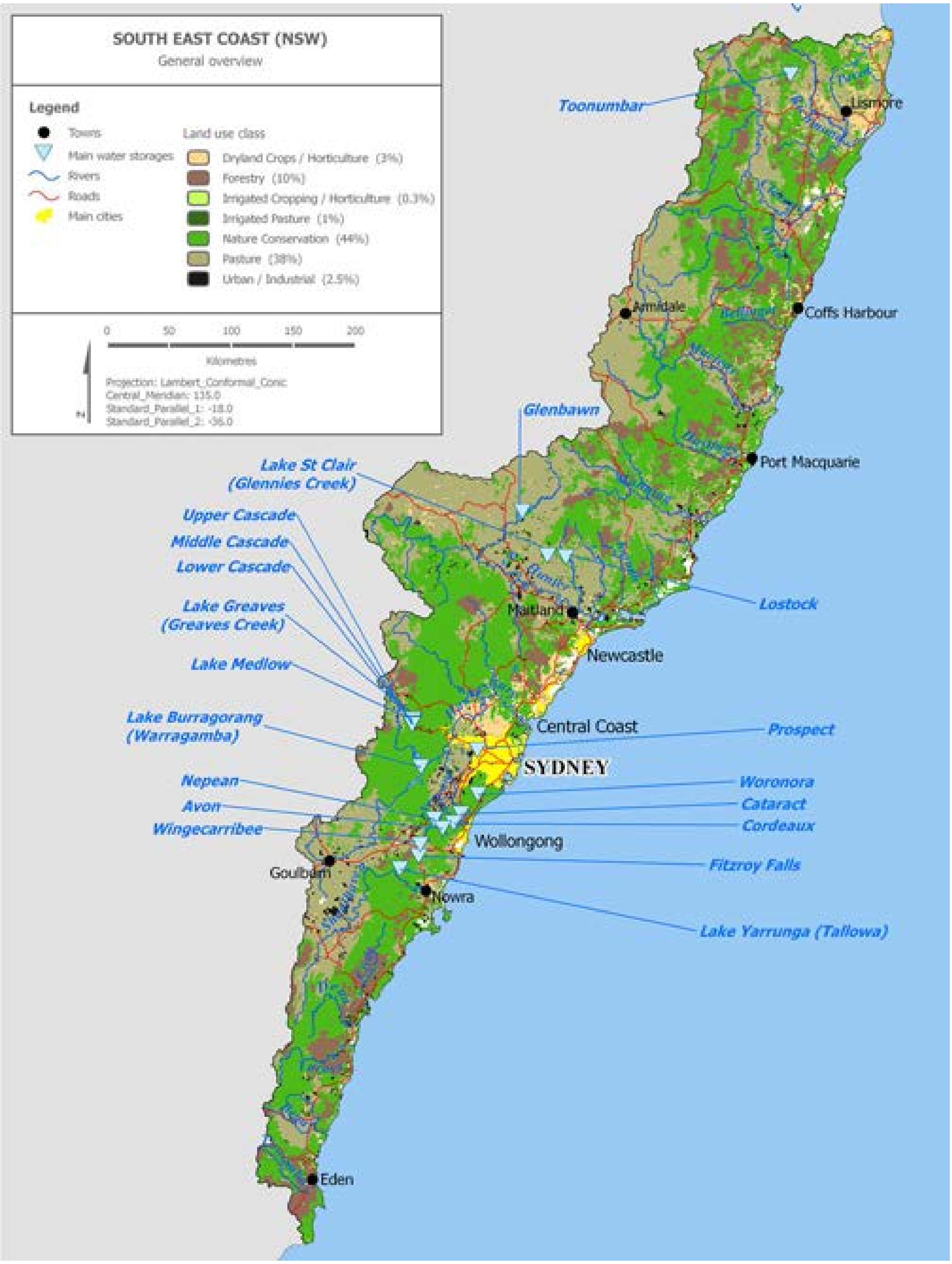


Figure 4-2. Key landscape and hydrological features of the South East Coast (NSW) region (land use classes based on Bureau of Rural Sciences 2006)

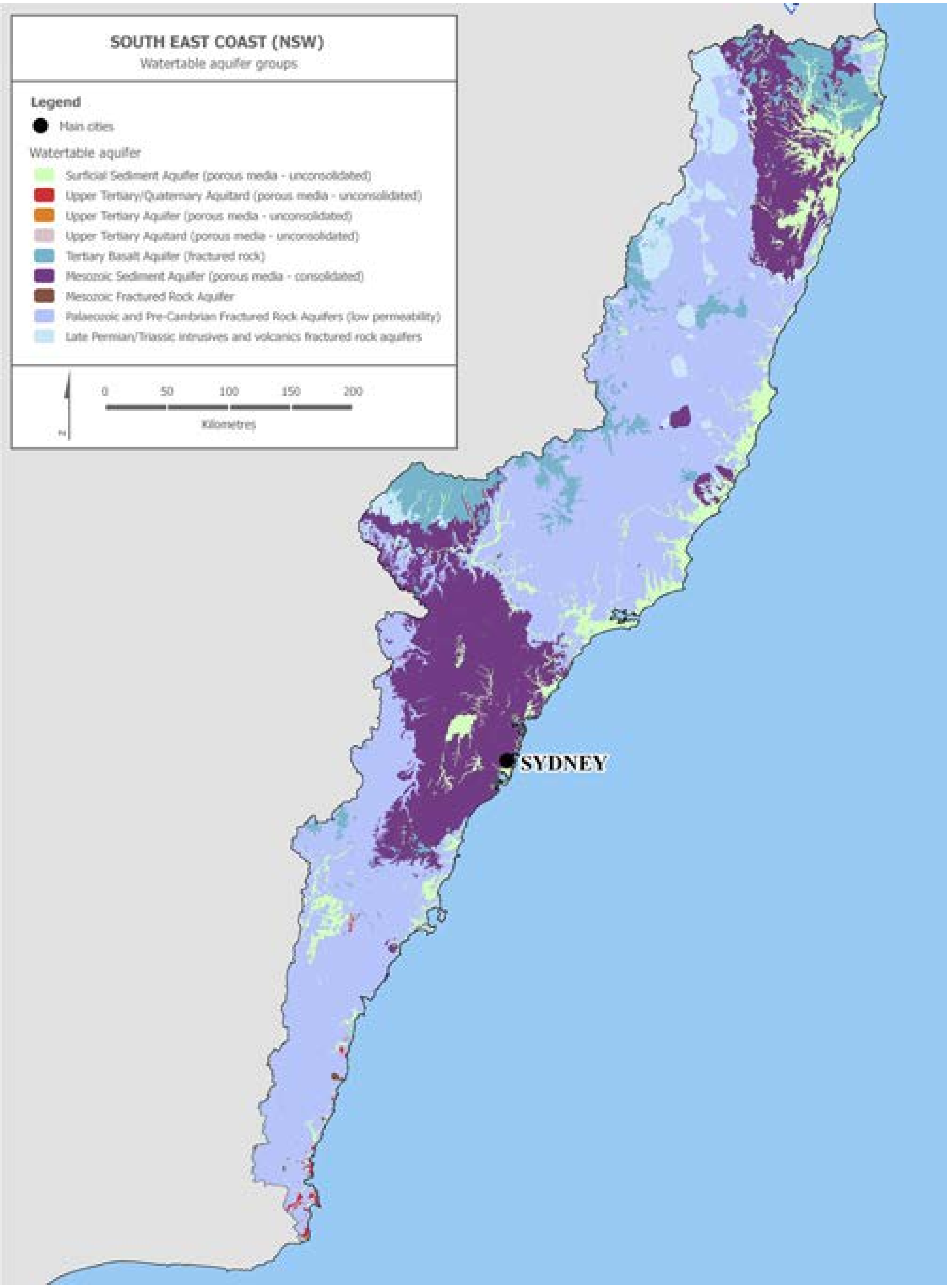


Figure 4-3. Watertable aquifer groups in the South East Coast (NSW) region (Bureau of Meteorology 2011e)

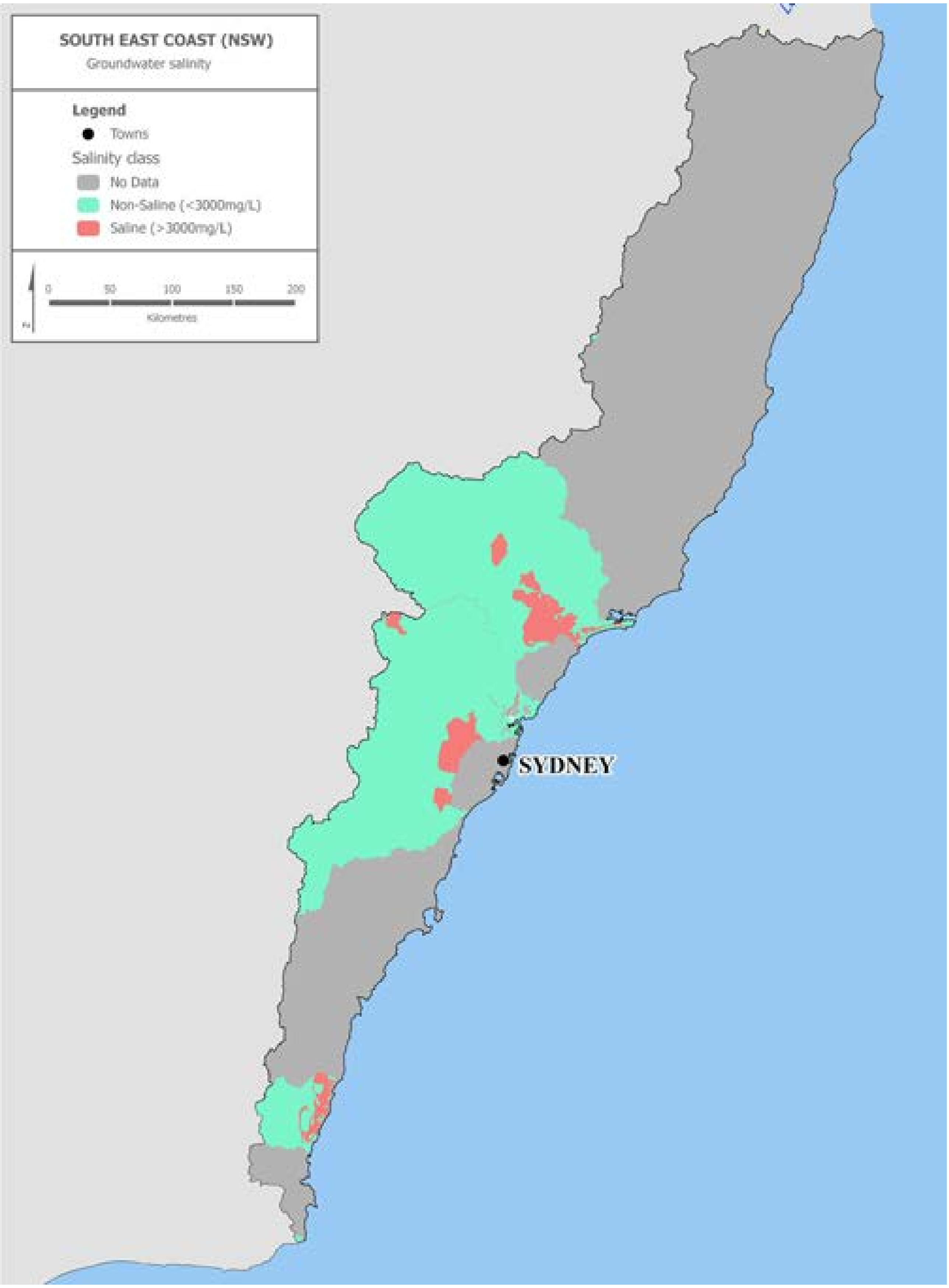


Figure 4-4. Watertable salinity classes within the South East Coast (NSW) region (Bureau of Meteorology 2011e)

4.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 4-5 shows that in the South East Coast (NSW) region, 2009–10 began with dry conditions prevailing for the months of July, August and September 2009, with consistently lower than normal rainfall for each of these months. Monthly rainfall for the remainder of 2009–10 generally fluctuated around the normal range, although higher than usual rainfall was recorded in December 2009 and February 2010, with April being drier than normal. High December rainfall resulted from the wider influence of ex-tropical cyclone *Laurence*, which also generated substantial rainfall for the adjacent inland areas of northern NSW. Regional rainfall was high in February 2010 due to a monsoonal low system that lead to widespread heavy rainfall and flooding across central and eastern Australia.

Despite the limited rainfall during the early months of 2009–10, modelled evapotranspiration through this period was relatively high. The wetter than usual end to the previous year (April–June 2009) maintained slightly higher than normal evapotranspiration from July–September. Through the remainder of the year, monthly evapotranspiration followed a similar pattern to rainfall with higher than normal values observed in the months following higher than normal rainfall.

The wetter than usual end to the previous year also led to relatively high levels of modelled landscape water yield through the beginning of 2009–10. Much of the remainder of the year shows normal conditions, although modelled landscape water yield shows a clear response to the high rainfall for February 2010.

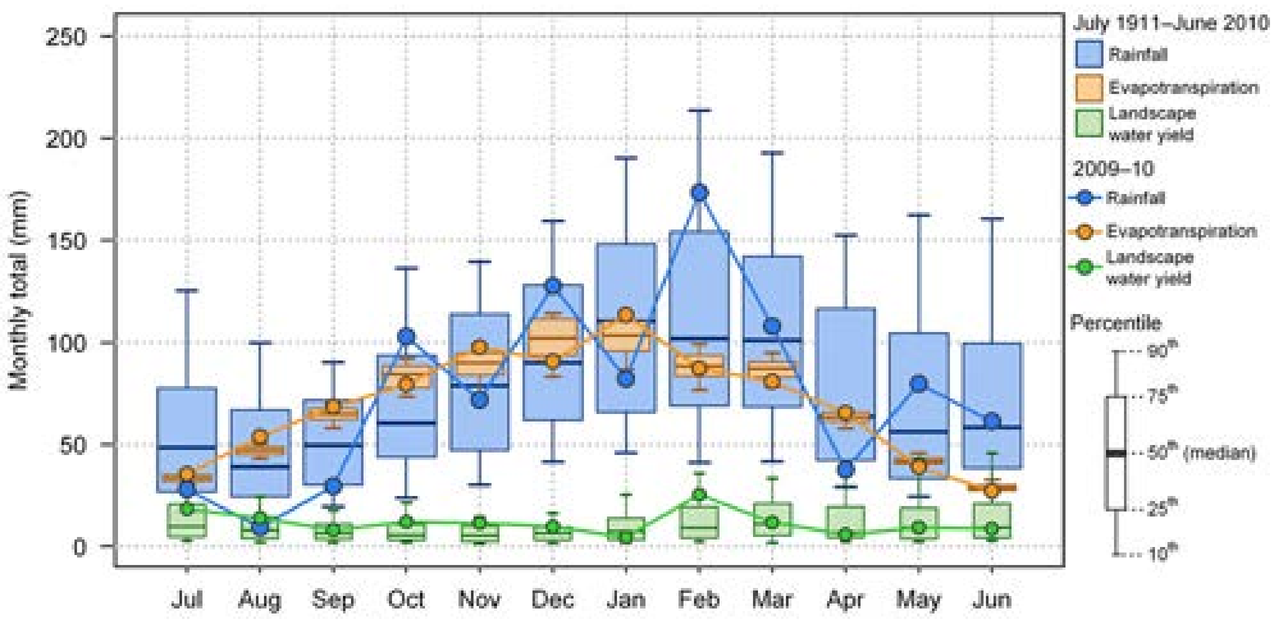


Figure 4-5. Monthly landscape water flows for the South East Coast (NSW) region in 2009–10 compared with the long-term record (July 1911 to June 2010)

4.4.1 Rainfall

Rainfall for the South East Coast (NSW) region for 2009–10 was estimated to be 913 mm, which is eight per cent below the region's long-term (July 1911 to June 2010) average of 995 mm. Figure 4-6 (a) shows that during 2009–10, the highest rainfall occurred close to the coast, particularly in the north of the region. Total annual rainfall was lower moving inland from the coast towards the western boundary of the region. Rainfall deciles for 2009–10, shown in Figure 4-6 (b), indicate rainfall was average across the majority of the region. The central coastal regions experienced drier than average conditions.

Figure 4-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 755 mm (2002–03) to 1,491 mm (1988–89). The annual average for the period was 984 mm. The data shows the total rainfall for 2009–10 (913 mm) was below the 30-year average, following two years of above average rainfall during 2007–08 and 2008–09. Annual rainfall in the six years between 2001–02 and 2006–07 was average or below average.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 4-7 (b). This graph shows that the seasonal distribution of rainfall for the region is characterised by wetter summers than winters. While there is significant variability in seasonal rainfall over the period, no obvious trends or patterns are apparent.

The relatively wet period experienced at the end of the 1980s reflected in the high annual rainfall totals (Figure 4-7 [a]) appears to be due to a peak in summer period rainfall averages from the mid-1980s through to the early 1990s.

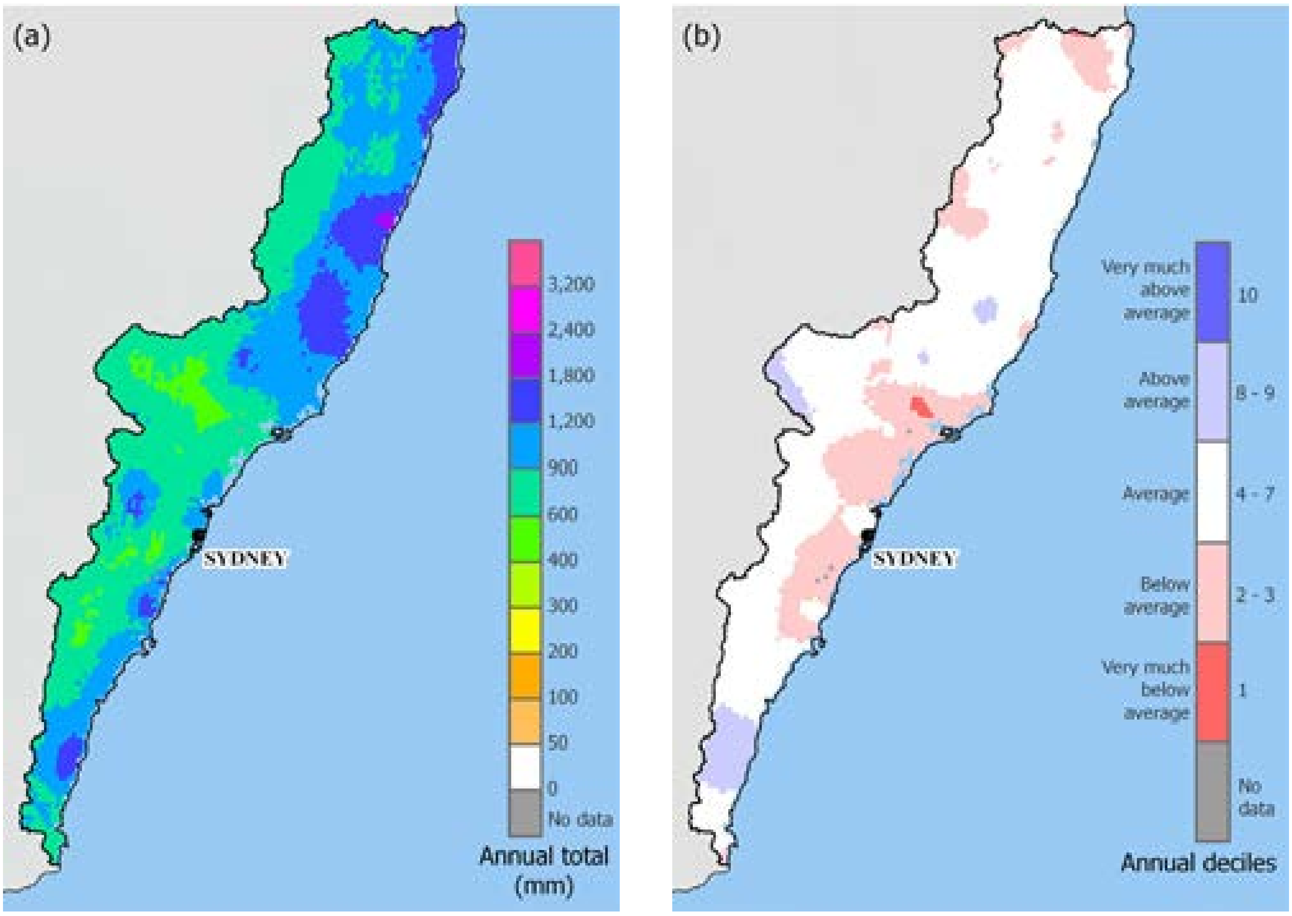


Figure 4-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (NSW) region

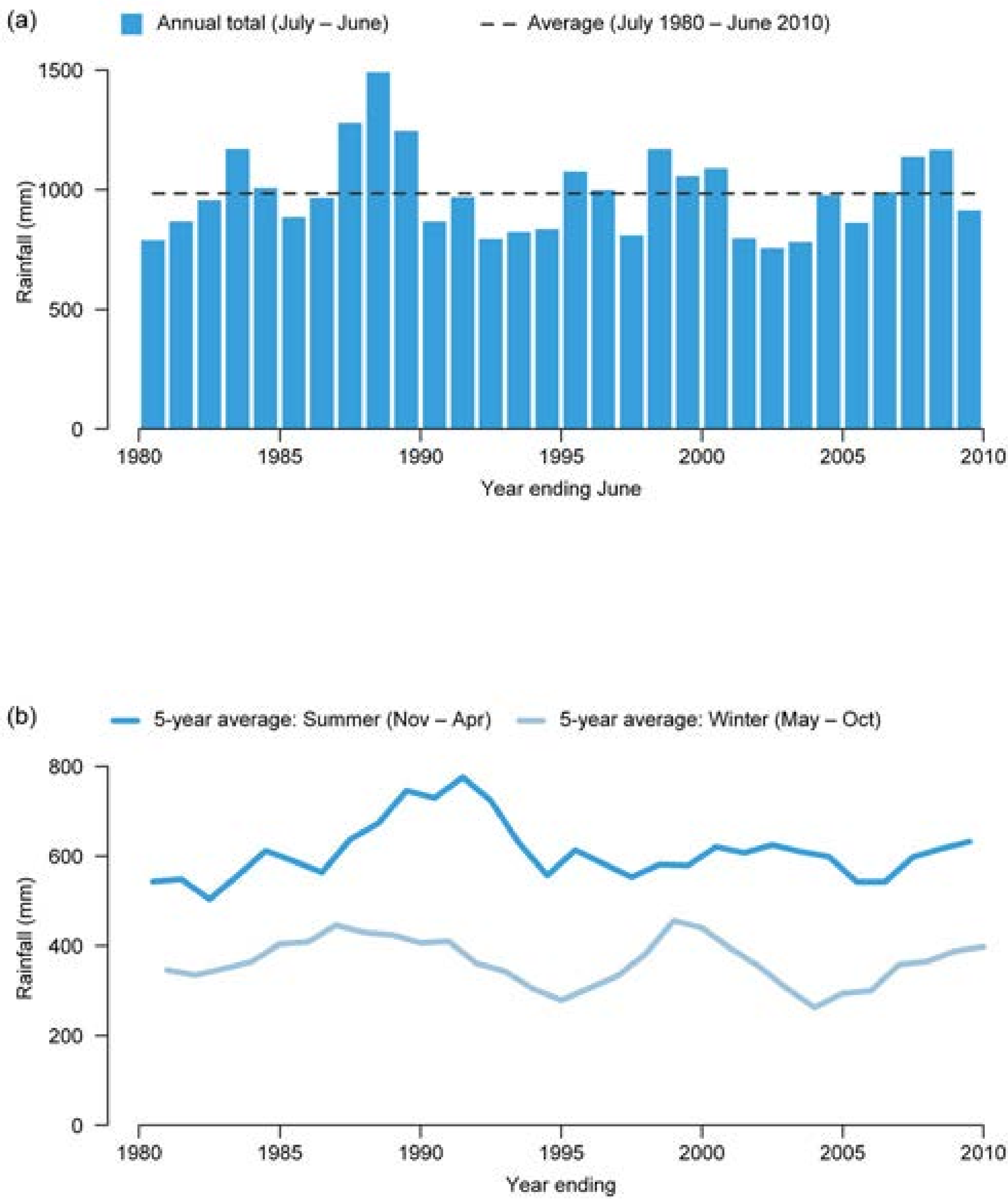


Figure 4-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the South East Coast (NSW) region

4.4.1 Rainfall (continued)

Figure 4-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

This analysis indicates that over the past 30 years there was a general reduction in summer and winter period rainfall across the central-south, south and far north of the region. The magnitude of change is indicated as greater for summer rainfall, which at the regional scale is higher on average than winter rainfall. Conversely, positive trends in both summer and winter rainfall are apparent across the central-north of the region.

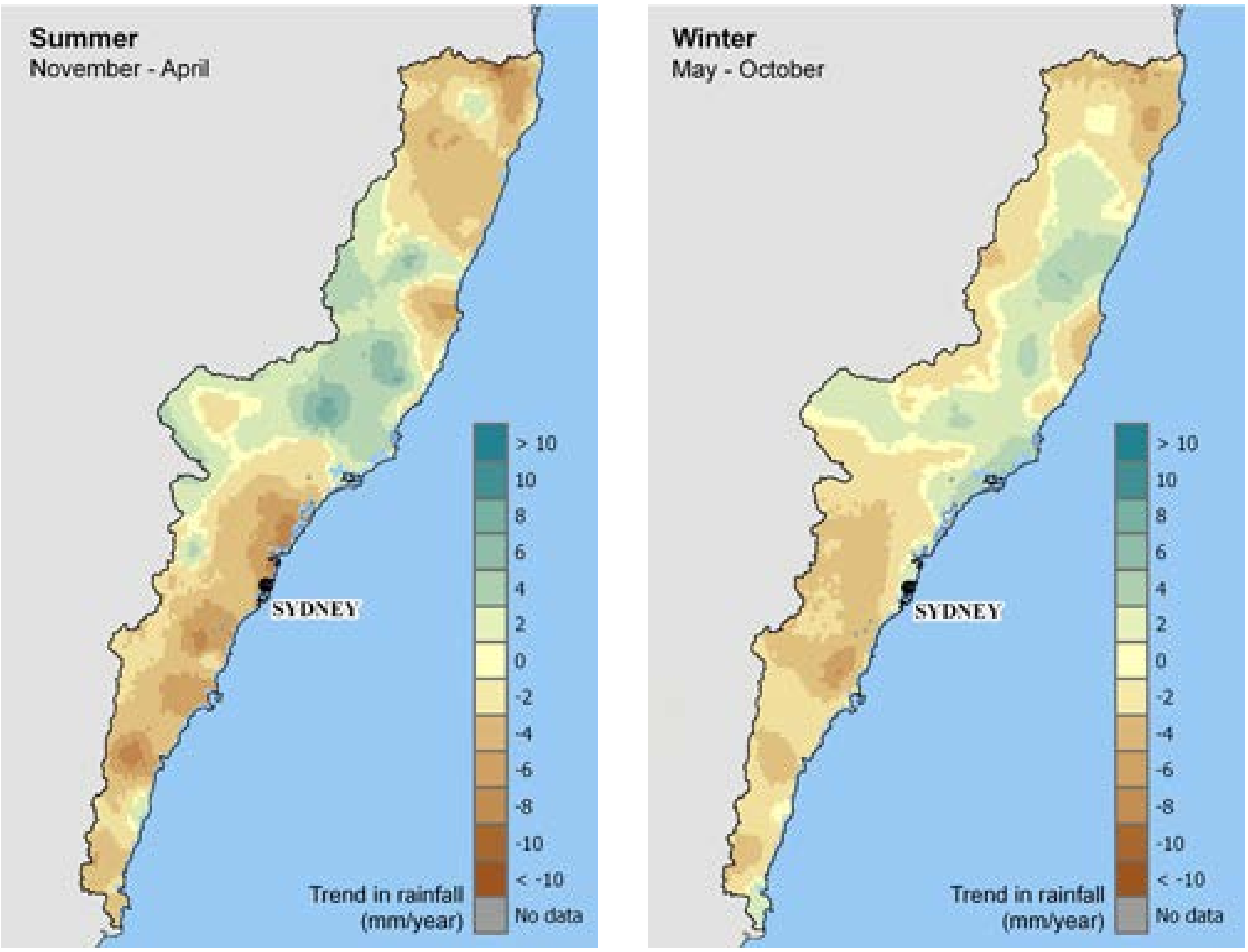


Figure 4-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the South East Coast (NSW) region. The statistical significance of these trends is often very low

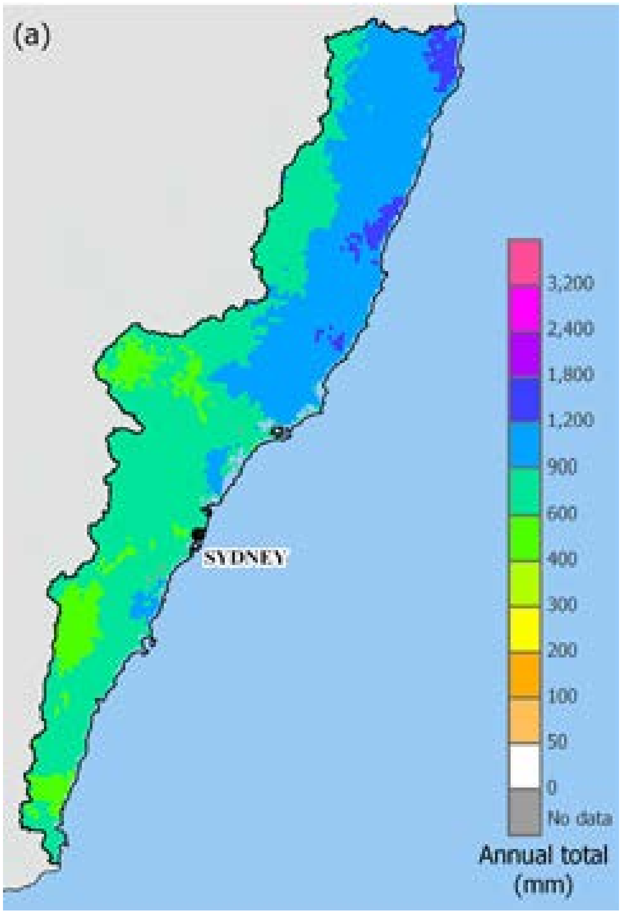
4.4.2 Evapotranspiration

Evapotranspiration for the South East Coast (NSW) region for 2009–10 was estimated to be 840 mm, which is one per cent above the region's long-term (July 1911 to June 2010) average of 829 mm. Figure 4-9 (a) shows that the evapotranspiration for 2009–10 was estimated to be highest over the northern half of the region, particularly along the coast. Evapotranspiration for 2009–10 was lower to the south and southwest of the region.

Evapotranspiration deciles for 2009–10, shown in Figure 4-9 (b), indicate evapotranspiration for this period was above average across large areas in the northern half of the region. Below average and very much below average values are observed across much of the southern half of the region, particularly in the very far south.

Figure 4-10 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 696 mm (1980–81) to 923 mm (1988–89). The annual average for the period was 819 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30 year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 4-10 (b). This graph highlights that, at a regional scale, evapotranspiration in summer is consistently much higher than during winter. There is no clear increasing or decreasing tendency in either summer or winter evapotranspiration over the 30-year period.



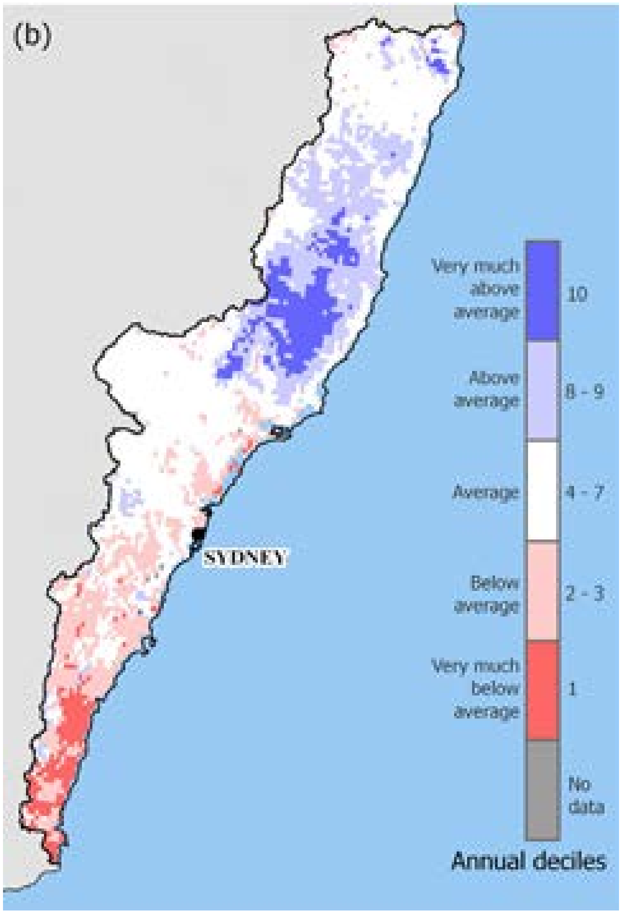


Figure 4-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (NSW) region

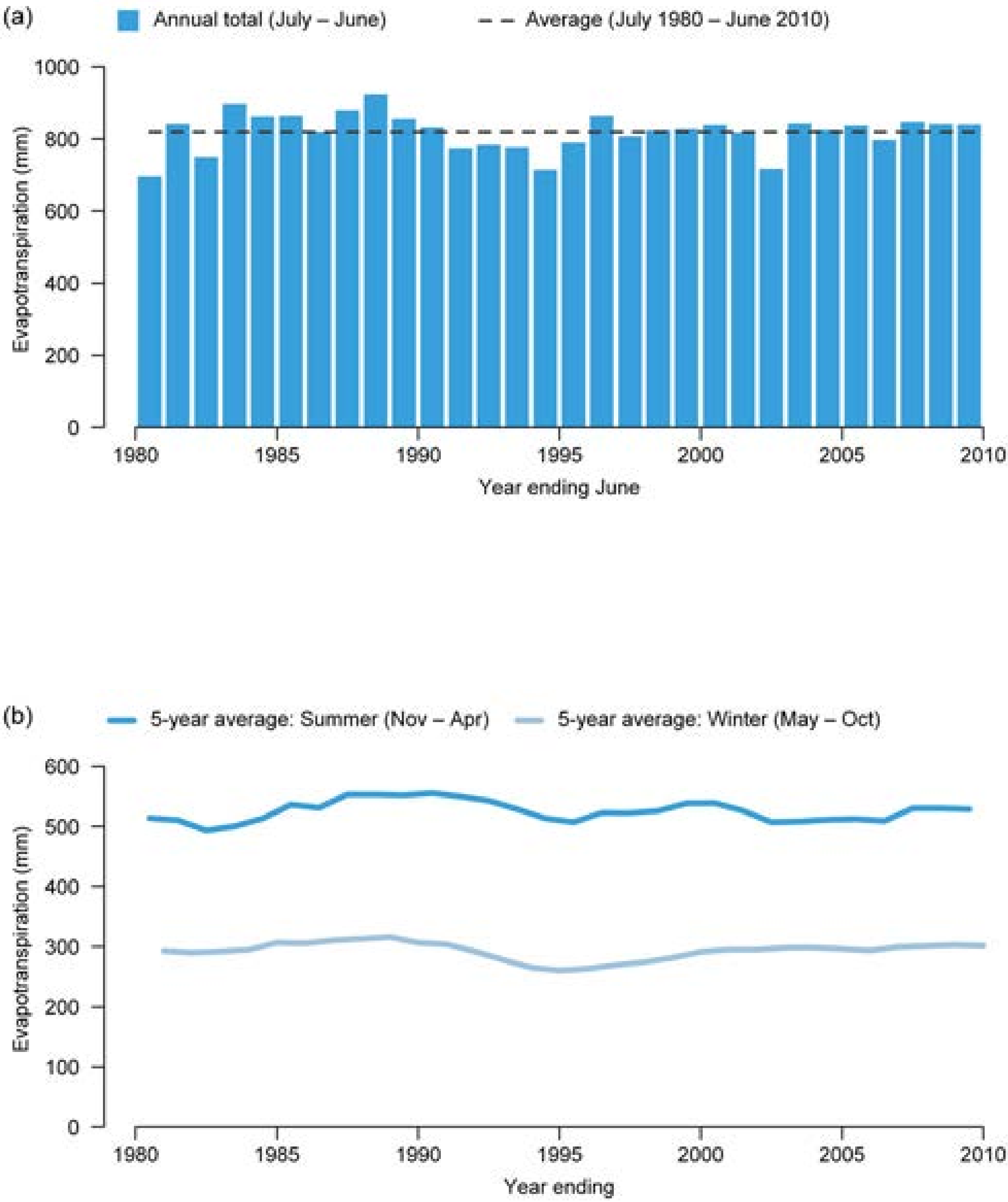


Figure 4-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the South East Coast (NSW) region

4.4.2 Evapotranspiration (continued)

Figure 4-11 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

In general, the spatial pattern indicates that trends in both summer and winter evapotranspiration closely reflect the pattern observed in seasonal rainfall trends (Figure 4-8). Over the past 30 years, both seasons show a general reduction in evapotranspiration in parts of the central-south, south and far north of the region. Slight increasing trends in summer and winter evapotranspiration are identified across the central-north of the region.

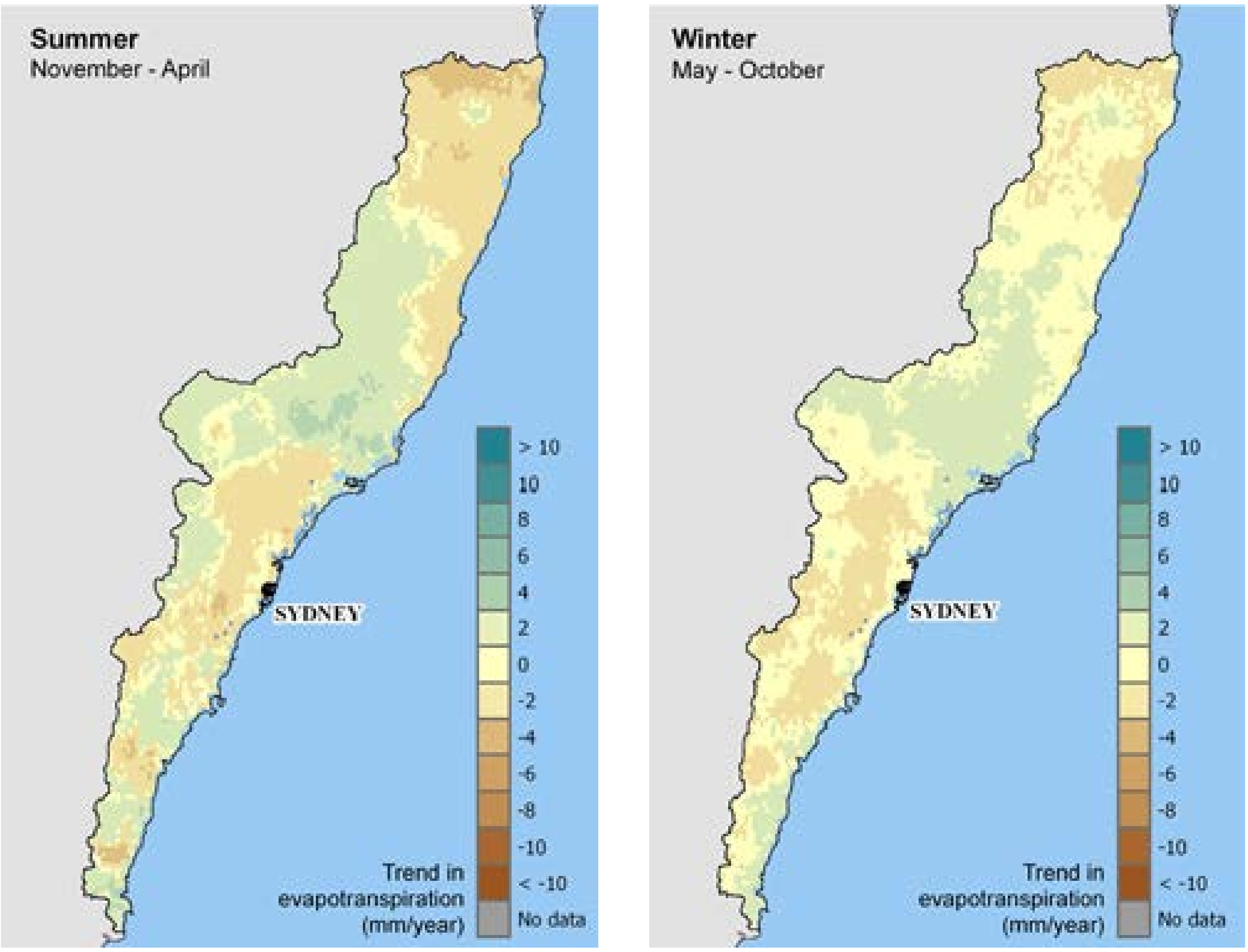


Figure 4-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the South East Coast (NSW) region. The statistical significance of these trends is often very low

4.4.3 Landscape water yield

Landscape water yield for the South East Coast (NSW) region for 2009–10 was 140 mm, which is eight per cent below the region's long-term (July 1911 to June 2010) average of 152 mm. The pattern and distribution of landscape water yield in 2009–10, shown in Figure 4-12 (a), is closely related to the distribution of rainfall over much of the region throughout the same period (see Figure 4-6). Landscape water yield in 2009–10 was highest along the coast in the northern half of the region and in the far south.

Landscape water yield deciles for 2009–10, shown in Figure 4-12 (b), indicate below average and very much below average landscape water yield across central and central-south areas of the region. Some areas in the central-north and far south experienced above average landscape water yields for 2009–10.

Figure 4-13 (a) shows annual landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 62 mm (1997–98) to 376 mm (1988–89). The annual average for the period was 146 mm. The data show that, in line with rainfall, landscape water yield for 2009–10 was below the 30-year average following two years of above average annual totals in 2007–08 and 2008–09.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) is presented using moving averages in Figure 4-13 (b). The data show that landscape water yield for the region is of a similar magnitude in both summer and winter periods.

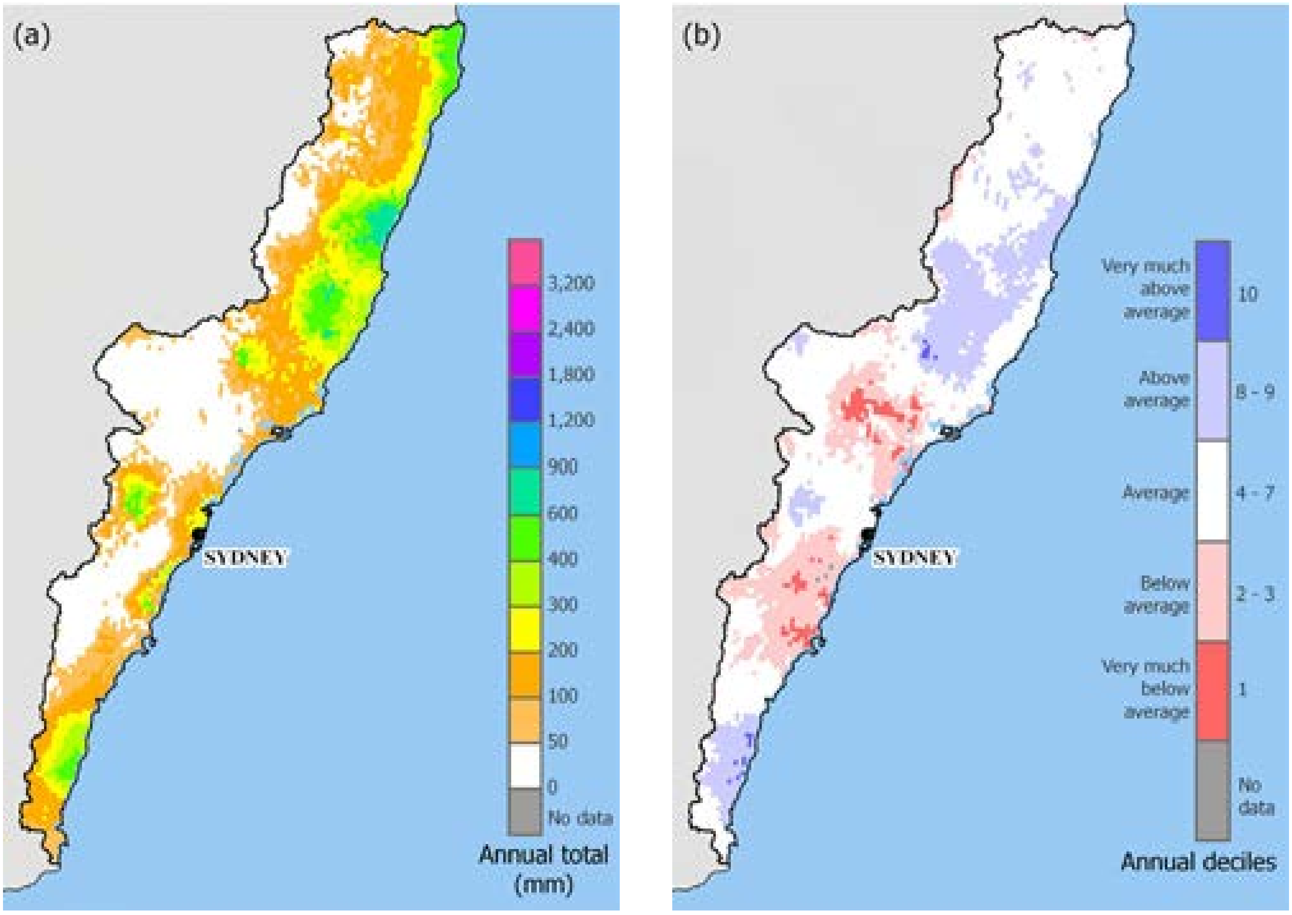


Figure 4-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (NSW) region

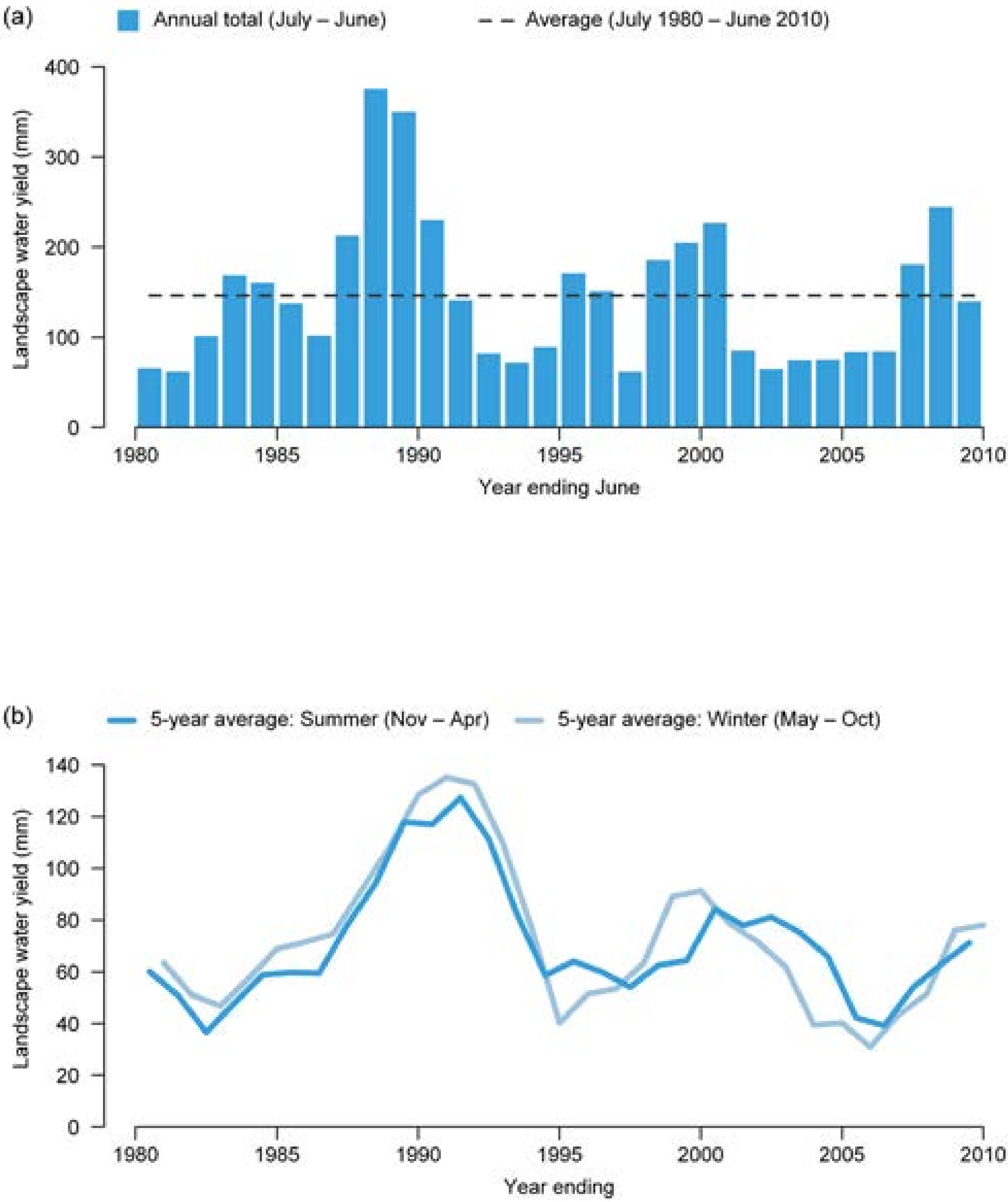


Figure 4-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the South East Coast (NSW) region

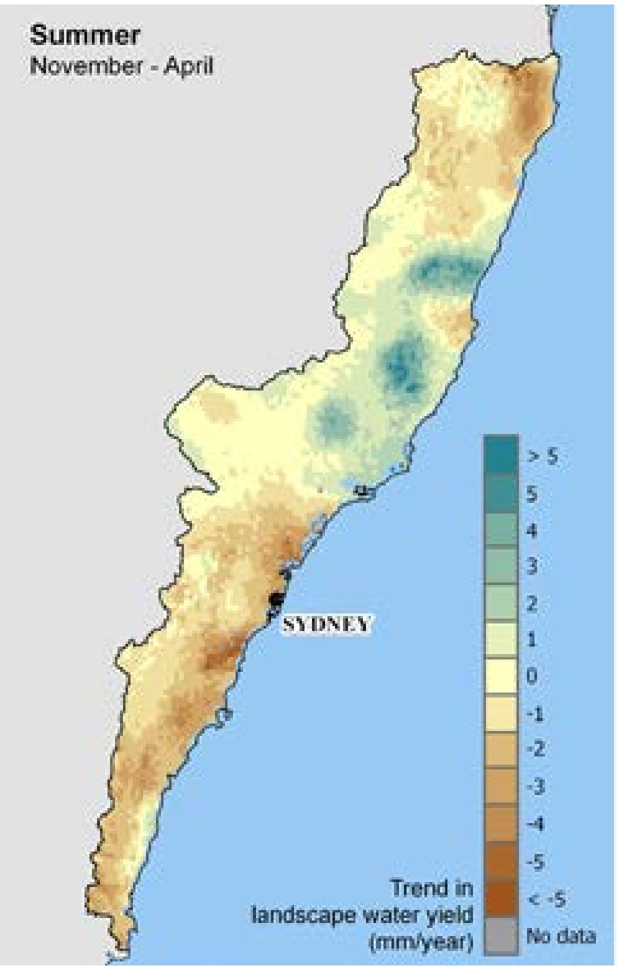
4.4.3 Landscape water yield (continued)

The seasonal averages indicate a general reduction in regional landscape water yield for both summer and winter since the wetter period of the early 1990s. The high annual totals experienced at the end of the 1980s (Figure 4-13) is reflected in increasing seasonal landscape water yield averages from the early 1980s through to the early 1990s.

Figure 4-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope (calculated for each 5 x 5 km grid cell) depicts the change in seasonal water yield over the 30 years.

The strongest negative trends for both summer and winter landscape water yield are observed across much of the southern half of the region and in the far north. The magnitude of the decreasing trends over the 30 years in the generally drier southern half of the region is high relative to the seasonal averages for these areas, particularly for the summer period.

Positive trends in landscape water yield are apparent for both summer and winter periods in the central north of the region. These patterns are very closely related to those identified for trends in seasonal rainfall across the region (Figure 4-8).



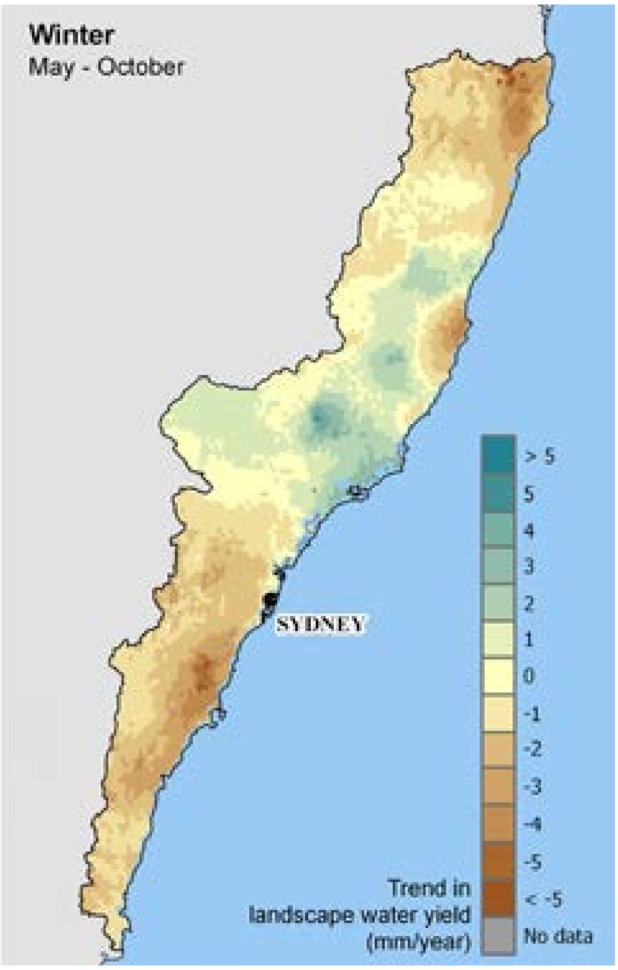


Figure 4-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the South East Coast (NSW) region. The statistical significance of these trends is often very low

4.5 Rivers, wetlands and groundwater

The 31 reliable stream gauges with relatively long records across 15 river basins were selected for examination of regional streamflow in this report (see Figure 4-15). Streamflow at these gauges in 2009–10 was analysed in relation to historical patterns of flow.

Groundwater management units within the region are key features that control the extraction of groundwater through planning mechanisms. According to Figure 4-16, most of the larger units are within the Sydney Basin and fractured rock areas. The smaller units mainly represent coastal sand, alluvial valley or Tertiary basalt aquifers. The Tomago sand beds unit within coastal sand aquifers in the eastern part of the region is important as it provides 20 per cent of the drinking water supply to the Hunter area.

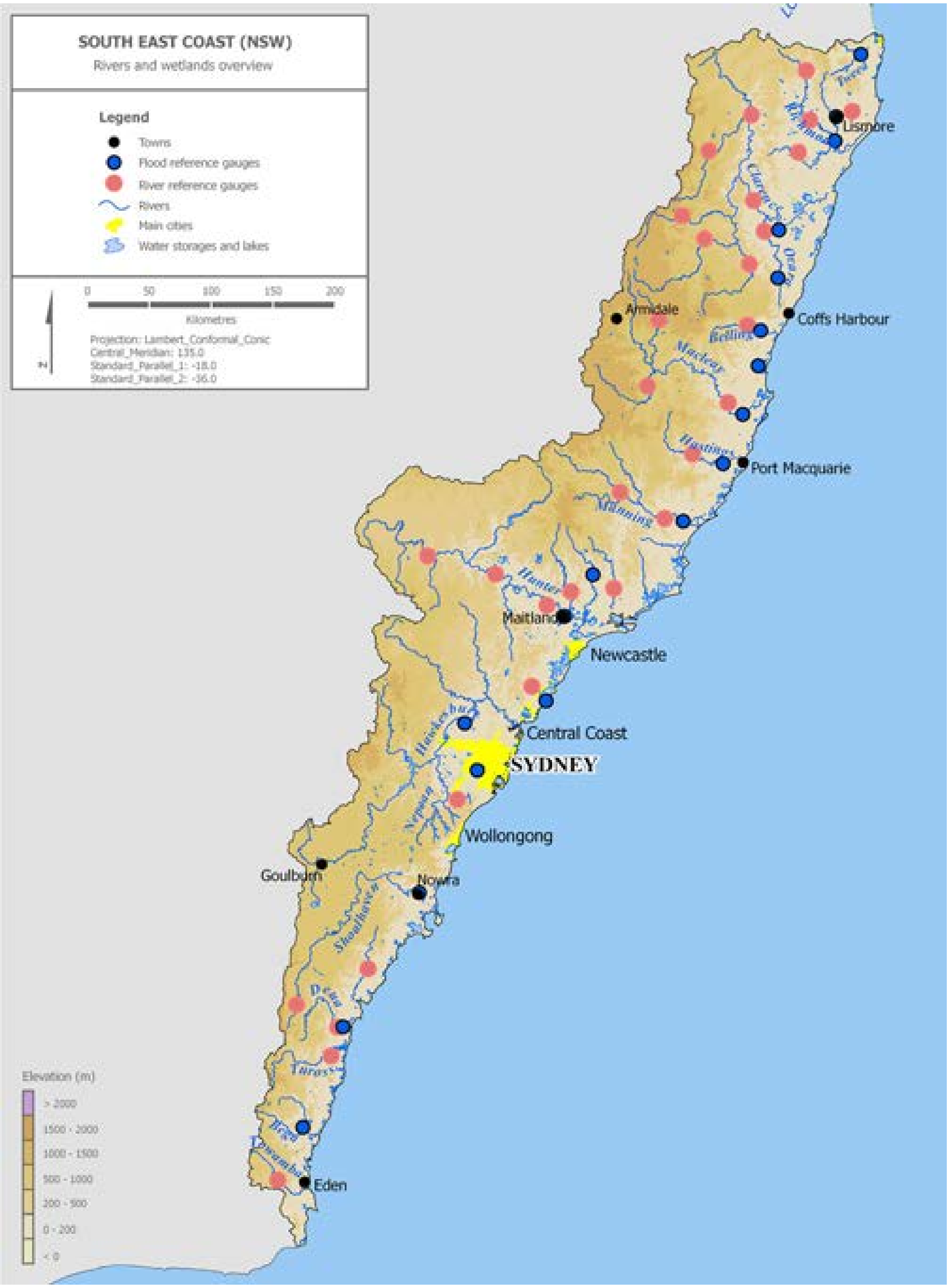


Figure 4-15. Stream gauges selected for analysis in the South East Coast (NSW) region

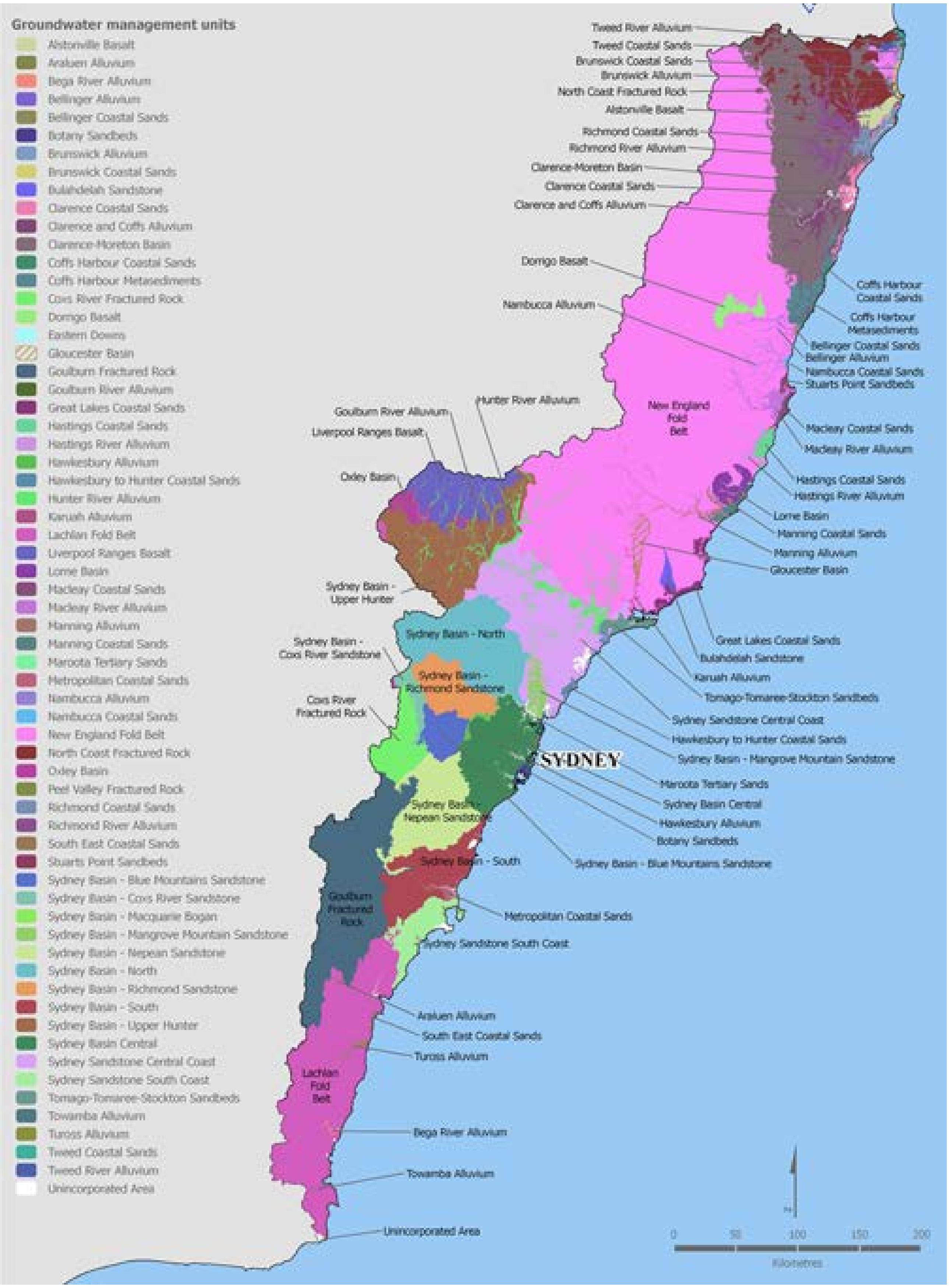


Figure 4-16. Major groundwater management units in the South East Coast (NSW) region (Bureau of Meteorology 2011e)

4.5.1 Streamflow and flood report

Figure 4-17 presents an analysis of river flows over 2009–10 relative to annual flows for the past 30 years at 30 monitoring sites throughout the South East Coast (NSW) region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for 2009–10 are colour-coded relative to the decile rank over the 1980 to 2010 period at each site.

With regard to total annual discharge for 2009–10, Figure 4-17 shows that observations from monitoring gauges in the north and south of the region generally reflected the near average modelled landscape water yield results in those areas (see Figure 4-12 [b]). The very much below average modelled landscape water yield results around the Hunter and Sydney regions are also supported by streamflow data from monitoring gauges in those regions (Figure 4-17).

Broadly, Figure 4-17 shows:

- streamflow for 2009–10 was average over large parts of the region's south and north
- the centre of the region experienced below average streamflow, with very much below average totals in the Hunter River basin.

Figure 4-17 shows a strong pattern of correlation between summer (November 2009 to April 2010) streamflow and total annual streamflow for 2009–10. The main difference was slightly higher streamflow in summer 2009–10 in the far north and south of the region.

Through flood monitoring partnership arrangements, data were available for a number of flood gauges allowing reporting on flood occurrence and severity at those sites. The 18 gauges shown in Figure 4-15 were selected as indicative stations for the South East Coast (NSW) region and are situated on rivers along the New South Wales coast from Bega River in the south to the Tweed River in the north of the state (Table 4-2). The stations were also selected on the basis of data quality and coverage for the 2009–10 year.

No major floods occurred in the NSW coastal river valleys during 2009–10. The main flood events occurred in November 2009 along the mid-north coast and in the south coast in February 2010.

The November floods along the mid-north coast resulted from a surface trough over northeast NSW that produced significant rainfall. Around 200–300 mm of rain fell in the area around Dorrigo and the catchments of Never-Never Creek, and the Orara River. This resulted in moderate flooding at Glenreagh and Bellingen. Minor flooding occurred at Macksville on the Nambucca River.

In February 2010, a low pressure system off the south coast resulted in heavy rainfall and flooding in the Bega River basin. Rainfall of up to 330 mm was recorded in the Bega River basin. This was the first flood for many years, with the flood peak at Bega of 6.8 metres (just below the moderate flood level) being the first significant flood since 1997.

4.5.2 Inflows to wetlands

Despite the presence of a number of Ramsar wetland sites in the South East Coast (NSW) region, no specific analysis of inflows to these sites in recent years is given in this section. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available.

4.5.3 Groundwater status

Groundwater status for the South East Coast (NSW) region was not able to be addressed in this report. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available.

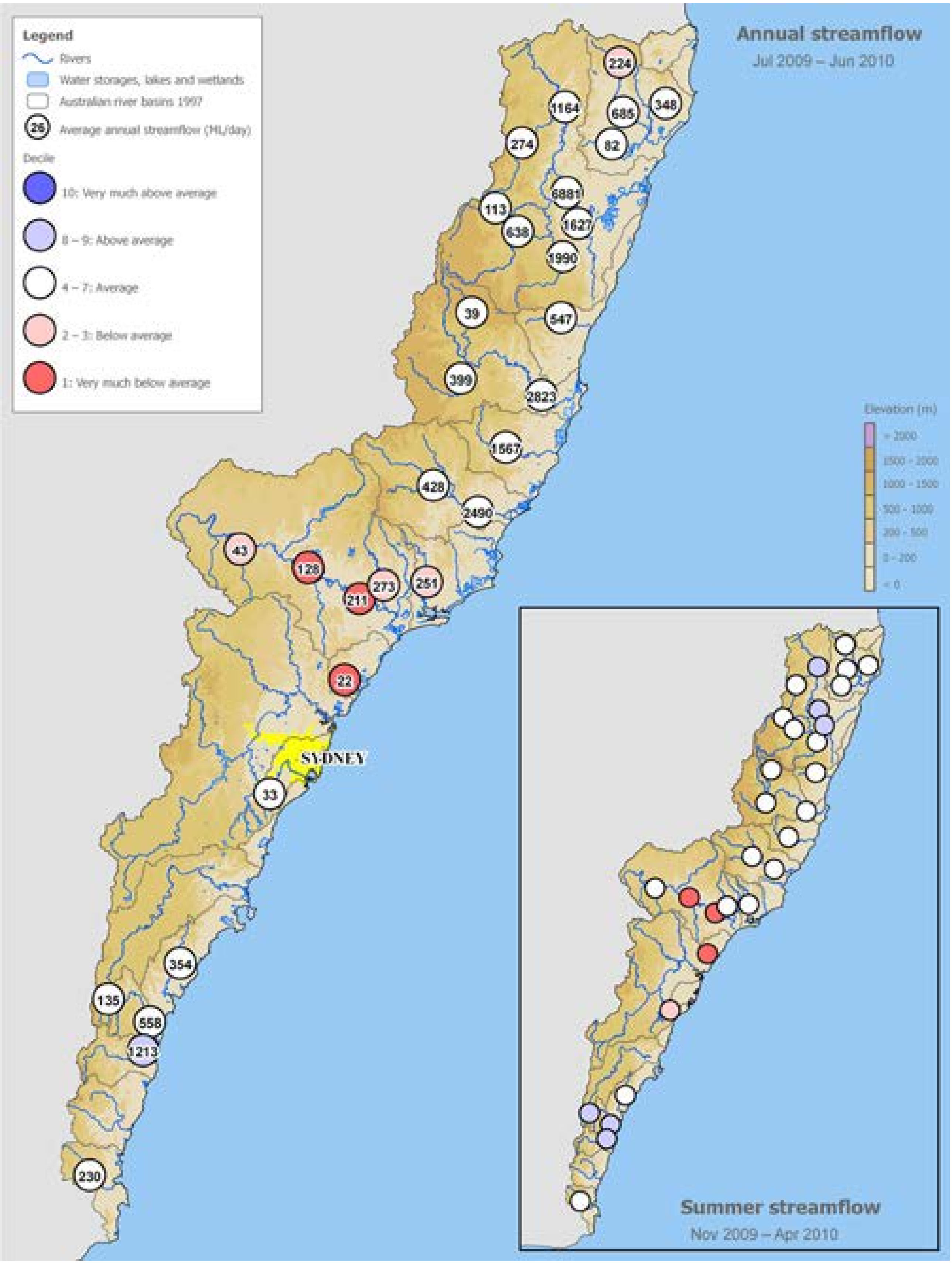
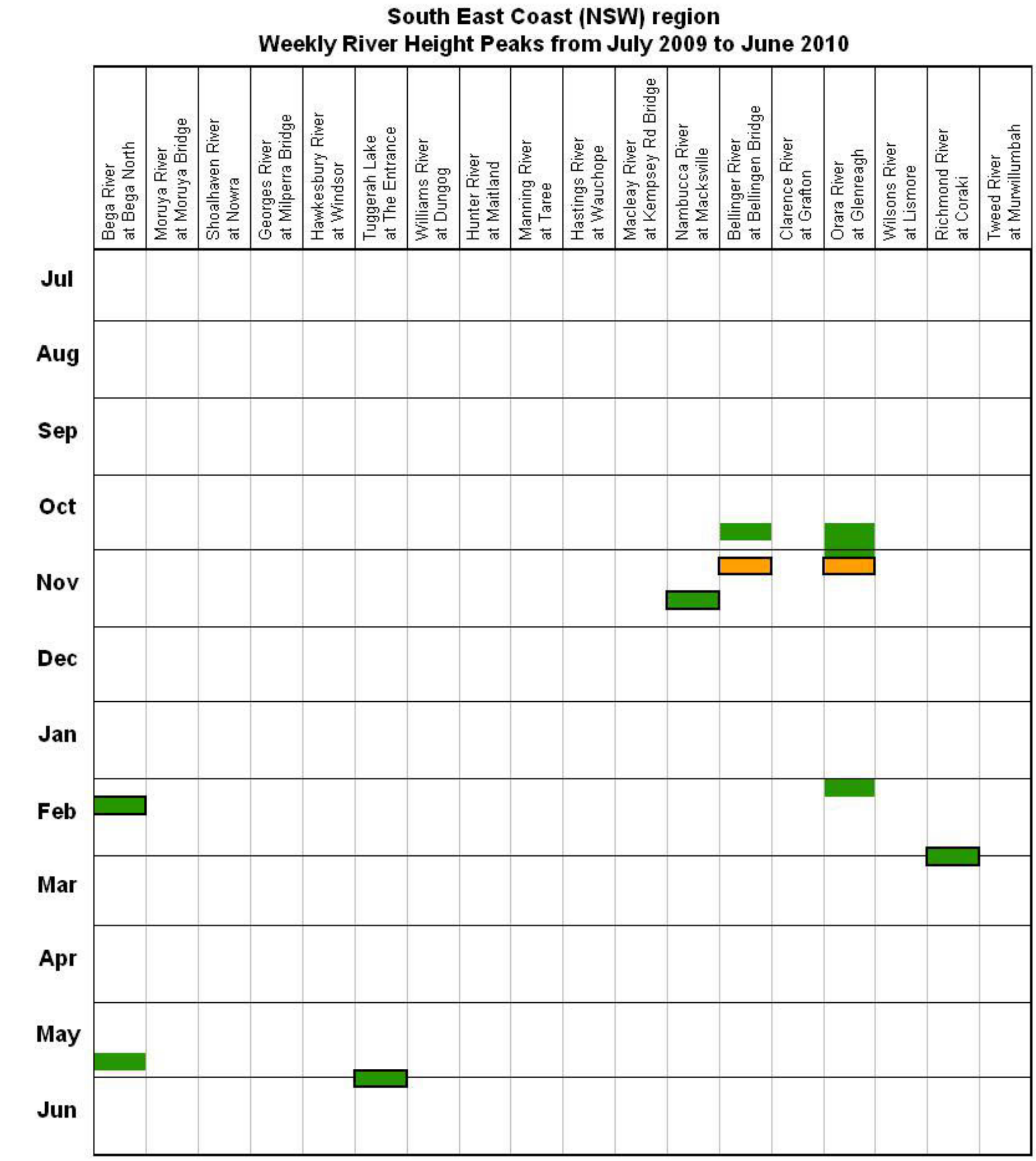


Figure 4-17 Annual and summer streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the South East Coast (NSW) region

Table 4-2. Weekly flood classifications for key flood gauging sites within the region (flood classes are derived in consultation with emergency services and local agencies; the peak height for the year is also included)



Peak flood level (m)

Bega River at Bega North	on 15/02/2010	6.8
Moruya River at Moruya Bridge	-	-
Shoalhaven River at Nowra	-	-
Georges River at Milperra Bridge	-	-
Hawkesbury River at Windsor	-	-
Tuggerah Lake at The Entrance	on 07/06/2010	0.9
Williams River at Dungog	-	-
Hunter River at Maitland	-	-
Manning River at Taree	-	-
Hastings River at Wauchope	-	-
Macleay River at Kempsey Rd Bridge	-	-
Nambucca River at Macksville	on 20/11/2009	1.9
Bellinger River at Bellingen Bridge	on 07/11/2009	7.2
Clarence River at Grafton	-	-
Orara River at Glenreagh	on 07/11/2009	11.6
Wilsons River at Lismore	-	-
Richmond River at Coraki	on 03/03/2010	3.4
Tweed River at Murwillumbah	-	-

River height classes (m)

	Bega	Moruya	Shoalhaven	Georges	Hawkesbury	Tuggerah	Williams	Hunter	Manning	Hastings	Macleay	Nambucca	Bellinger	Clarence	Orara	Wilsons	Richmond	Tweed
Major	8.0	3.2	4.3	4.2	12.2	2.2	8.5	10.5	3.7	5.5	6.6	2.6	8.2	5.4	13.0	9.7	5.7	4.8
Moderate	7.0	2.6	3.3	3.3	7.0	1.8	7.6	8.9	2.4	4.3	5.7	2.1	6.7	3.6	9.0	7.2	5.0	4.0
Minor	4.6	2.0	2.3	2.0	5.8	0.9	4.9	5.9	1.8	2.5	4.5	1.7	3.7	2.1	5.2	4.2	3.4	3.0

Colour codes:
- Below flood level
- Annual flood peak
- Major flooding
- Moderate flooding
- Minor flooding

4.6 Water for cities and towns

4.6.1 Regional overview

The South East Coast (NSW) region includes the most populous city in Australia, Sydney, which is surrounded by heavily urbanised and industrialised areas. To the north and south of Sydney, in a narrow strip along the coast, lie the three next largest urban areas in New South Wales; namely Newcastle, the Central Coast to the north, and Wollongong south of Sydney.

Other urban centres in the region (with more than 25,000 people) are Maitland, Richmond–Windsor, Nowra–Bomaderry, Lismore and coastal towns Port Macquarie and Coffs Harbour. These centres are shown in Figure 4-18 and in Table 4-3 together with their population, river basin and main urban water supply sources. The population of these urban centres accounts for about 71 per cent of the total population of NSW (Australian Bureau of Statistics 2010b).

The largest water storage in the region is Lake Burragorang (Warragamba Reservoir), which is located west of Sydney on the Warragamba River in the headwaters of the Hawkesbury River basin. It is one of the largest domestic water supply storages in the world.

Sydney Water and Hunter Water are two of the larger water suppliers in the region. Sydney Water supplies water to Sydney, Wollongong, and Richmond–Windsor. Hunter Water supplies water to Newcastle and Maitland. Gosford–Wyong Councils' Water Authority supplies water to the Central Coast.

The following sections focus on the Sydney Water supply area which includes the urban centres of Sydney, Richmond–Windsor and Wollongong. Variations in the volume of water held in storage over 2009–10 and over the preceding 20-year period for four of the storages in this supply area are shown in Figure 4-19.

Table 4-3. Cities and their water supply sources in the South East Coast (NSW) region

City	Population*	River basin	Major supply sources
Sydney	4,500,000	Hawkesbury River	Warragamba Reservoir Upper Nepean reservoirs (Cataract, Avon, Cordeaux and Nepean) Shoalhaven system reservoirs (Wingecarribee, Fitzroy Falls, Tallowa Reservoir [Lake Yarrunga] and Bendeela Pondage) Woronora Reservoir Blue Mountains reservoirs (Lower Cascade, Middle Cascade, Upper Cascade, Lake Medlow and Lake Greaves) Lake Oberon Prospect Reservoir
Newcastle	540,000	Hunter River	Grahamstown Reservoir, Chichester Reservoir, Tomago Sandbeds
Central Coast	310,000	Macquarie–Tuggerah Lakes	Mangrove Creek Reservoir, Mardi Reservoir, Mooney Mooney Reservoir
Wollongong	289,000	Wollongong Coast	Avon
Maitland	69,000	Hunter River	Grahamstown Reservoir, Chichester Reservoir, Tomago Sandbeds
Coffs Harbour	52,000	Clarence River Bellinger River	Karangi Reservoir, Orara River
Port Macquarie	43,000	Hastings River	Port Macquarie Off-Creek Reservoir, Cowarra Off-Creek Reservoir
Nowra–Bomaderry	34,000	Shoalhaven River	Shoalhaven River with water released from Lake Yarrunga (Tallowa Reservoir)
Lismore	32,000	Richmond River	Rocky Creek Reservoir
Richmond–Windsor	25,000	Hawkesbury River	Hawkesbury River

* Australian Bureau of Statistics (2010b)

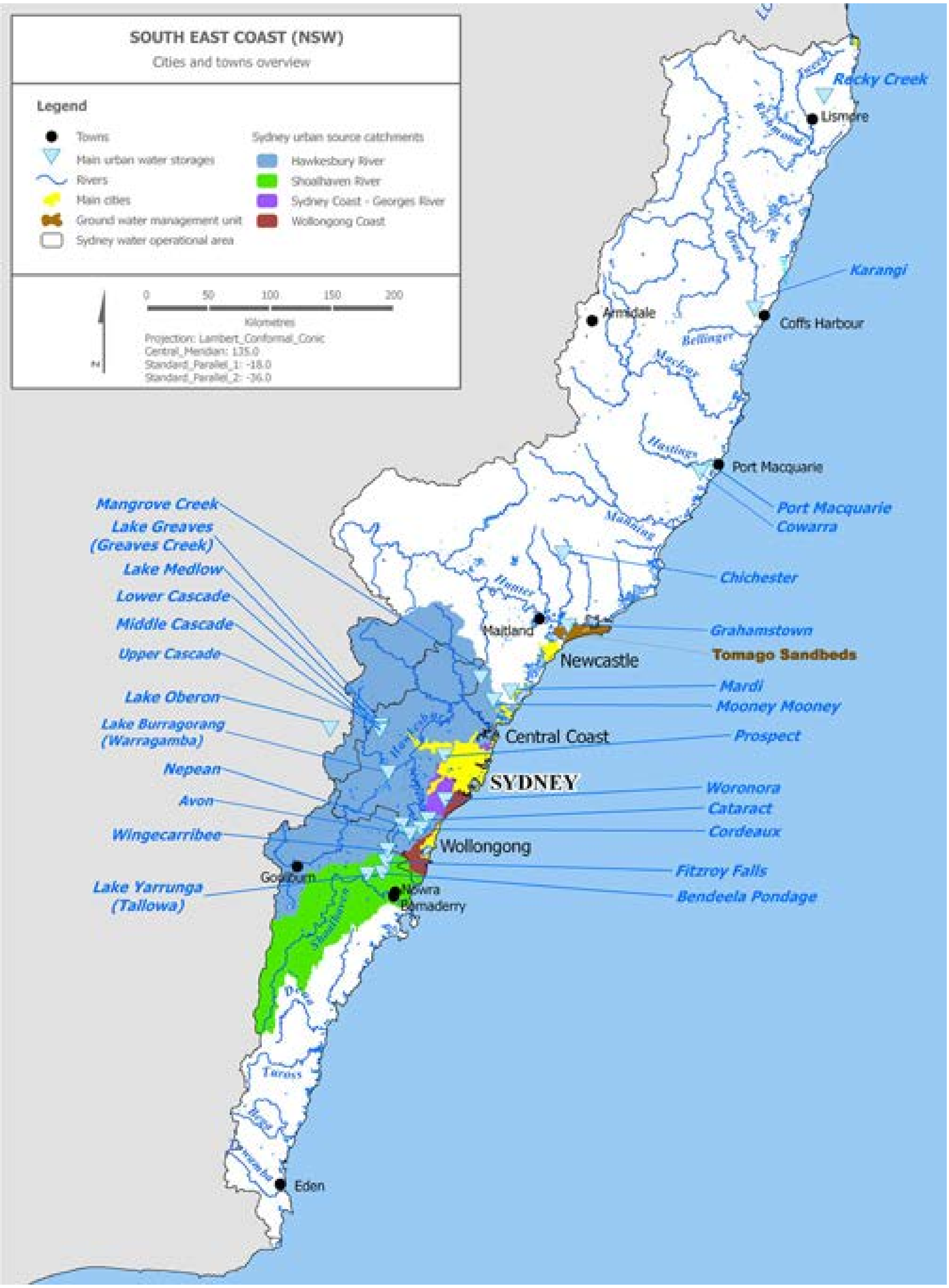
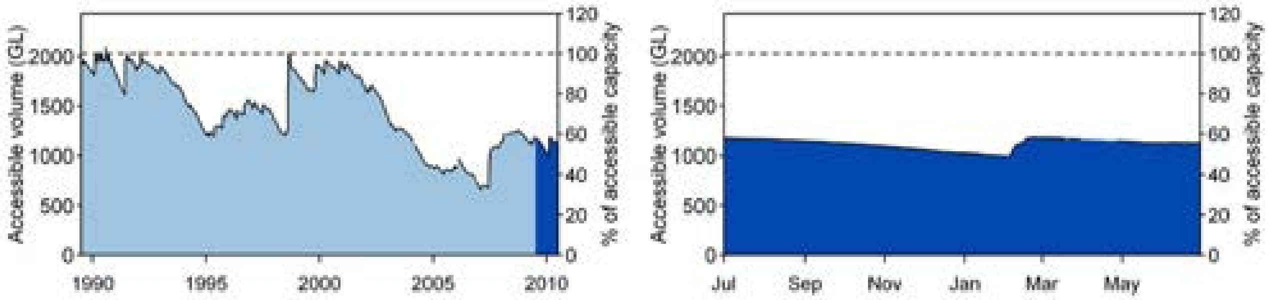
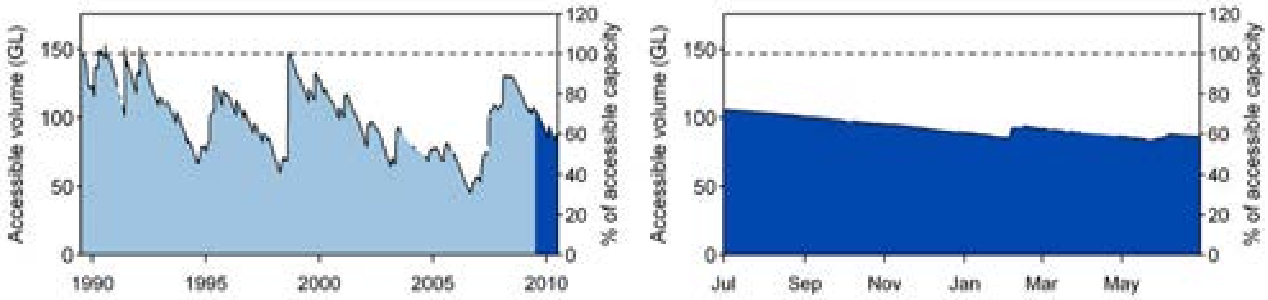


Figure 4-18. Urban areas and supply storages in the South East Coast (NSW) region

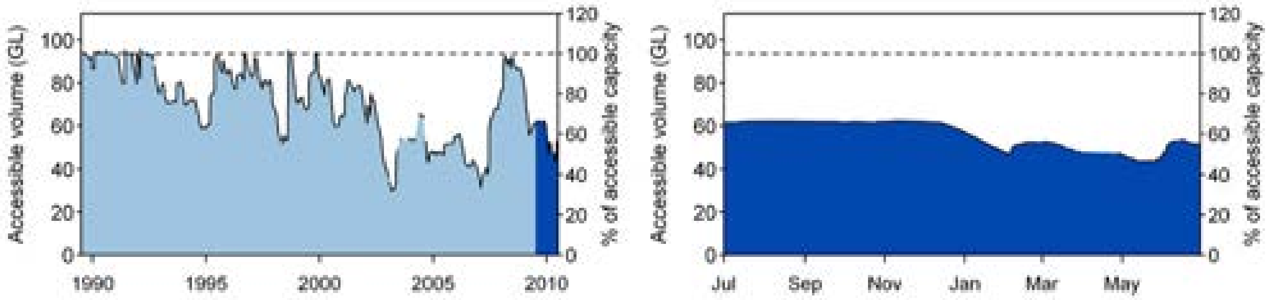
Greater Sydney (Warragamba)



Greater Sydney (Avon)



Greater Sydney (Cordeaux)



Greater Sydney (Cataract)

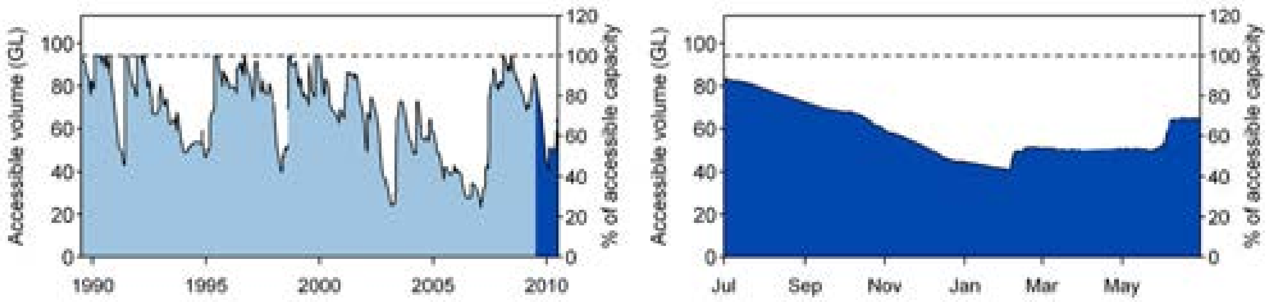


Figure 4-19. Variation in the amount of water held in selected storages in the Sydney Water supply area since 1989 (light blue) and during 2009–10 (dark blue). Gaps in the black line indicate unavailable data points

4.6.2 The Greater Sydney region

The urban centres of Sydney and Richmond–Windsor lie within the catchments of the Hawkesbury–Nepean River and the metropolitan Sydney rivers. Sydney, with a built up area of 4,000 km^2, is one of the largest cities in the world in terms of area (City of Sydney 2011). The city of Wollongong is situated south of Sydney in the Wollongong Coast catchment. These three urban centres account for nearly 60 per cent of the population of NSW 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 section.

The Hawkesbury–Nepean River has a catchment of approximately 22,000 km^2 (NSW Government 2011a). The rivers of the Illawarra and metropolitan Sydney are relatively small. The main Illawarra rivers are the Minnamurra River and the Macquarie Rivulet. The main metropolitan Sydney rivers are the Georges, Woronora and Hacking rivers in the south and the Parramatta River in the northwest.

The urban water for the Greater Sydney region is supplied by Sydney Water, which serves an urban population of over four million. Water supplies are mainly sourced from catchment areas occupying approximately 16,000 km^2, managed by the Sydney Catchment Authority. The 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.

While water from the reservoir system provides most of Greater Sydney's drinking water needs, the 2006 Metropolitan Water Plan (National Water Commission 2009a) 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 Fish River water supply scheme, which originates in Oberon, supplements Sydney's water supply by providing water to the Blue Mountains area. Water from Tallowa (Lake Yarrunga), Fitzroy Falls and Wingecarribee reservoirs is used to supply local communities and supplement Sydney Catchment Authority water storages during drought (NSW Government 2011b).

The Metropolitan Water Plan sets out the NSW Government's strategies to provide a secure supply of water that can meet the long-term needs of Sydney (NSW Office of Water 2010a). The plan is designed to be flexible to enable adaptation to challenges such as drought, climate change and a growing population. The plan was first released in 2004 and is reviewed every four years.

Urban water infrastructure and management

The two main agencies responsible for managing Sydney's water supply system and associated infrastructure are the Sydney Catchment Authority and Sydney Water. The Sydney Catchment Authority is a NSW Government agency created in 1999 to manage and protect Sydney's drinking water supply catchments and storages. The Sydney Catchment Authority supplies bulk water to its customers, including Sydney Water and a number of local councils.

The Sydney Catchment Authority works in partnership with local councils, landholders, government agencies, industry and other community stakeholders to protect the health of catchments to the south and west of the city, reaching west past Lithgow and south past Goulburn (NSW Office of Water 2010a).

Sydney Water is a statutory corporation owned by the NSW Government and is responsible for providing drinking water, recycled water, wastewater services and some stormwater services to Sydney, Illawarra and the Blue Mountains. Sydney Water is Australia's largest water utility with 3,000 staff and an area of operation covering 12,700 km^2 (Sydney Water Corporation 2011a). In 2009–10, Sydney Water supplied over 506 GL of drinking water to over 4.4 million customers (National Water Commission 2011a).

The major water supply infrastructure for Sydney is given in Figure 4-20. Greater Sydney is known to have one of the highest per capita water storage capacities in the world (NSW Government 2011c). The inter-connected reservoir network represents a complex urban water system and includes a total of 21 storages (11 major reservoirs) that hold more than 2,500 GL of water (Sydney Catchment Authority 2011a). Water taken from the Hawkesbury River is used to supply Richmond–Windsor. The water supply for Wollongong is sourced from the Avon Reservoir.

4.6.2 The Greater Sydney region (continued)

Figure 4-20 also shows the water treatment plants and the treated water delivery systems for the Greater Sydney area. Water sourced from the reservoir 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 catchments of the Wollondilly and Coxs river systems covering an area of 9,050 km^2 (Figure 4-20). It is the largest urban water storage in Australia and accounts for about 80 per cent of water supplies in the Sydney area (Sydney Catchment Authority 2011b).

The reservoirs of the Upper Nepean collect water from the catchments of the Cataract, Cordeaux, Avon and Nepean rivers (Figure 4-20). The catchments of the Upper Nepean lie in one of the highest rainfall regions in New South Wales (NSW Government, 2010a). Together with the Shoalhaven River basin, they provide more reliable inflows than the catchments of Warragamba. The Upper Nepean transfer system can provide the equivalent of 30 per cent 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 4-20).

The Blue Mountains reservoir system comprises three small catchments feeding six reservoirs, which provide water for the Blue Mountains region. Water can also be sourced from the Fish River Scheme which originates in Oberon (Sydney Catchment Authority 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 (Figure 4-20).

Woronora Reservoir, the water supply source for the Sutherland Shire in Sydney's southeast, collects water from the Woronora River catchment (Figure 4-20).

The Shoalhaven system in the south (which includes Wingecarribee Reservoir, Fitzroy Falls Reservoir, Bendeela Pondage and Tallowa Reservoir) is an integral part of Sydney's water supply system (Figure 4-20). 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 Reservoir on the Shoalhaven River to supplement water supplies in times of drought. The system can provide around 30 per cent of supply to the Greater Sydney region. Water is transferred using the river system to provide additional water into Warragamba Reservoir or the Upper Nepean reservoirs (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 (Sydney Water Corporation 2011b). When operating at full capacity, the desalination plant can produce 90 GL of water per year, enough water to supply up to 15 per cent of Sydney's current water needs. Water from the desalination plant enters the system at Erskineville and is distributed to approximately 1.5 million people across the Sydney central business district, inner west, eastern suburbs, southern Sydney and parts of the Sutherland Shire, and at times as far west as Auburn (NSW Government 2011d).

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. This scheme provides recycled water to more than 19,000 homes (Sydney Water Corporation 2011c). The Wollongong Recycled Water Scheme supplies water for industrial and irrigation use. The remaining recycled water schemes mainly supply agricultural areas and sports fields.

Sydney Water collects and treats Sydney's wastewater via a network of 24,000 km of pipes and 29 wastewater treatment plants, 13 of which are recycling plants (Sydney Water Corporation 2011d). Sydney Water owns all of the 29 wastewater treatment plants and operates 28 of them. One plant, Gerringong–Gerroa, is operated by Veolia Water on behalf of Sydney Water.

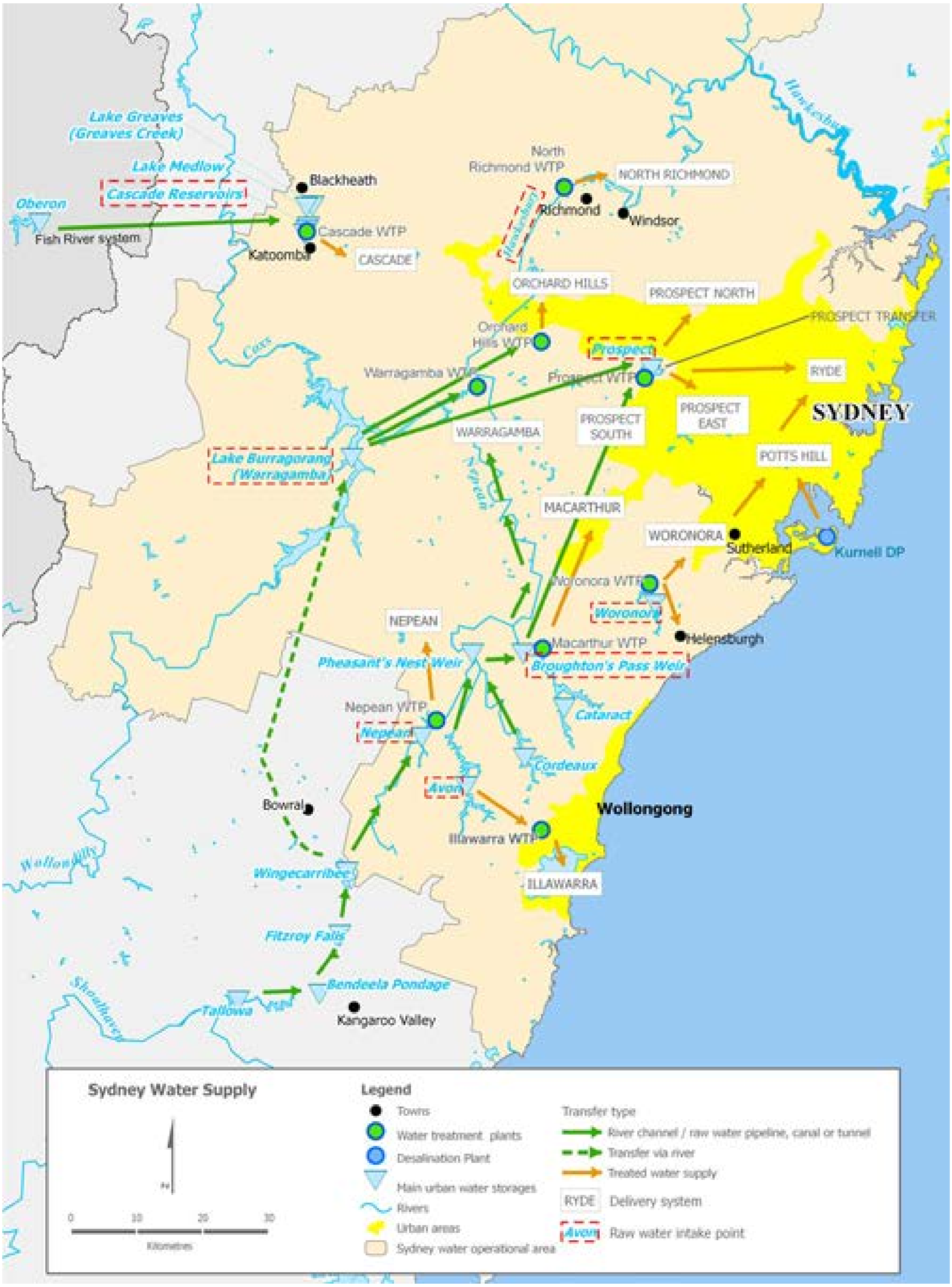


Figure 4-20. Water supply schematic for Greater Sydney

Surface storage levels and volumes in recent years

Sydney's rainfall is highly variable and the catchments are subject to infrequent but severe droughts, such as those in the 1890s, the 1930–40s and the recent drought of 2001–07. While there were periods of low inflows, there were also numerous large inflow events where storages filled quickly, even when levels were low (NSW Government 2010a).

The volume of water in a storage is influenced by inflows from the upstream catchments, water transfers between storages and the volume taken for water supplies under different demand management conditions (including water restrictions). The interconnected reservoir network in Sydney allows water to be transferred to where it is needed. For example, in 2008–09 the recorded inflow to the Warragamba Reservoir was 260 GL, including 46 GL of bulk water transfers from the Shoalhaven System via Wingecarribee Reservoir (Sydney Catchment Authority 2011c).

Figure 4-21 illustrates the combined volume of water stored in Warragamba, Cordeaux, Cataract and Avon reservoirs. These four reservoirs represent about 90 per cent of the total storage capacity of the Sydney's reservoir network since 1990.

In 2009–10, the combined storage of the four reservoirs remained between 50–60 per cent of the accessible capacity. In the early part of the year, the combined storage was close to 60 per cent. There was a gradual decrease in storage to 50 per cent in the first half of the year. Above average rainfall in February 2010 allowed the combined storage volume to rise to close to 60 per cent and further rainfall in May and June 2010 maintained this level.

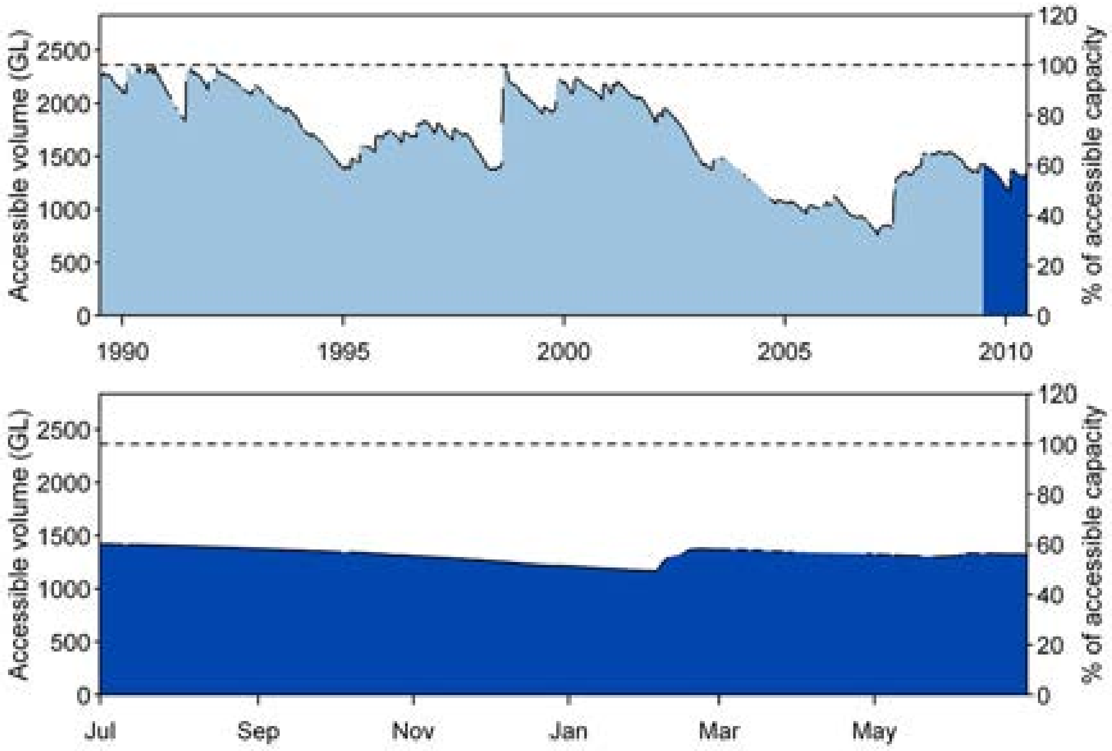


Figure 4-21. Combined surface water storage volumes for Warragamba and Cataract, Cordeaux and Avon reservoirs since 1989 (top) and during 2009–10 (bottom). Gaps in the black line indicate unavailable data points

As illustrated in Figure 4-21, the combined storage reached near full accessible capacity in 1990 and remained relatively high until 1993. Thereafter the storage volume decreased gradually to below 60 per cent in response to below average rainfall in 1993–94. Mandatory water restrictions were introduced in Sydney from November 1994 to October 1996 to reduce demand and, with above average rainfall in 1995, the combined storages improved to above 70 per cent of the accessible capacity.

Following below average rainfall during 1996–97, the combined storage gradually decreased to below 60 per cent of accessible capacity by 1998, but heavy rainfall associated with a La Niña event in that year allowed the combined storage to rise rapidly to near full capacity. The storage volume remained above 80 per cent until 2002. By 2005, the storage volume of the four reservoirs decreased to close to 40 per cent of accessible capacity following a severe drought in 2002–03 and three consecutive years of below average rainfall. The combined storage volume remained low until 2007, then rose to 60 per cent of capacity by 2008 following the wettest year in Sydney since 1998, and has remained close to this level since.

Water restrictions in recent years

Figure 4-22 shows the water restrictions in place in Sydney in recent years as a measure to reduce the demand on water supplies. When the accessible volume of Warragamba Reservoir was decreasing, mandatory water restrictions were introduced in Sydney from 1 November 1994. Mandatory water restrictions were lifted on 16 October 1996 (Sydney Water Corporation 2010) following improvements in water storage volumes following above average rainfall in 1995.

During 2002, Sydney experienced the effects of the onset of one of the worst periods of drought in recorded history. Surface water storage levels began to decline rapidly and, as a strategy to reduce water consumption, voluntary water restrictions were introduced in Sydney from 15 November 2002 (Sydney Water Corporation 2010). Despite this, the volume of water in Warragamba Reservoir continued to decrease under the ongoing drought conditions.

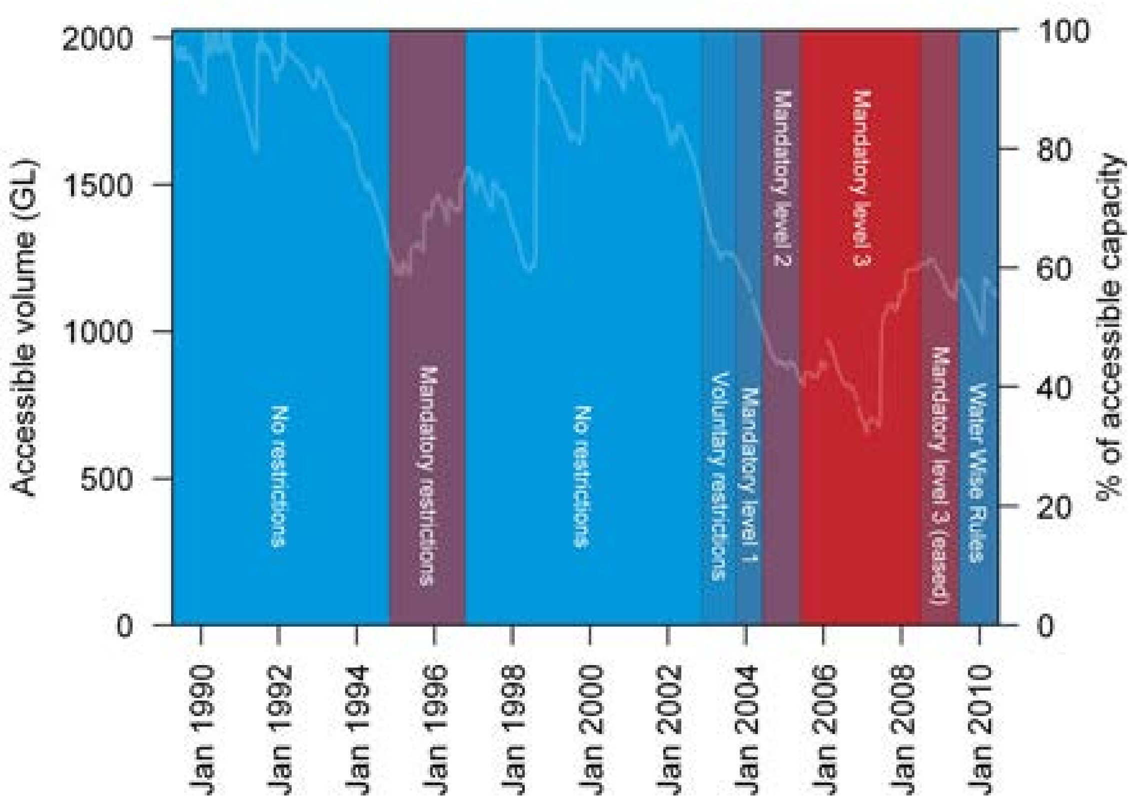


Figure 4-22. Urban water restriction levels in Sydney since 1989 shown against accessible water volume in Warragamba Reservoir

4.6.2 The Greater Sydney region (continued)

An overview of the restrictions and their date of introduction after 2002 are given by Sydney Water Corporation (2011e). With the total combined storage of Sydney's reservoir network falling below 60 per cent of its capacity, Sydney Water introduced mandatory water restrictions level 1 at the beginning of October 2003. When Sydney's total reservoir storage dropped below 50 per cent 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 reservoir storage dropped below 40 per cent of capacity.

Storage in Warragamba Reservoir reached the lowest level observed in recent years in 2007. This was followed by an improvement in the storage volume in response to above average rainfall in 2007. Level 3 water restrictions were eased on 21 June 2008 with the total combined reservoir storage volumes in Sydney reaching about 65 per cent. Combined reservoir storage volumes remained at around 60 per cent over the following 12 months and water restrictions were replaced by Water Wise Rules on 21 June 2009 to encourage continued water saving.

Source and supply of water in recent years

Figure 4-23 shows the total volume of water sourced from surface water, recycling, and desalination by Sydney Water from 2005–06 to 2009–10 (National Water Commission 2011a). The volume sourced from surface water includes water received from the bulk supplier (Sydney Catchment Authority) and surface water taken from the Hawkesbury River for supply to Richmond–Windsor.

The total volume of water sourced in 2009–10 was 516 GL. Over the past five years, the highest volume of water sourced (532 GL) was in 2005–06. Over the next two years, annual volume sourced decreased to 491 GL in response to water restrictions. The total volume of water sourced increased during the following two years, influenced by 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 99 per cent of the total water sourced in 2005–06 to 94 per cent in 2009–10. The volume of surface water taken from the network of reservoirs ranged from 98 per cent of the total water sourced in 2005–06 to 93 per cent in 2007–08.

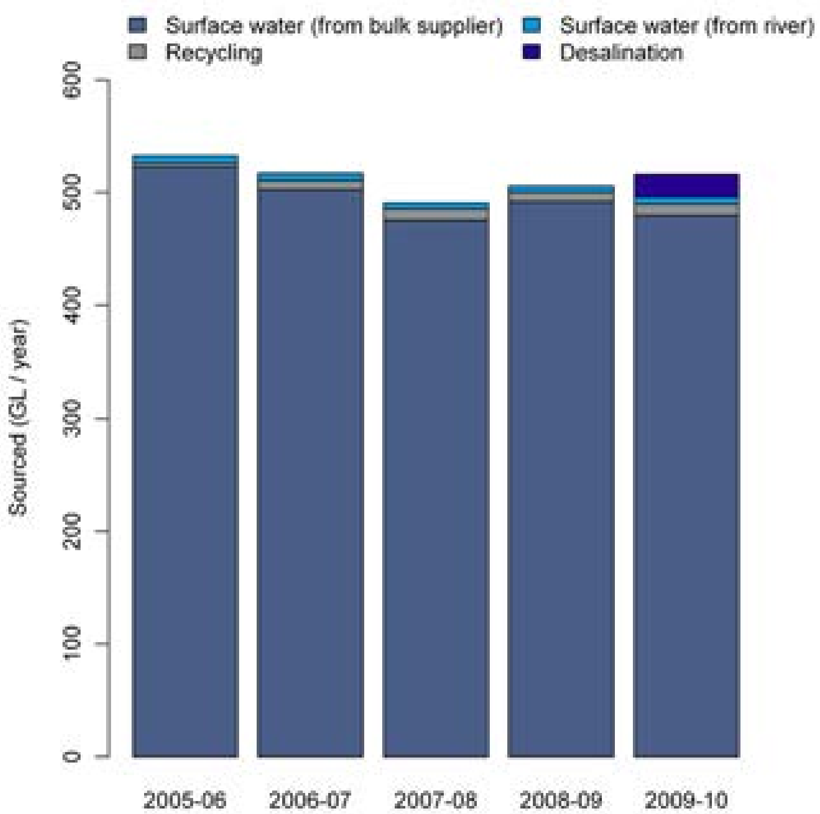


Figure 4-23. Total urban water sourced for Greater Sydney from 2005–06 to 2009–10

4.6.2 The Greater Sydney region (continued)

With the commissioning of the Kurnell desalination plant in January 2010, water sourced from desalination accounted for 3.9 per cent of total water sourced in 2009–10. Water from recycling comprises a small yet significant component of water sourced, ranging from 0.7 per cent in 2005–06 to 2.1 per cent in 2007–08. In 2009–10, water sourced from recycling accounted for 2.0 per cent.

Figure 4-24 shows the total volume of water delivered to residential, commercial, municipal and industrial consumers in the Greater Sydney region from 2002–03 to 2009–10 (National Water Commission 2011a). The total volume of water delivered to the residential sector in 2009–10 accounted for 66 per cent of total potable water consumption.

Total water supplied decreased gradually from 635 GL in 2002–03 to 482 GL in 2007–08. Water use increased again in the following two years, but use in 2009–10 was still relatively low compared with 2002–03. Based on the information available (National Water Commission 2011a) the average total water consumption across the Greater Sydney region dropped from 419 litres per person per day in 2002–03 to 312 litres per person per day in 2009–10.

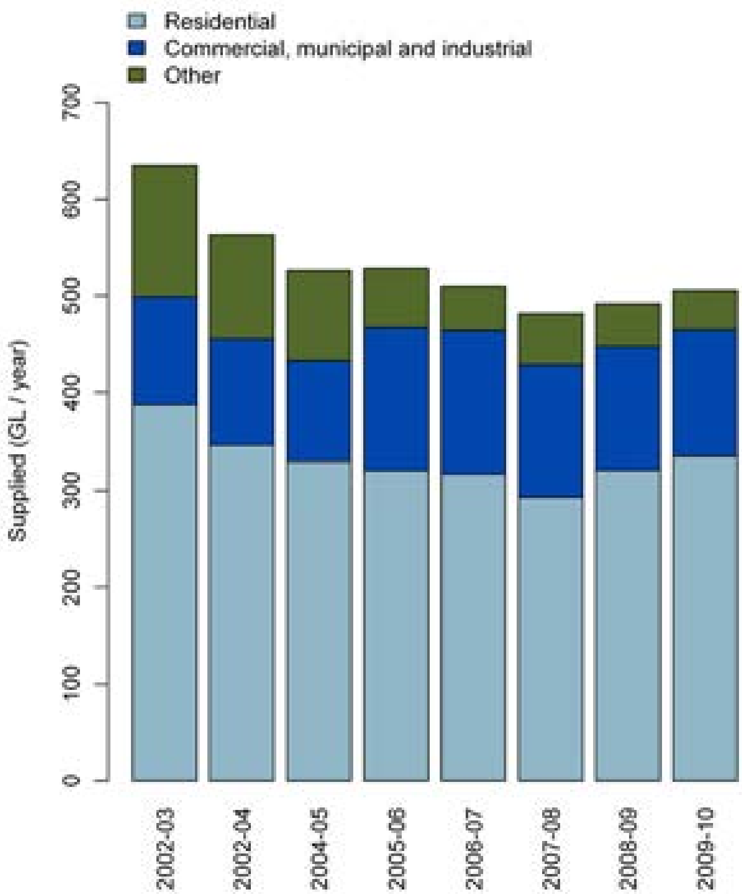


Figure 4-24. Total urban water supplied to Greater Sydney from 2002–03 to 2009–10

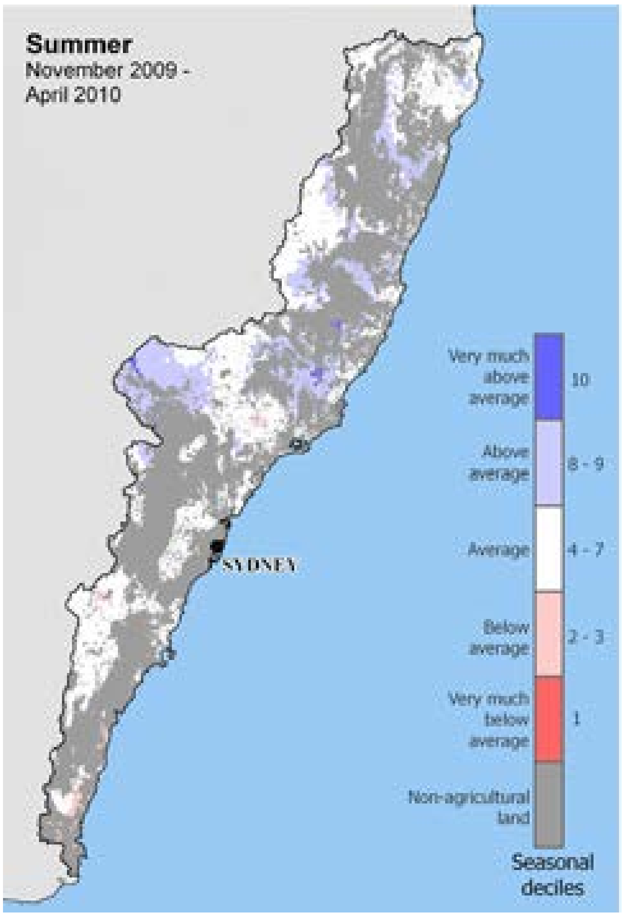
4.7 Water for agriculture

The South East Coast (NSW) region has a climate that varies from subtropical in the northeast to semi-arid in the western inland areas. In the subtropical north, dairy is the largest agricultural industry. Although mild winters and warm hot summers are also conducive to avocado, banana, citrus and other fruit production. In the mid-coast catchments of the region, wine grapes and dairy pasture are the two most important irrigated industries. The region's southern coastal catchments have extensive forested headwaters, wetlands, river estuaries and freshwater swamps. Irrigated pasture for dairy production is the main agricultural industry followed by vegetables and floriculture.

4.7.1 Soil moisture in 2009–10

Upper soil moisture conditions were generally average to above average in dryland agricultural areas in central and northern parts of the region over the summer 2009–10 (November to April). The south of the region shows generally drier soil moisture conditions (Figure 4-25).

Upper soil moisture conditions increased over much of the region during the winter (May–October) of 2010 in most dryland agricultural areas. Very much above average soil moisture conditions developed across central and northern areas, particularly in the western upland areas as a result of consistently above average rainfall across the north of the region. Upper soil moisture conditions remained at a generally average level across the south of the region (Figure 4-25).



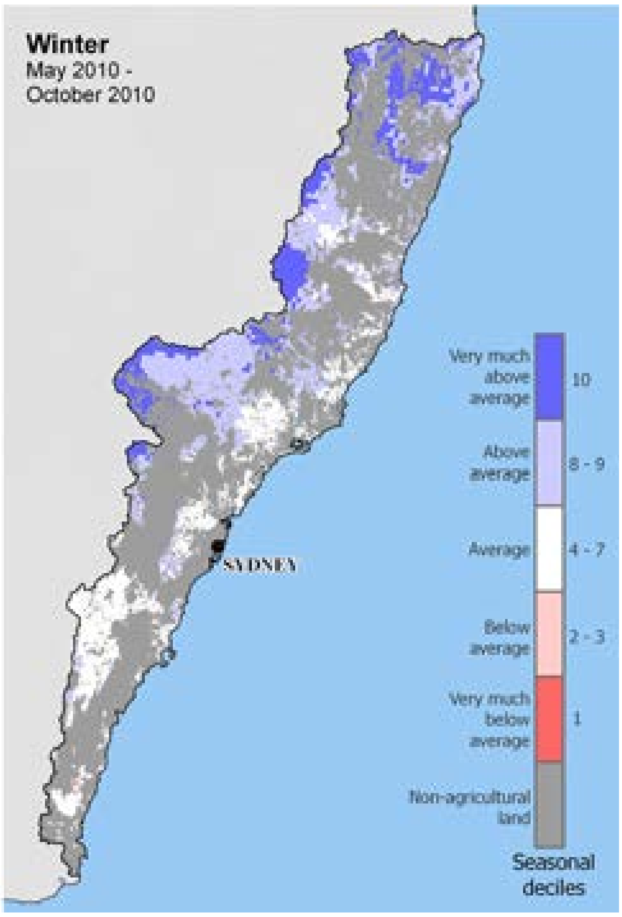


Figure 4-25. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the South East Coast (NSW) region

Figure 4-26. Context map of irrigation areas and infrastructure in the South East Coast (NSW) region

4.7.2 Irrigation areas

Unregulated rivers are the major water source for the irrigation industry in most parts of the region (Figure 4-26). In the subtropical northern coast, irrigation is necessary during spring and early summer. Irrigation from farm dams is widespread and provides a level of security during droughts. Irrigation from groundwater is very limited (Hope 2003a). In the mid-coast, most of the licences for irrigation are located in the Hunter catchment along the Williams and Goulburn rivers and Wollombi Brook (Hope 2003b). In the southern coast, irrigated agriculture occurs mainly in the Hawkesbury–Nepean and Bega catchments (Hope 2003c).

Irrigation water use in the region between 2005–06 and 2009–10 is shown in Figure 4-27 and Figure 4-28 by natural resource management region. Data were sourced from the *Water Use of Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011). The data show that the highest irrigation water use occurs in the regulated Hunter catchment. A general decline in water use as a consequence of drought and low inflows can also be observed in a majority of the catchments. In the next section the Hunter River catchment is used as an example for water resource conditions and irrigated agriculture in 2009–10.

Hunter River basin irrigation

The Hunter River drains the largest coastal catchment in New South Wales, covering some 22,000 km^2 and is one of the most highly developed agricultural and industrialised regions in Australia. Approximately 80 per cent of the irrigated area in the mid-coast catchments of the South East Coast (NSW) region is in the Hunter River basin. Irrigation is used to grow pasture and lucerne for dairy farms. Vineyards are the second most important irrigated enterprise 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. The location of irrigation areas are shown in Figure 4-29.

Irrigation water resources in the Hunter River basin

The Hunter River basin contains the only regulated water supplies in the NSW mid-coast region. The Hunter River discharges approximately 1,800 GL of water per year. Most of the water in the Hunter Valley comes from the north-eastern areas of the catchment.

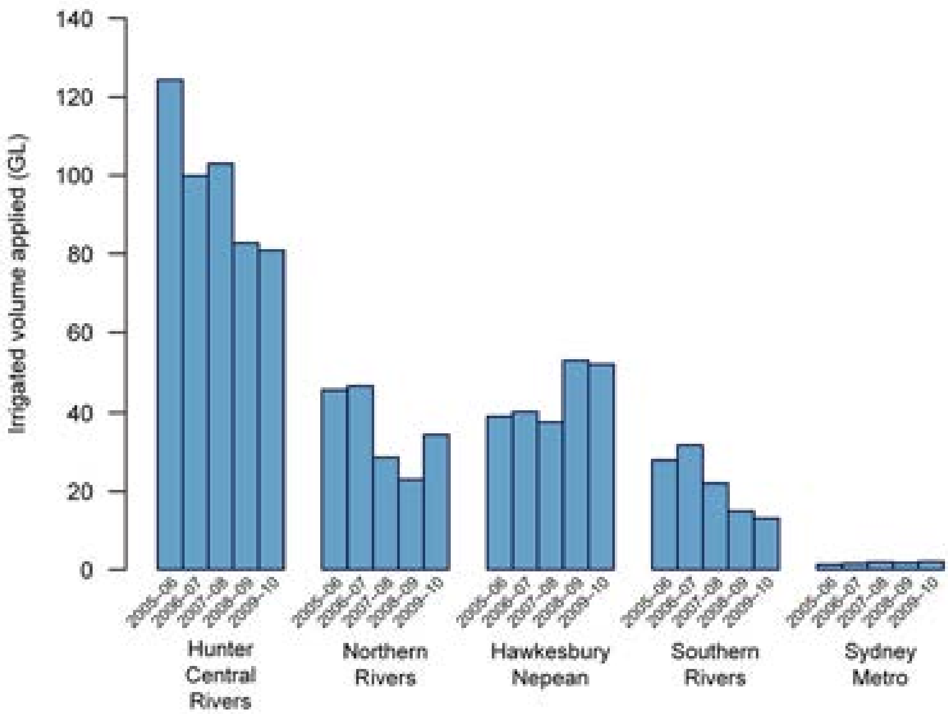


Figure 4-27. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the South East Coast (NSW) region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

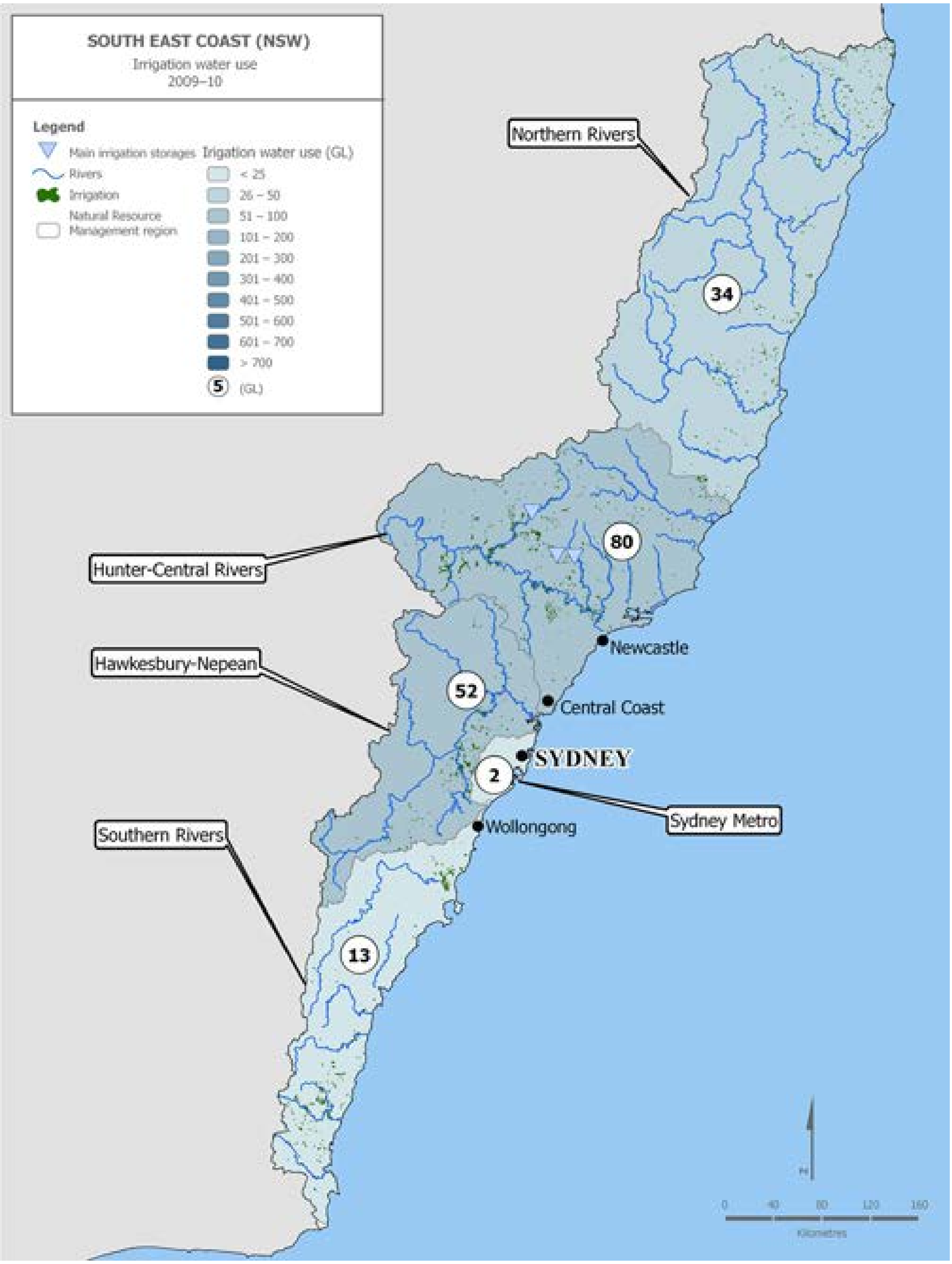


Figure 4-28. Annual irrigation water use per natural resource management region for 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

4.7.2 Irrigation areas (continued)

The major tributaries of the Hunter River include:

- Goulburn River, which drains almost half of the river basin, but contributes only around 23 per cent of the river flow
- Paterson, Allyn and Williams rivers, draining the wetter area to the northeast of the Hunter Valley
- Wollombi Brook, which drains the south-eastern segment of the river basin
- Upper Hunter River, which drains most of the northern section of the river basin.

Water is controlled by three reservoirs: Glenbawn, Lake St Clair (behind Glennies Creek dam) and Lostock reservoirs. The regulated river sections of the Hunter River Valley are:

- Hunter River downstream of Glenbawn Reservoir
- Glennies Creek downstream of Glennies Creek reservoir
- Paterson River.

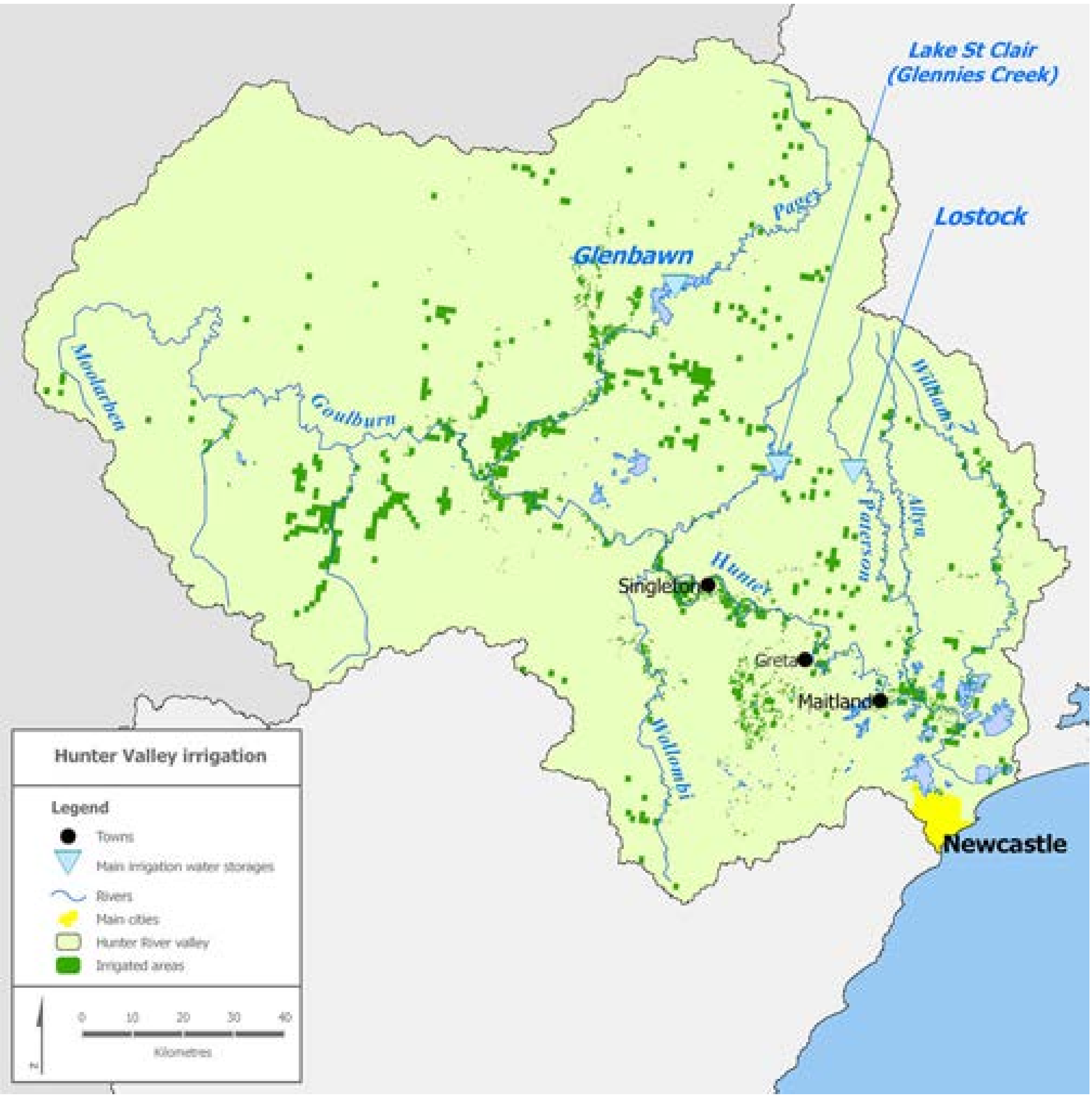


Figure 4-29. Hunter River basin irrigation areas

4.7.2 Irrigation areas (continued)

The Hunter region has an estimated 32,800 GL of available groundwater, most of which is in the fractured or porous rocks (Water Resource Commission 1980). Only 1.4 per cent of this can be used, as most is too saline. Good quality groundwater is generally found within the riverine alluvium of the Hunter River and tributaries. This water is almost fully committed to agriculture.

Glenbawn Reservoir, with an accessible storage 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 to Maitland. The reservoir has an area of 26 km^2 with a maximum depth of 85 m. It provides town water, stock water, irrigation water, industrial water and environmental flows.

Glenbawn is operated in conjunction with Glennies Creek Reservoir. Glennies Creek 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 water for irrigation, stock and industries such as coal mining (State Water Corporation 2011).

In 2009–10, flows in the catchments upstream of Glenbawn were at historically low levels during late spring and early summer but increased during late summer in response to heavy rainfalls (Figure 4-30).

Inflows to the two storages and water diversions for general security and high security entitlements over the past three decades are shown in Figure 4-31. Diversions increased in drought years in response to greater irrigation water demand. Total inflows to Glenbawn and Glennies Creek in 2009–10 were below average at 76 GL but were enough to maintain the storages' volume at more than 60 per cent of accessible capacity (Figure 4-32).

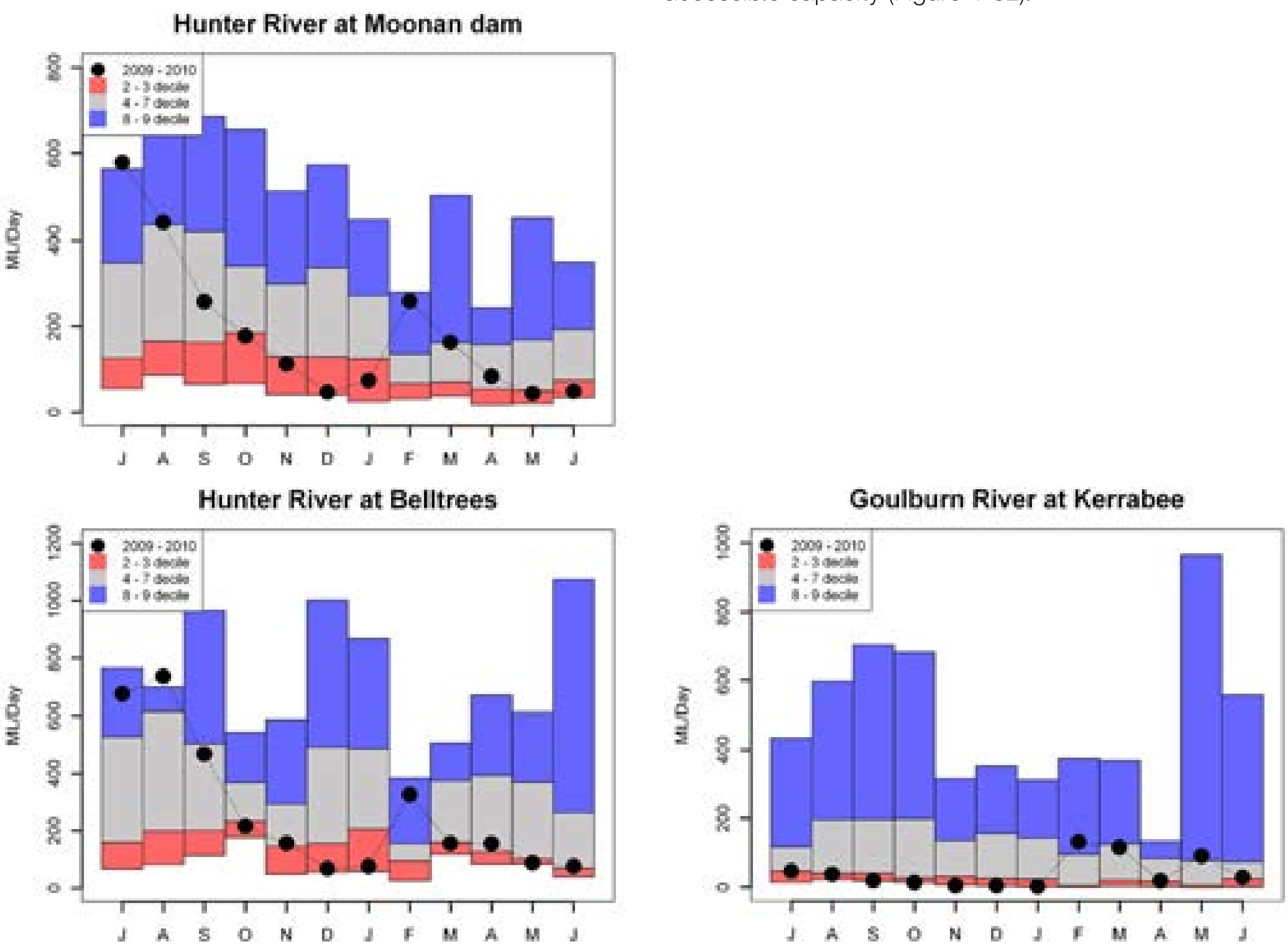


Figure 4-30. Monthly discharge hydrographs compared to discharge deciles at reference gauges for inflows into Glenbawn Reservoir (Hunter River at Moonan and Belltrees) and Goulburn River flowing into the Hunter River

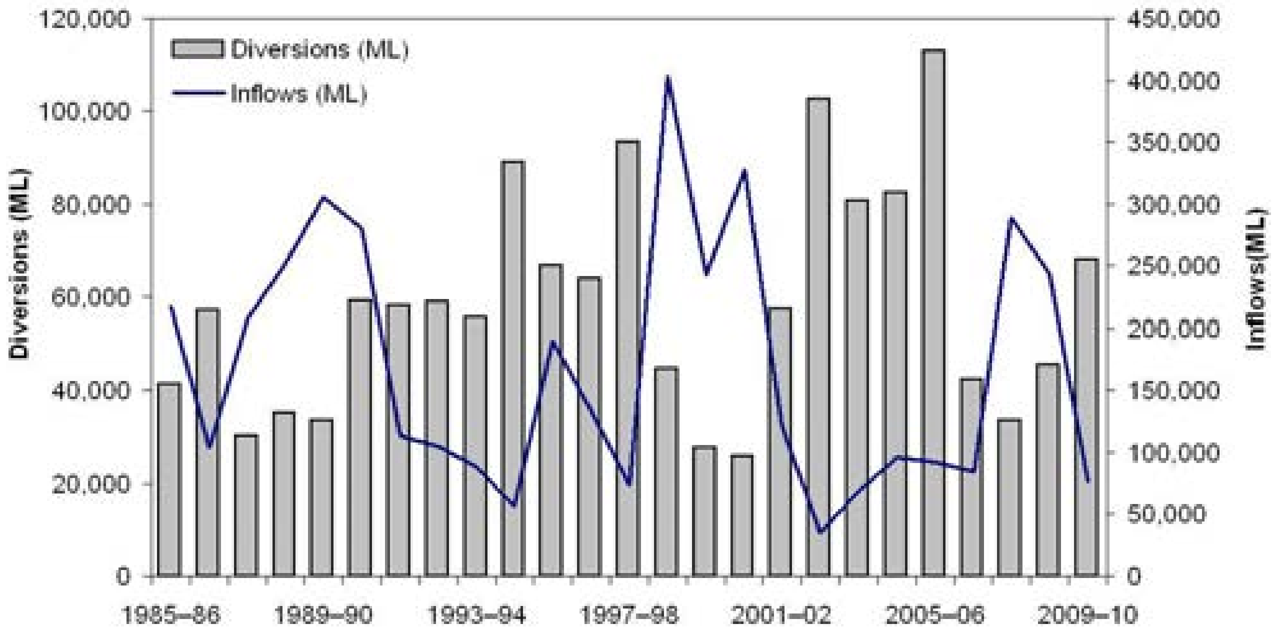


Figure 4-31. Historic inflows to Glenbawn and Glennies Creek reservoirs together with diversions in the regulated Hunter Catchment (data from New South Wales Office of Water,-pers. comm.)

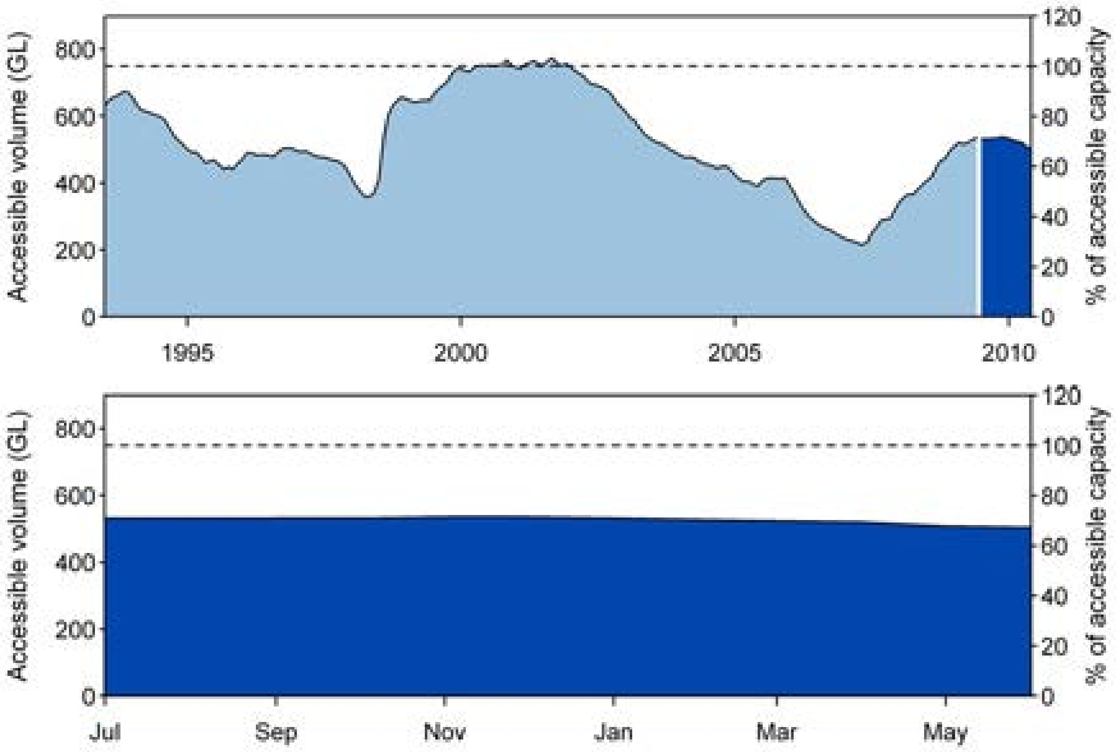


Figure 4-32. Water storage volumes available for irrigation at Glenbawn since 1992 (top) and during 2009–10 (bottom)

4.7.2 Irrigation areas (continued)

Irrigation water management in the Hunter River basin

The Hunter Regulated River water sharing plan (NSW Department of Water and Energy 2009) 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 (NSW 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). The plan also establishes water reserves (or environmental contingency allowances) of 20 GL per year in both Glenbawn and Glennies Creek reservoirs. 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 six ML/ha. In most years, water allocation for general security use was 100 per cent or more.

Table 4-4 shows diversion volumes for the two categories of allocated entitlements between 2001 and 2010. General security diversions were very low in the years following the 2006 El Niño drought, but have returned to a relatively high level in 2009–10.

Table 4-4. Total water inflows to the storages and allocations in the Hunter catchment

Year	Inflows (ML)	General security (ML)	High security, LWU, S&D * (ML)	Total diversions (ML)
2000–01	328,000	20,000	6,000	26,000
2001–02	121,000	42,000	16,000	57,000
2002–03	35,000	85,000	18,000	103,000
2003–04	69,000	63,000	18,000	81,000
2004–05	96,000	65,000	17,000	82,000
2005–06	93,000	91,000	22,000	113,000
2006–07	84,000	18,000	25,000	42,000
2007–08	289,000	19,000	15,000	34,000
2008–09	243,000	32,000	13,000	45,000
2009–10	76,000	53,000	15,000	68,000

*LWU = local water utility, S&D = stock and domestic

5. South East Coast (Victoria)

5. South East Coast (Vic)

5.1 Introduction

This chapter examines water resources in the South East Coast (Victoria) region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers, wetlands and aquifers. Information on water use is also provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Surface water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

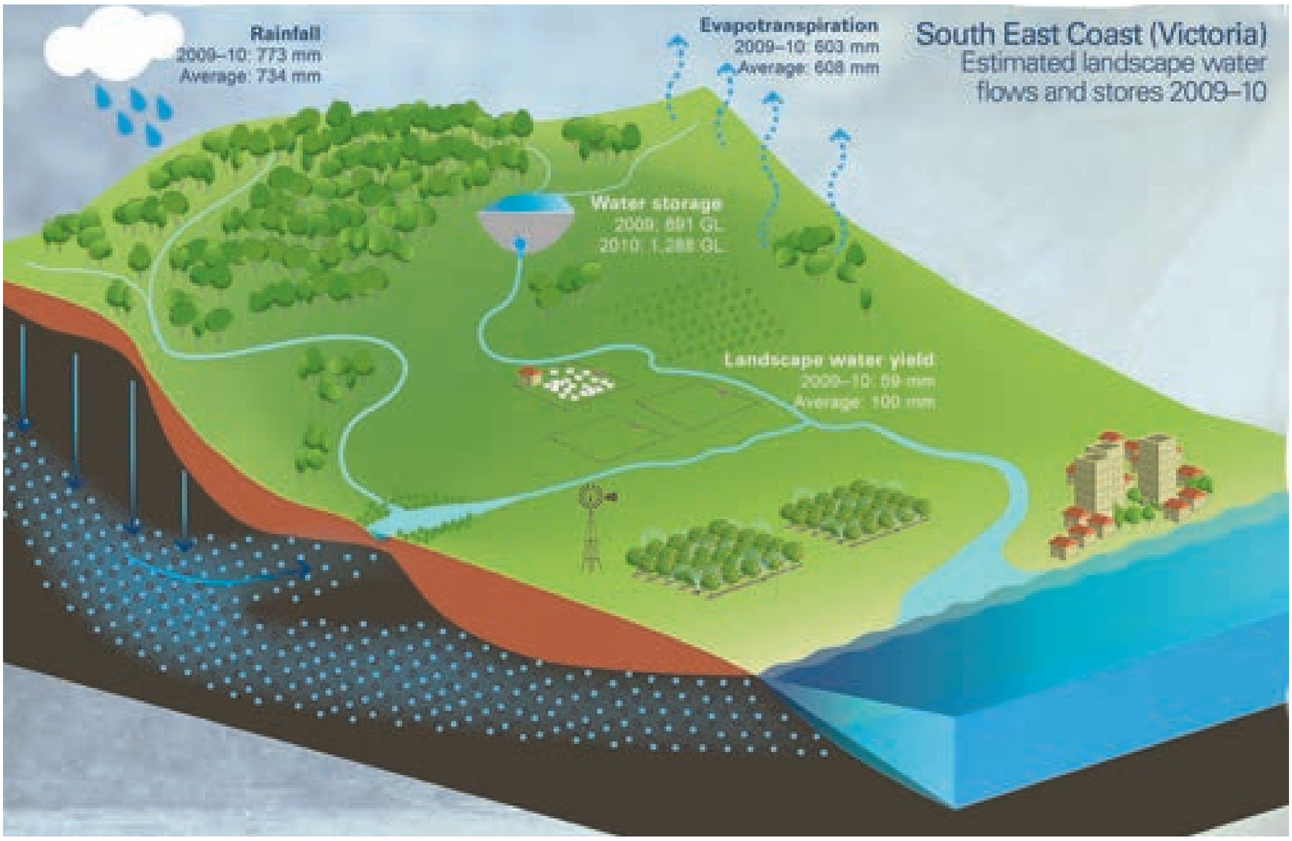


Figure 5-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the South East Coast (Victoria) region

5.2 Key data and information

Figure 5-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the South East Coast (Victoria) region. Rainfall for the year was in the top end of the average range and evapotranspiration was in the lower part of the average range (see Table 5-1). However, the annual landscape water yield[1] total was below average as a result of the substantial increase in soil moisture. There was a rise in surface water storage volumes which can be attributed to the fact that most of the storages are located in the northern headwaters, part of which experienced average landscape water yield totals.

Table 5-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

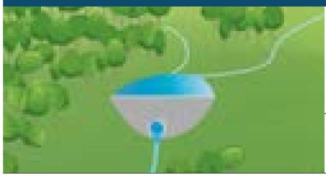
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 5 1. Key information on water flows, stores and use in the South East Coast (Victoria) region[2]

Landscape water balance

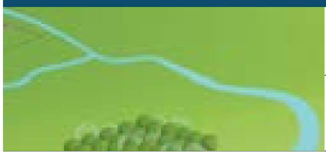
	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	773 m	+5%	69	855 mm (1992–93)	571 mm (2002–03)
Evapotranspiration	603 mm	-1%	33	635 mm (1988–89)	535 mm (1982–83)
Landscape water yield	59 mm	-4 %	11	195 mm (1992–93)	41 mm (2008–09)

Surface water storage (comprising approximately 91% of the region's total surface water storage)



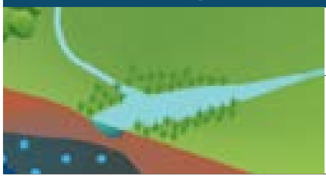
Total accessible capacity	July 2009		June 2010		
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	% Change
6,940 GL	891 GL	12.8%	1,288 GL	18.6%	+5.8%

Measured streamflow in 2009–10



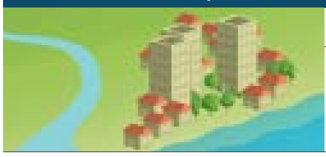
Western rivers	Inner western rivers	Eastern inland rivers	Eastern coastal rivers
Predominantly average	Below to very much below average	Predominantly average	Below to very much below average

Wetlands inflow patterns in 2009–10



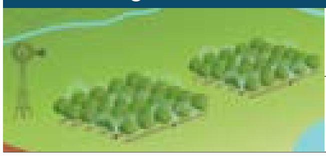
Western district lakes	Gippsland lakes	Reedy Creek – Connewarre wetland complex
Average to below average	Above average in late summer, else predominantly below average	Average to below average

Urban water use (Melbourne)



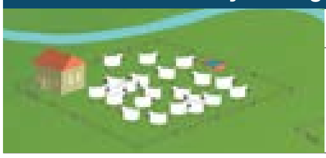
Water supplied 2009–10	Trend in recent years	Restrictions
349 GL	Slight decrease	Eased from level 3a to level 3

Annual irrigation water use in 2009–10 for the natural resource management regions



Southeast	West Gippsland	Glenelg Hopkins	Port Phillip and Westernport	Corangamite	East Gippsland
345 GL	282 GL	72 GL	79 GL	13 GL	16 GL

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Average to very much below average in the east, below average to very much above average in the west	Average to below average in the east, average to very much above average in the west

*A rank of 1 indicates the lowest annual result on record, 99 the highest on record.

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

5.3 Description of region

The South East Coast (Victoria) region is a long east-west strip in southern Victoria, bordered in the south by the Victorian and South Australian coastlines. It is set between the Great Dividing Range in the north, the eastern boundaries of the East Gippsland and Snowy River basins in the east and Mount Gambier and the Millicent coast of South Australia in the west.

The climate of the region is affected by a seasonal movement of the major atmospheric systems in Australia, which brings warm temperate conditions. This merges with a moderate Mediterranean climate in the south.

The region covers approximately 134,600 km² of land area, with river basins varying in size from 1,400 km² to 12,000 km². The region's landscape varies from mountainous and extensively covered by forests in East Gippsland to undulating with numerous volcanic cones in the Hopkins River basin and flat with alluvial deposits in the Werribee River basin.

There are numerous rivers and tributaries in the region, of which the Thomson, Macalister and Snowy rivers constitute the major streams. Others include the Glenelg, Bunyip, Latrobe, Hopkins and Maribyrnong rivers. Most of the river basins in the region have at least one major storage and the total storage capacity of the region exceeds 6,900 GL. The Thomson Reservoir in the Thomson River basin is the largest storage supplying surface water to the region.

The region has a population greater than 4.4 million (Australian Bureau of Statistics 2010b). The largest population centre is Melbourne in the south. Other centres with populations greater than 25,000 include Geelong, Ballarat, Melton, Warrnambool and Sunbury.

Melbourne Water, supplying the city of Melbourne, is the largest bulk water supplier in the region. Town centres are supplied water from systems operated by local government councils, except southwest of Melbourne where water is supplied from a more complicated supply system operated by a number of organisations. Geelong's drinking water is sourced from catchments on the upper Barwon and Moorabool rivers. Barwon Water has been in the process of diversifying its water supply through the use of groundwater in recent years. Central Highlands Water and Western Water are the entities responsible for water supply to Ballarat and Melton respectively, predominantly from surface water sources. Further detail about water supply to significant urban areas is provided in Section 5.6.

The mix of land use in the South East Coast (Victoria) region is illustrated in Figure 5-2. Although national parks and state forests occupy large portions, a significant amount of the region is cleared for grazing sheep and cattle. Hardwood timber production is a major industry in some river basins such as the Snowy, East Gippsland and Barwon river basins. Dryland agriculture, particularly cereal cropping, is a major land use in some areas such as the Millicent coast. Irrigated agriculture is concentrated around storages in the Thomson and Werribee river basins. This includes irrigation districts at Lake Glenmaggie, Bacchus Marsh and Werribee. Extensive parts of some river basins, such as the Yarra, are urbanised with agricultural production such as viticulture and market gardening.

The groundwater systems of the South East Coast (Victoria) region are relatively varied and complex. Hydrogeological features include the Otway Basin, Port Phillip and Westernport basins, Gippsland Basin and Tarwin Basin, basement outcrops (fractured rock), and the karstic limestone area (Murray Group aquifer) in southeast South Australia. The basement fractured rock typically provides low groundwater yield. The basins can provide significant groundwater resources from permeable layers of sediments, limestone and fractured basalt.

Figure 5-3 shows the major aquifer groups present at the watertable. The region is bounded in the north by fractured rock groundwater systems that typically provide a low volume groundwater resource. The volcanic basalt plans to the west of Melbourne are also a significant feature. More potential for groundwater extraction is provided by the aquifers associated with the Otway Basin, Port Phillip and Westernport basins, Gippsland Basin, and Tarwin Basin in South Victoria (Southern Rural Water 2009) and the Murray Group aquifer in southeast South Australia. These aquifers have been grouped in the figure as:

- lower mid-Tertiary aquifer (porous media – unconsolidated)
- upper mid-Tertiary aquifer (porous media – unconsolidated)
- upper Tertiary aquifer (porous media – unconsolidated)
- upper Tertiary/Quaternary aquifer (porous media – unconsolidated).

Figure 5-4 shows the classification of watertable aquifers as fresh or saline water according to groundwater salinity. As shown in Figure 5-4, most parts of the region are considered to have fresh water.

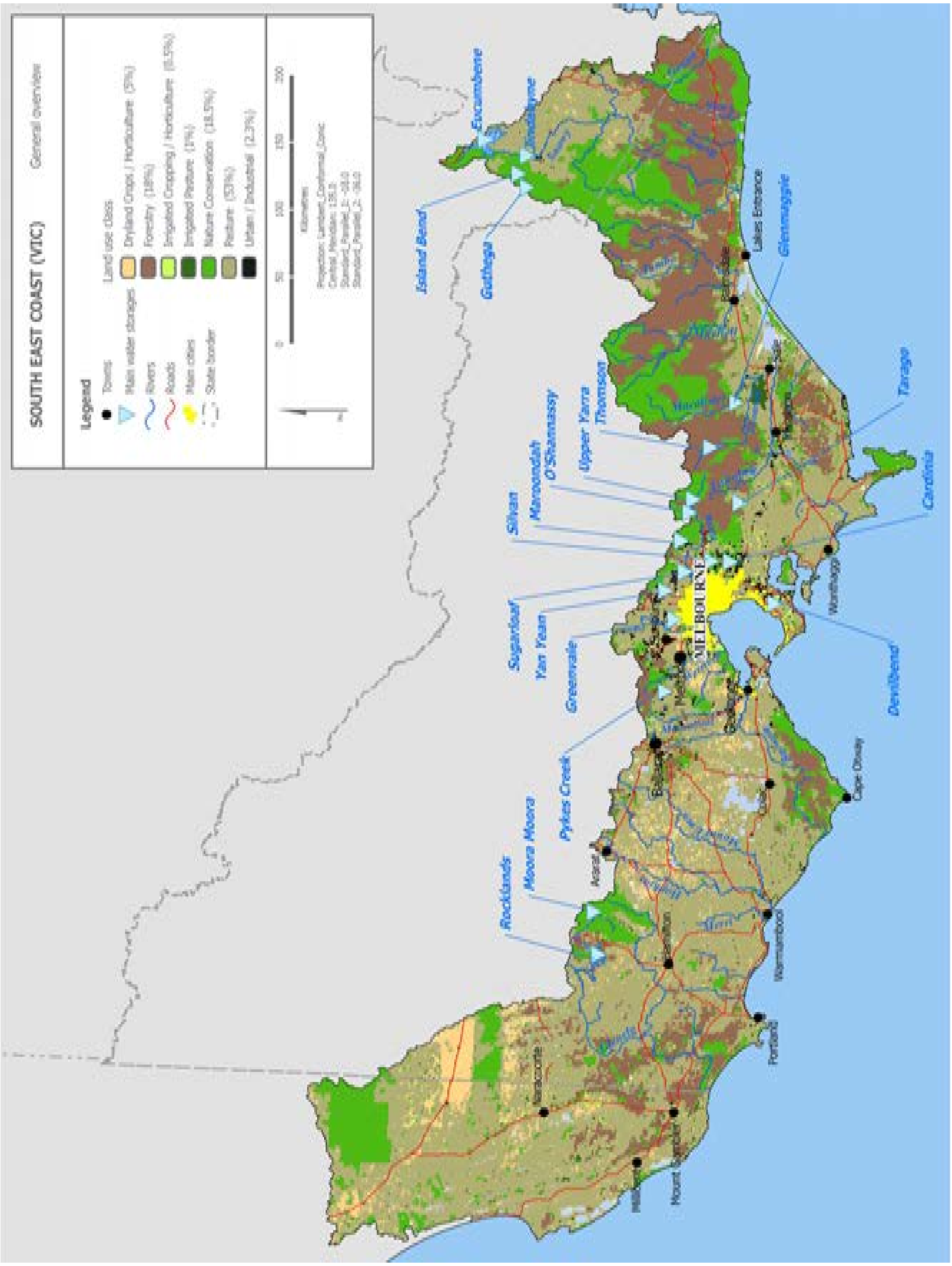


Figure 5-2. Key landscape and hydrological features of the South East Coast (Victoria) region (land use classes based on Bureau of Rural Sciences 2006)

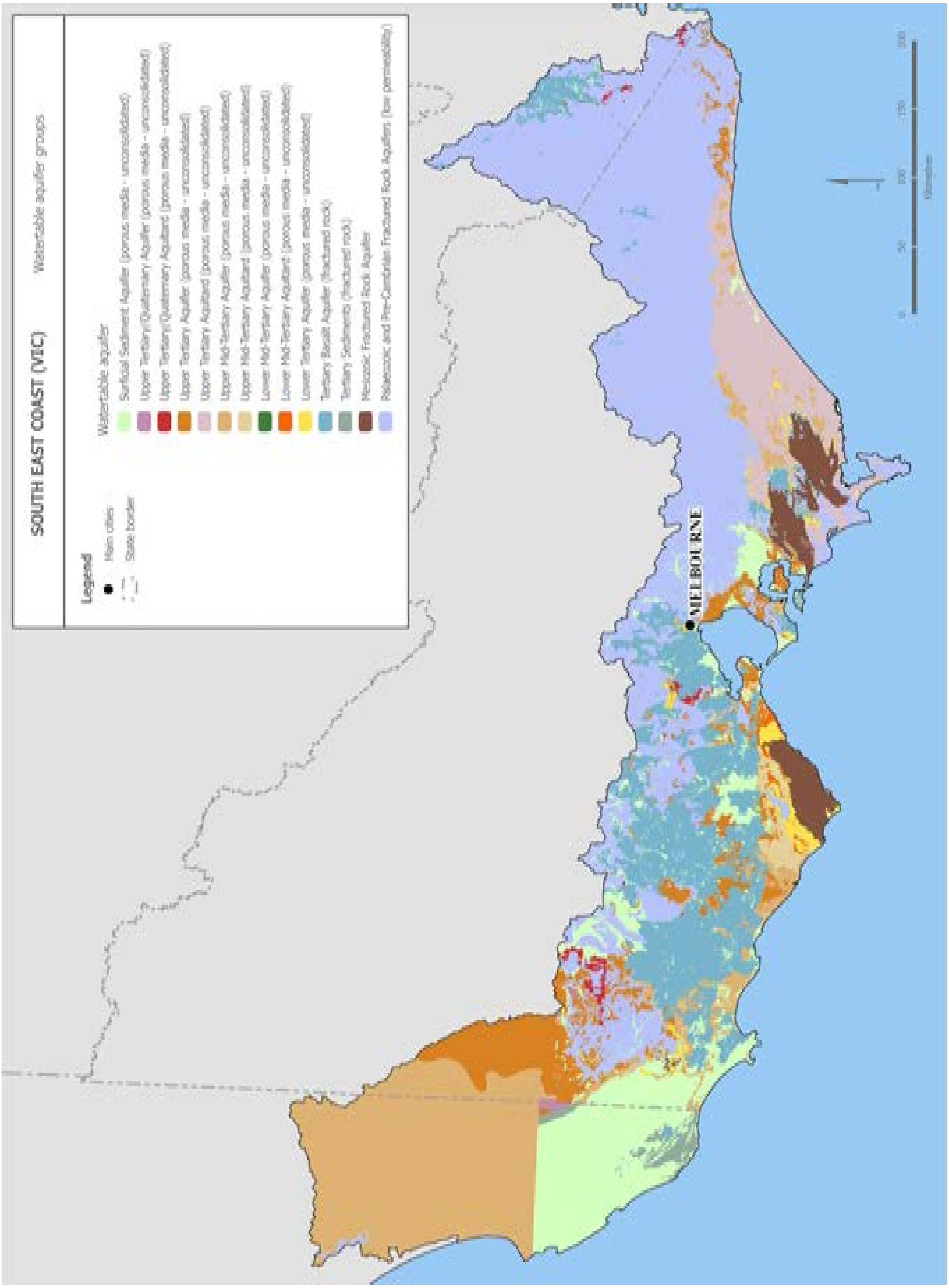


Figure 5-3. Watertable aquifer groups in the South East Coast (Victoria) region (Bureau of Meteorology 2011e)

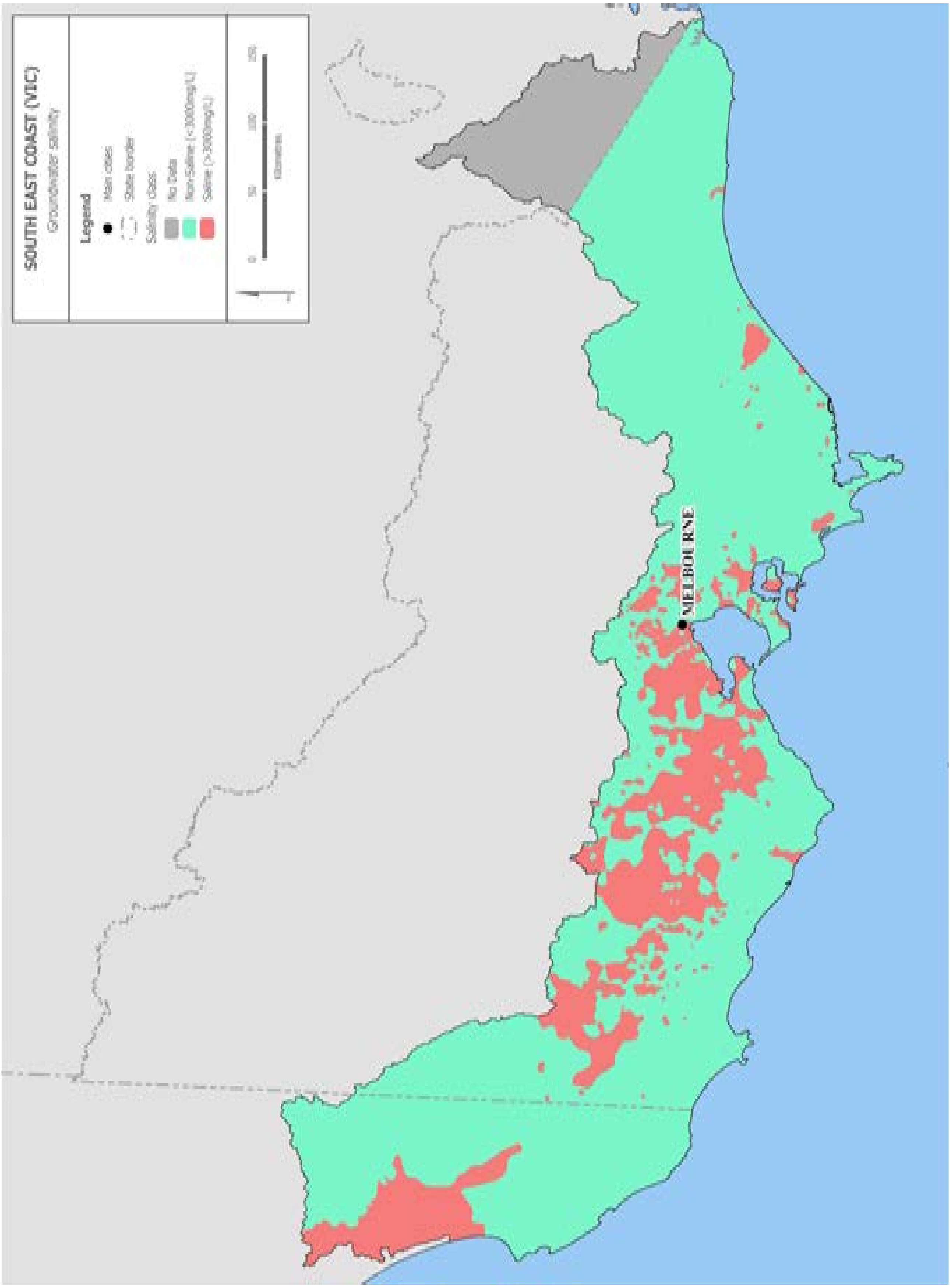


Figure 5-4. Watertable salinity classes within the South East Coast (Victoria) region (Bureau of Meteorology 2011e)

5.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 5-5 shows that in the South East Coast (Victoria) region, 2009–10 began with relatively wet conditions prevailing between July and September 2009. Monthly rainfall was generally at normal, or slightly below normal, levels from October 2009 to January 2010. In February 2010, large parts of the eastern and central South East Coast (Victoria) region were unusually wet and the region received more than double the monthly average February rainfall. Higher than normal rainfall continued into March 2010 and remnants of a monsoonal low that had established over northeast Australia drifted southward and interacted with an approaching cold front, triggering severe thunderstorm activity over Melbourne in early March 2010 (Bureau of Meteorology 2011d).

Modelled evapotranspiration for the region shows a very distinct seasonal pattern, with peak levels occurring during the late spring and summer months with evaporative losses consistently higher than rainfall. Evapotranspiration at the beginning of the year was relatively low as a result of the very dry preceding year, which constrained the availability of water. November and December 2009 show slightly higher than normal values, which returned to generally normal, or slightly below normal, for the remainder of the year.

Modelled landscape water yield was very low throughout much of the year. July 2009 to January 2010 experienced very much lower than normal totals. Generally normal levels of monthly rainfall, combined with very dry antecedent conditions, contributed to the reduced totals. Landscape water yield was higher than normal during February 2010 in response to the extremely high rainfall.

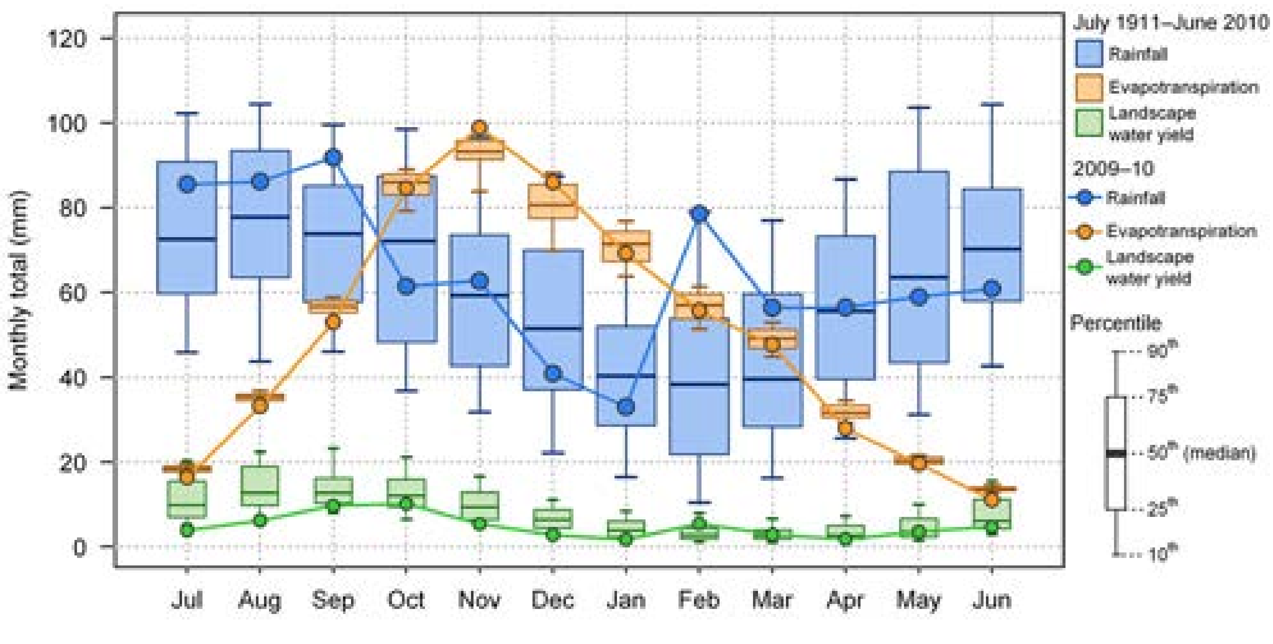


Figure 5-5. Monthly landscape water flows for the South East Coast (Victoria) region in 2009–10 compared with the long-term record (July 1911 to June 2010)

5.4.1 Rainfall

Rainfall for the South East Coast (Victoria) region in 2009–10 was estimated to be 773 mm, which is five per cent above the region's long-term (July 1911 to June 2010) average of 734 mm. Figure 5-6 (a) shows that during 2009–10, the highest rainfall occurred in the high altitude areas along the north-eastern boundary of the region and also across the more exposed southerly points to the southeast and southwest of Melbourne.

Rainfall deciles for 2009–10, shown in Figure 5.6 (b), indicate that rainfall was above average across much of the west and central-west as well as in the northeast of the region. Most of the eastern side of the region largely experienced average rainfall conditions with below average rainfall in limited areas.

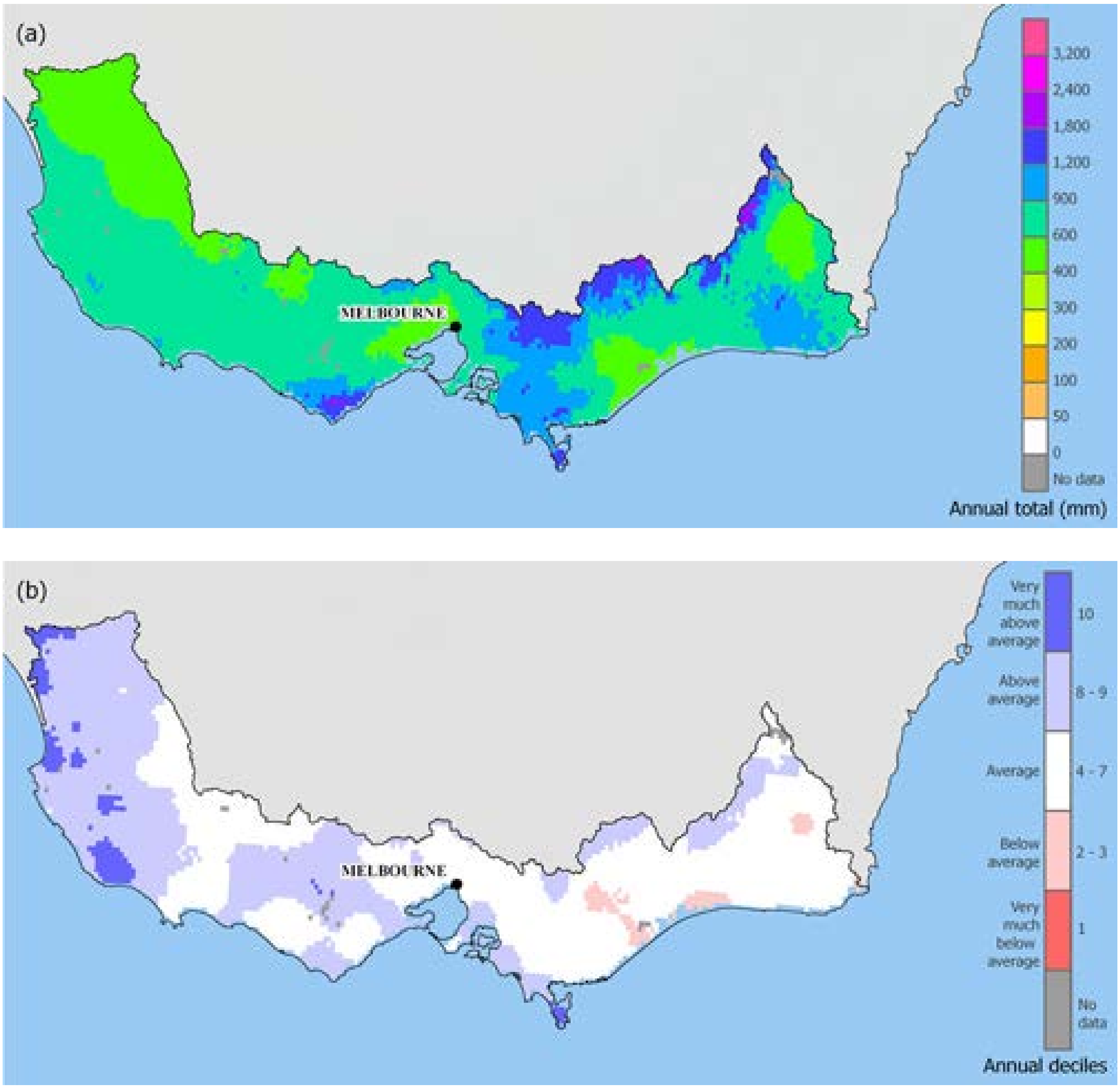


Figure 5-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (Victoria) region

5.4.1 Rainfall (continued)

Figure 5-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 571 mm (2002–03) to 855 mm (1992–93). The annual average for the period was 707 mm. The data show that rainfall for 2009–10 was above the 30-year average following five consecutive years of below average annual rainfall from 2004–05. There were only three years of above average rainfall since 1994–95, including 2009–10.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 5-7 (b). This graph shows seasonal rainfall for the region is characterised by wetter winters than summers. The sequence of low annual rainfall from 1994–95 is reflected in both winter and summer periods, with a general decrease in the averages over the second half of the 30-year period. This reduction in seasonal rainfall is more apparent in the higher winter period rainfall.

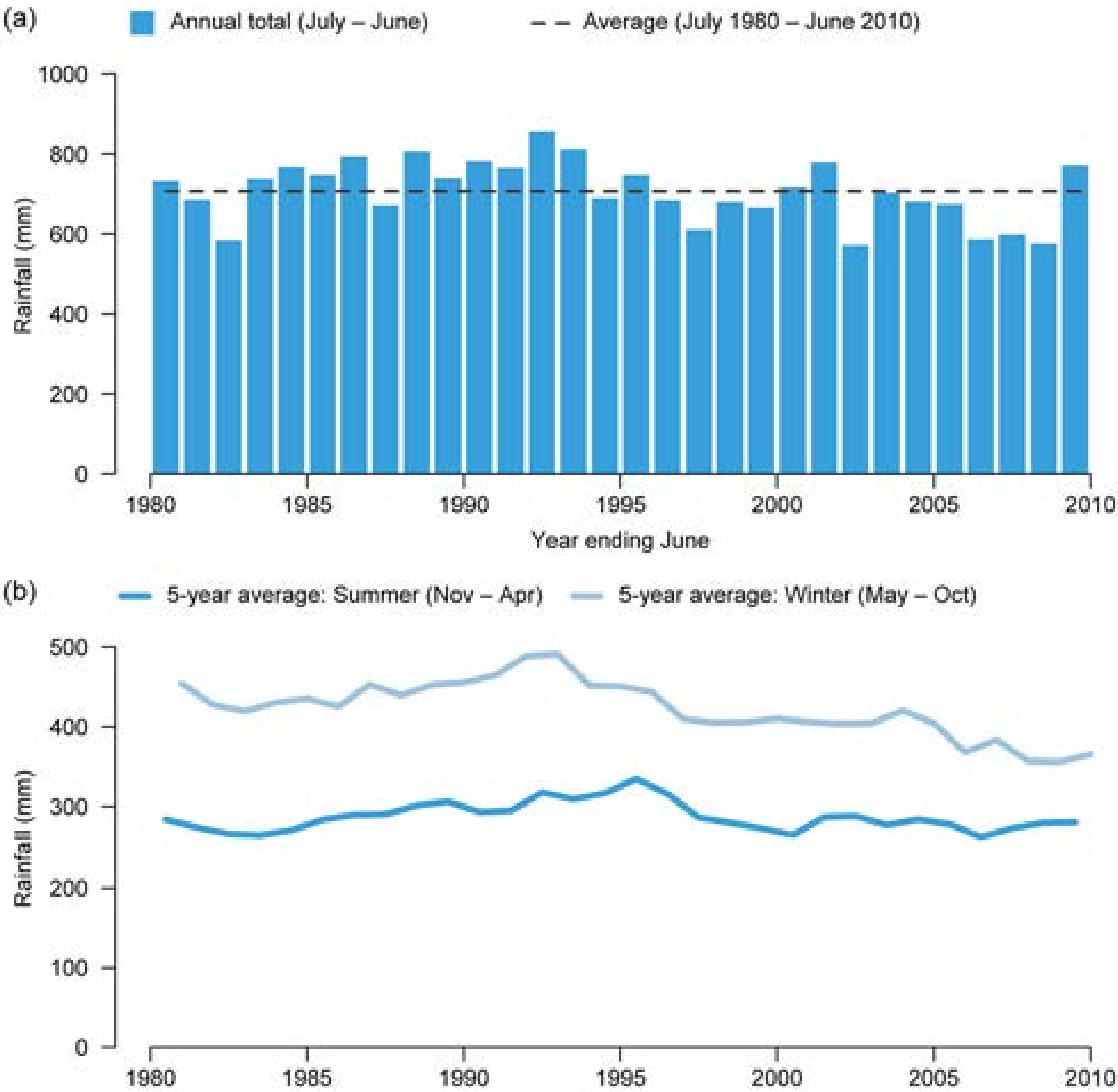


Figure 5-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the South East Coast (Victoria) region

5.4.1 Rainfall (continued)

Figure 5-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis of summer rainfall indicates a mixed pattern of rainfall trends across the region. Slight positive trends are observed across the west of the region with negative trends of a slightly greater magnitude apparent across the eastern side. The equivalent analysis of the winter rainfall shows negative trends across almost the entire region. The strongest reductions are observed to the north of the region along much of the boundary with the Murray–Darling Basin. The magnitudes of these strongly negative winter rainfall trends across the region are high relative to the average winter period rainfall over the 30 years.

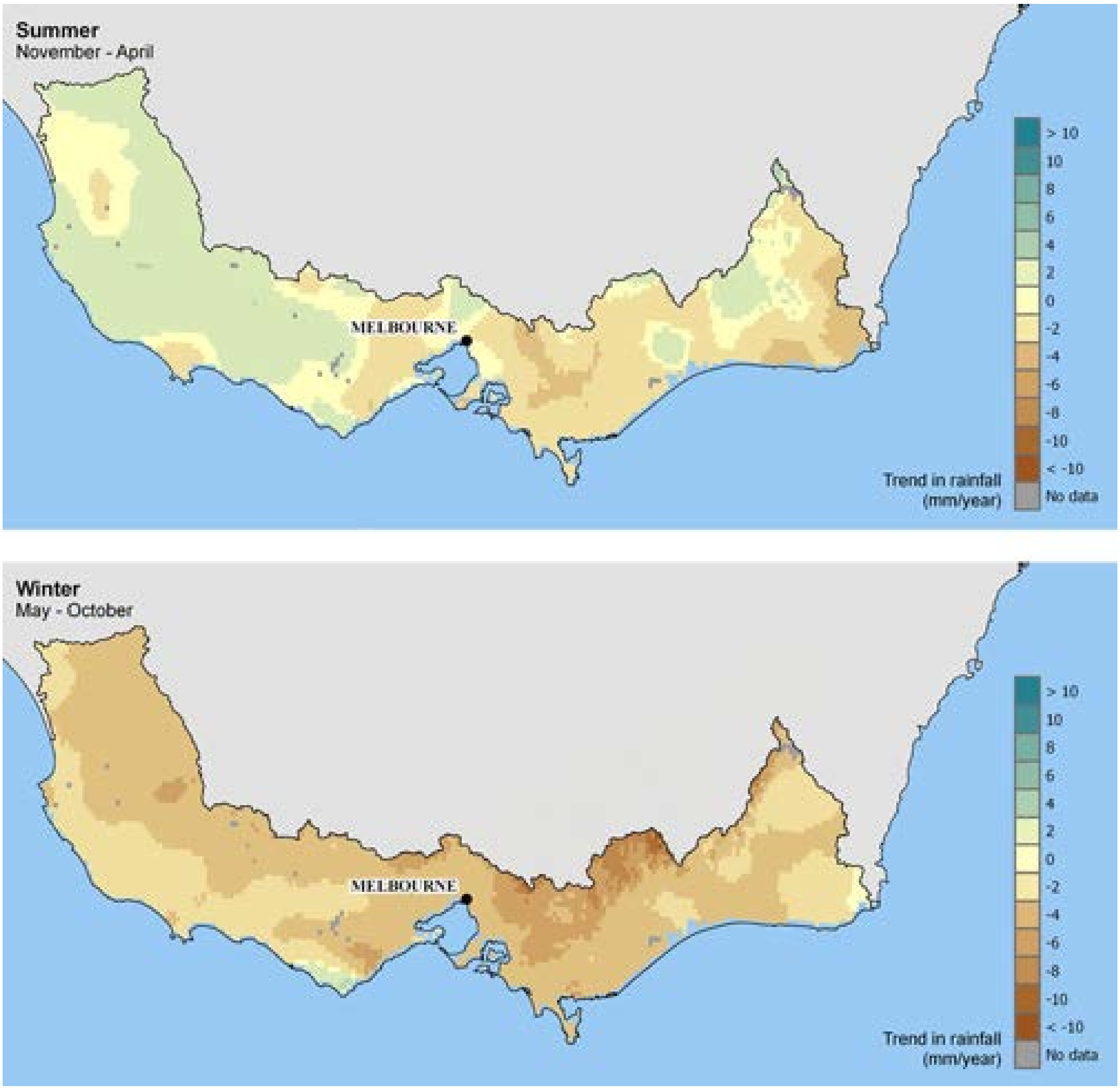


Figure 5-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the South East Coast (Victoria) region. The statistical significance of these trends is often very low

5.4.2 Evapotranspiration

Evapotranspiration for the South East Coast (Victoria) region for 2009–10 was estimated to be 603 mm, which is one per cent lower than the region's long-term (July 1911 to June 2010) average of 608 mm. The distribution of evapotranspiration during 2009–10, shown in Figure 5-9 (a), is relatively consistent across the region with some relationship to the distribution of rainfall (Figure 5-6 [a]) with low evapotranspiration generally coinciding with the areas of lower rainfall.

Evapotranspiration deciles for 2009–10, shown in Figure 5-9 (b), indicate a very mixed distribution of above and below average evapotranspiration. Below average or very much below average levels are identified across much of the region and are interspersed with areas of very much above average evapotranspiration.

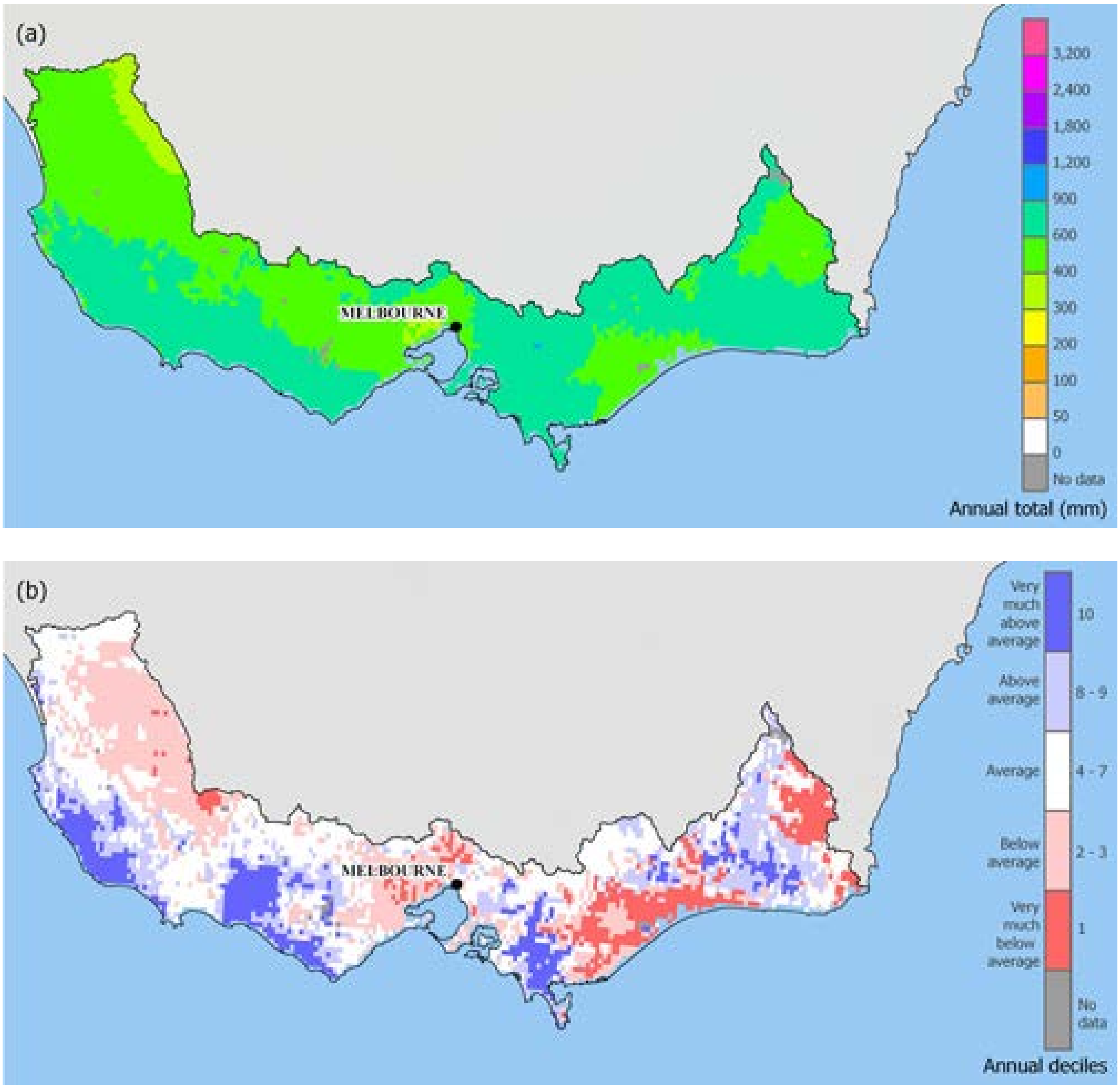


Figure 5-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (Victoria) region

5.4.2 Evapotranspiration (continued)

Figure 5-10 (a) shows annual evapotranspiration for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 535 mm (1982–83) to 635 mm (1988–89). The annual average for the period was 592 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 5-10 (b). This graph highlights that evapotranspiration in summer is consistently much higher than in winter reflecting the strongly seasonal nature of evaporation conditions across the region. Figure 5-10 (b) suggests a slight decrease in summer evapotranspiration, which is more apparent towards the end of the 30-year period.

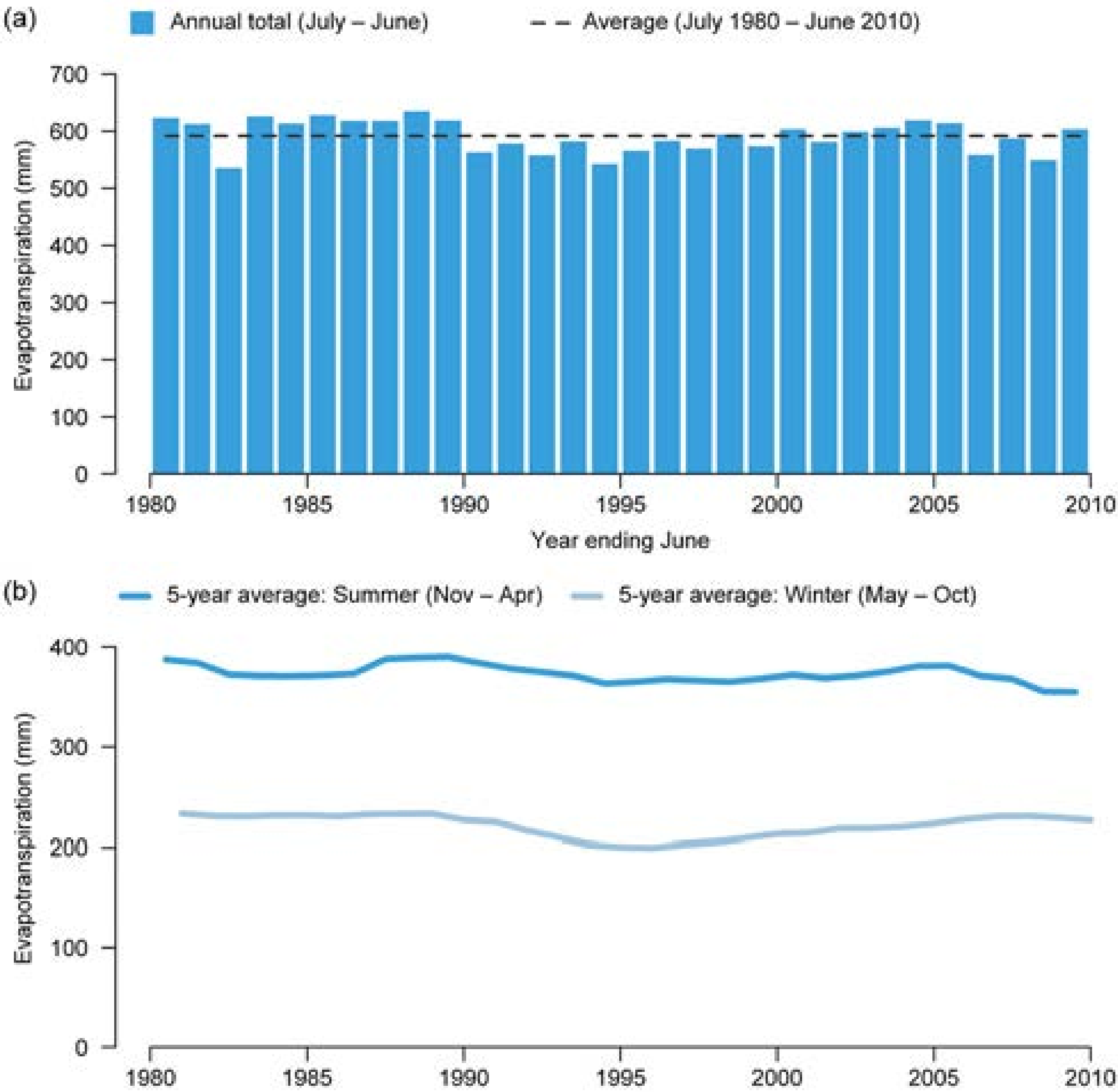


Figure 5-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the South East Coast (Victoria) region

5.4.2 Evapotranspiration (continued)

Figure 5-11 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis indicates slight reductions in evapotranspiration over much of the west of the region extending to areas north of Melbourne. The east of the region shows slight increases in summer evapotranspiration with negative trends observed along the southern coast. The winter period analysis does not appear to show as clearly defined evapotranspiration trends, but indicates that there may be a slight reduction in winter evapotranspiration over the 30-year period.

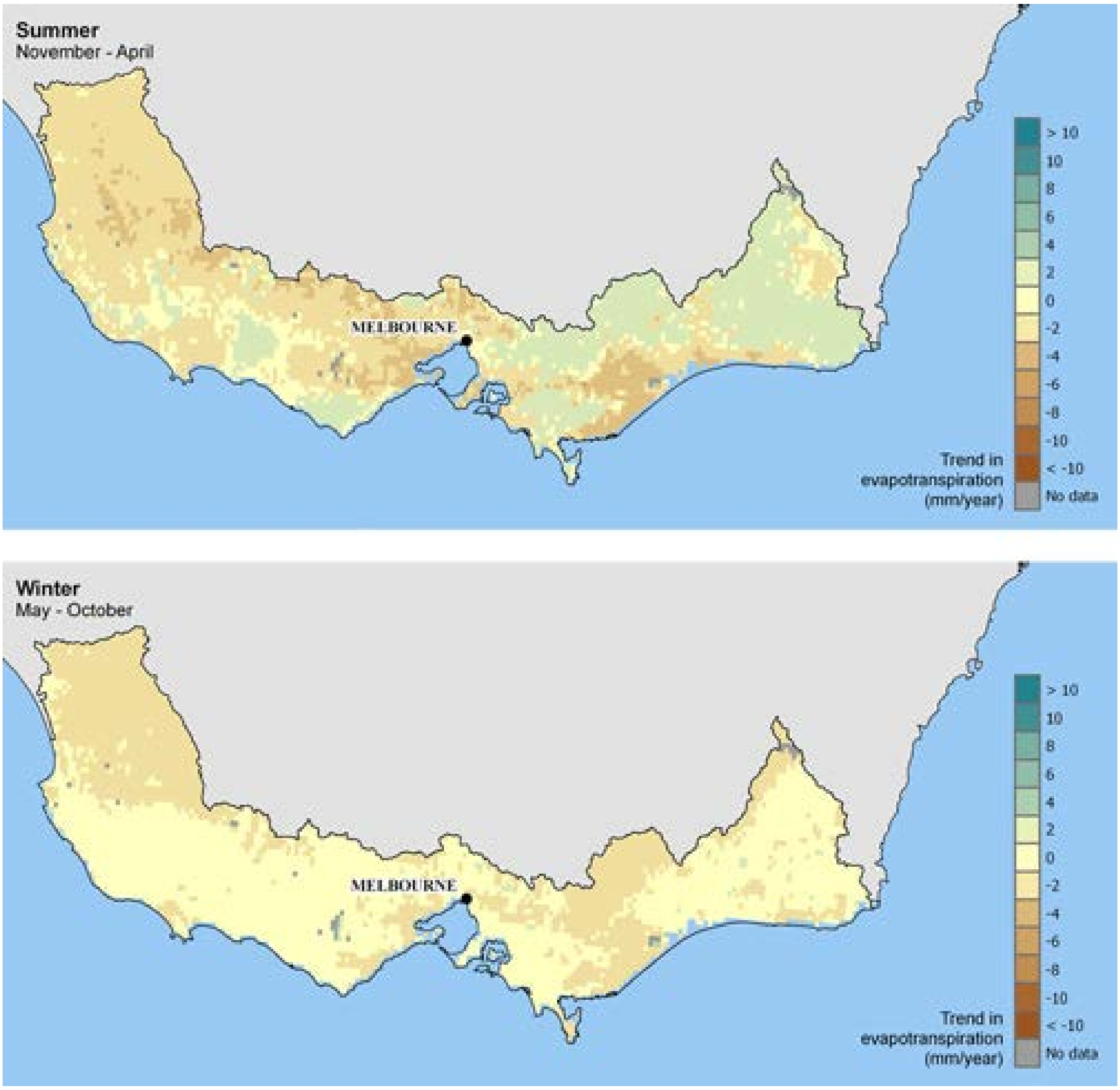


Figure 5-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the South East Coast (Victoria) region. The statistical significance of these trends is often very low

5.4.3 Landscape water yield

Landscape water yield for the South East Coast (Victoria) region for 2009–10 was estimated to be 59 mm, which is 41 per cent below the region's long-term (July 1911 to June 2010) average of 100 mm. Figure 5-12 (a) shows that during 2009–10, landscape water yield was relatively low across much of the region with the highest values occurring in the high rainfall areas along the north-eastern boundary of the region.

Landscape water yield deciles for 2009–10, shown in Figure 5-12 (b), indicates landscape water yield was very much below average across the majority of the region with limited areas of average values.

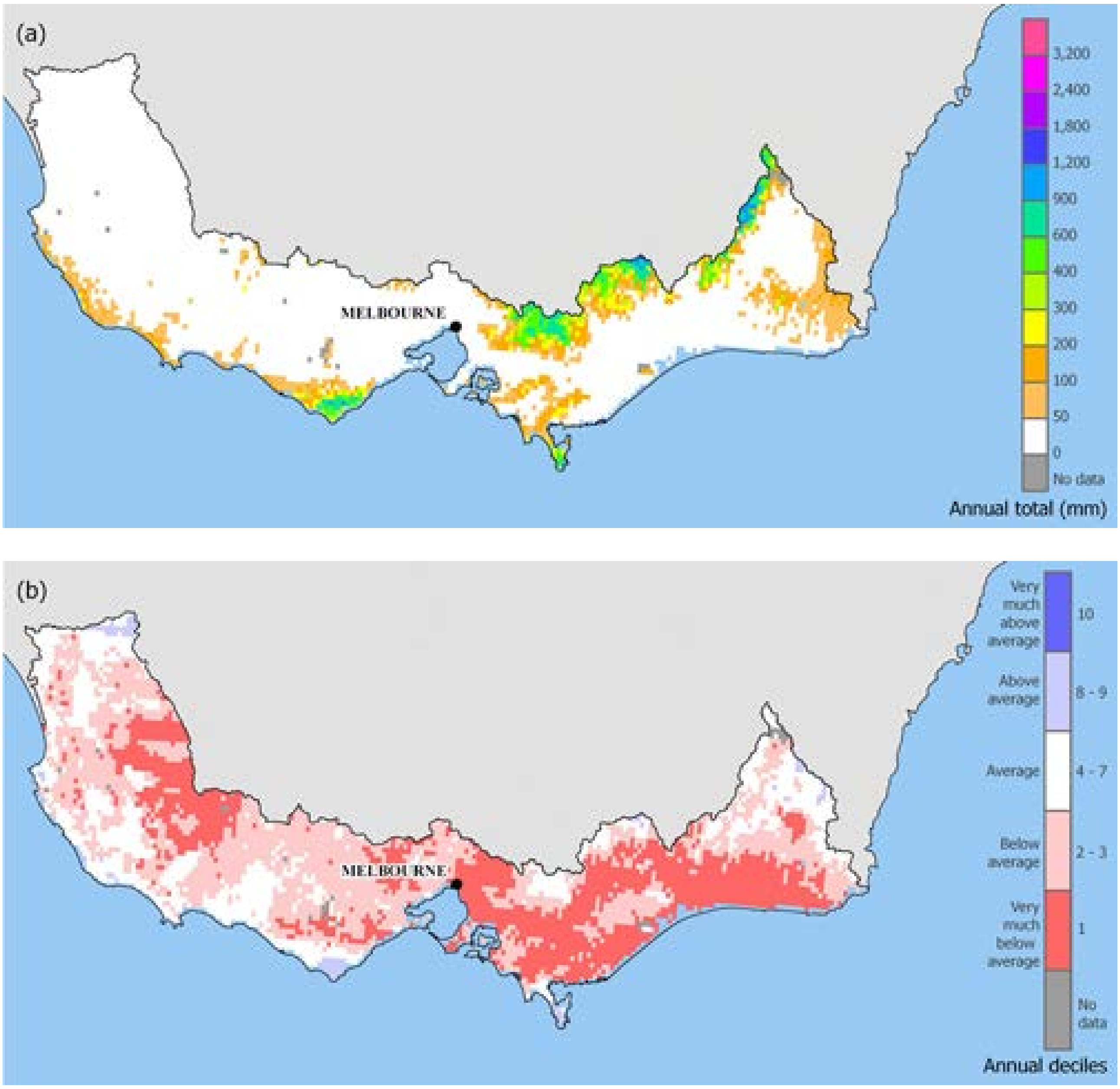


Figure 5-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South East Coast (Victoria) region

5.4.3 Landscape water yield (continued)

Figure 5-13 (a) shows annual landscape water yield for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 41 mm (2008–09) to 195 mm (1992–93). The annual average for the period was 93 mm. The data show that landscape water has been consistently below the 30-year average since 2002–03. The relatively wet period during the 1990s is clearly reflected in the annual totals.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) is presented using moving averages in Figure 5-13 (b). Regionally, landscape water yield is consistently higher during the winter period, although the magnitude of this difference is much reduced towards the end of the period. The wet period experienced during the early and mid-1990s is clearly reflected in both the seasonal averages. Since the mid-1990s there is a clear downward trend in modelled landscape water yield, particularly during the winter season.

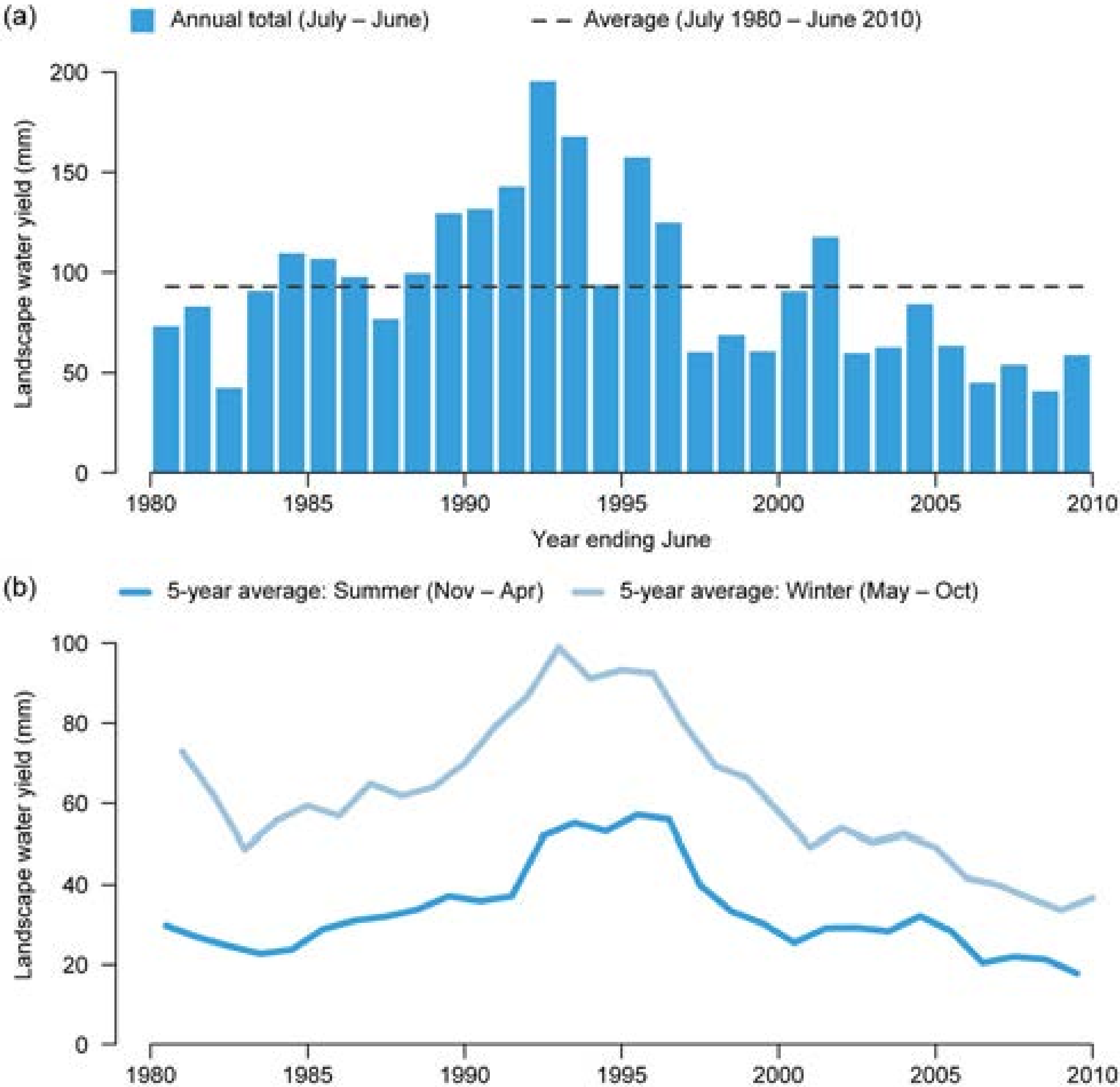


Figure 5-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the South East Coast (Victoria) region

5.4.3 Landscape water yield (continued)

Figure 5-14 provides a spatial representation of trends in summer (November–April) and winter (May–October) landscape water yield throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal water yield over the 30 years.

The summer period analysis indicates a slight reduction in landscape water yield across much of the east of the region. The winter period analysis shows stronger downward trends, particularly across the centre of the region and along the northeast regional boundary. The magnitudes of these strong negative trends over the 30-year period, particularly for the winter period, are high relative to the respective seasonal averages.

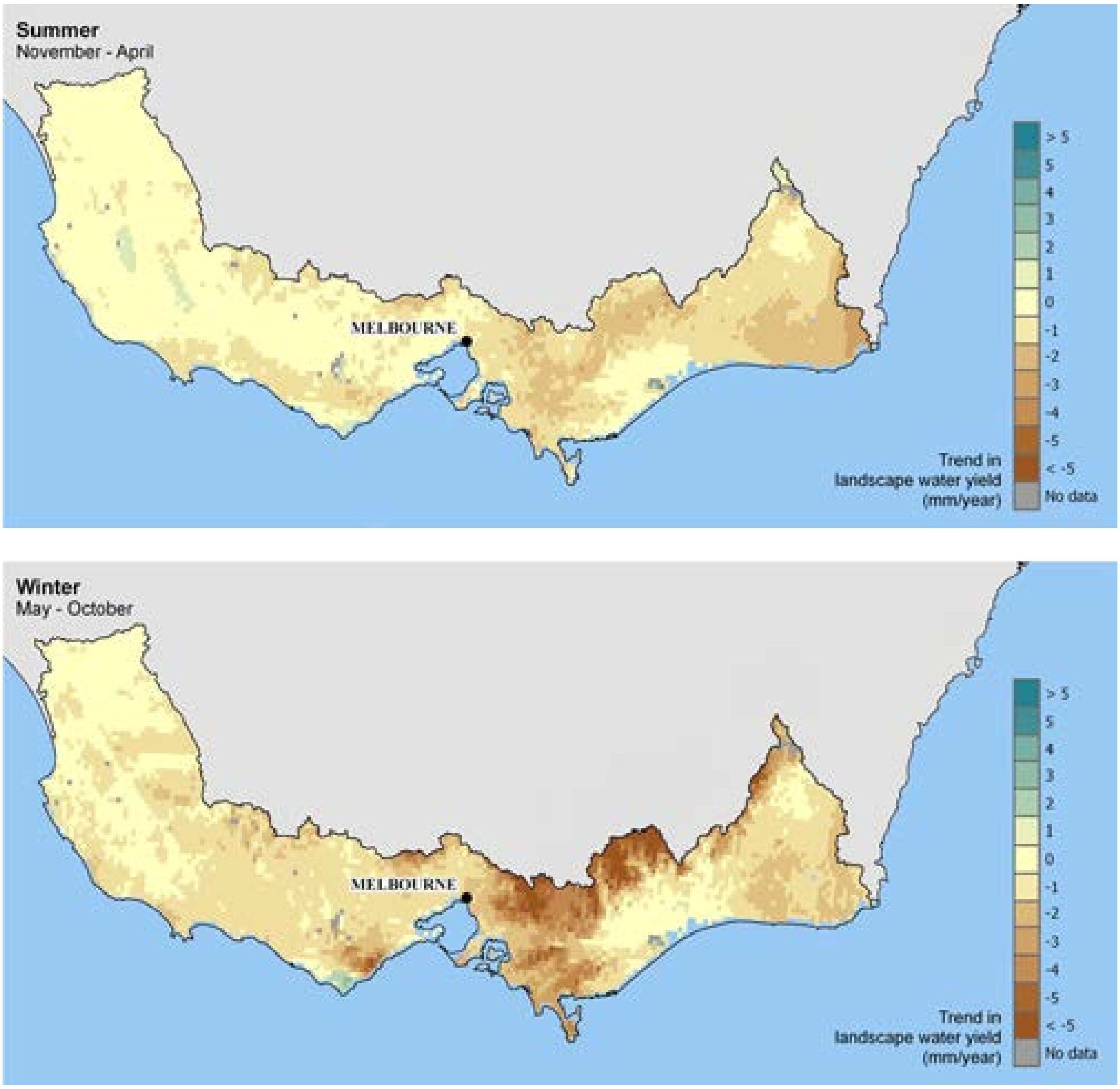


Figure 5-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the South East Coast (Victoria) region. The statistical significance of these trends is often very low

5.5 Rivers, wetlands and groundwater

The 39 reliable stream gauges with relatively long historical records across 16 geographically representative river basins were selected for examination of regional streamflow in this report (see Figure 5-15). Streamflow at these gauges in 2009–10 was analysed in relation to historical patterns of flow.

Seven of these gauges and two additional gauges were also selected for analysis of patterns of wetland river inflows for the region (see Figure 5-5).

The groundwater management units within the region are presented in Figure 5-16. Most of the units are relatively small in area and are located near the coast with the exception of some larger units at the western and eastern ends of the region.

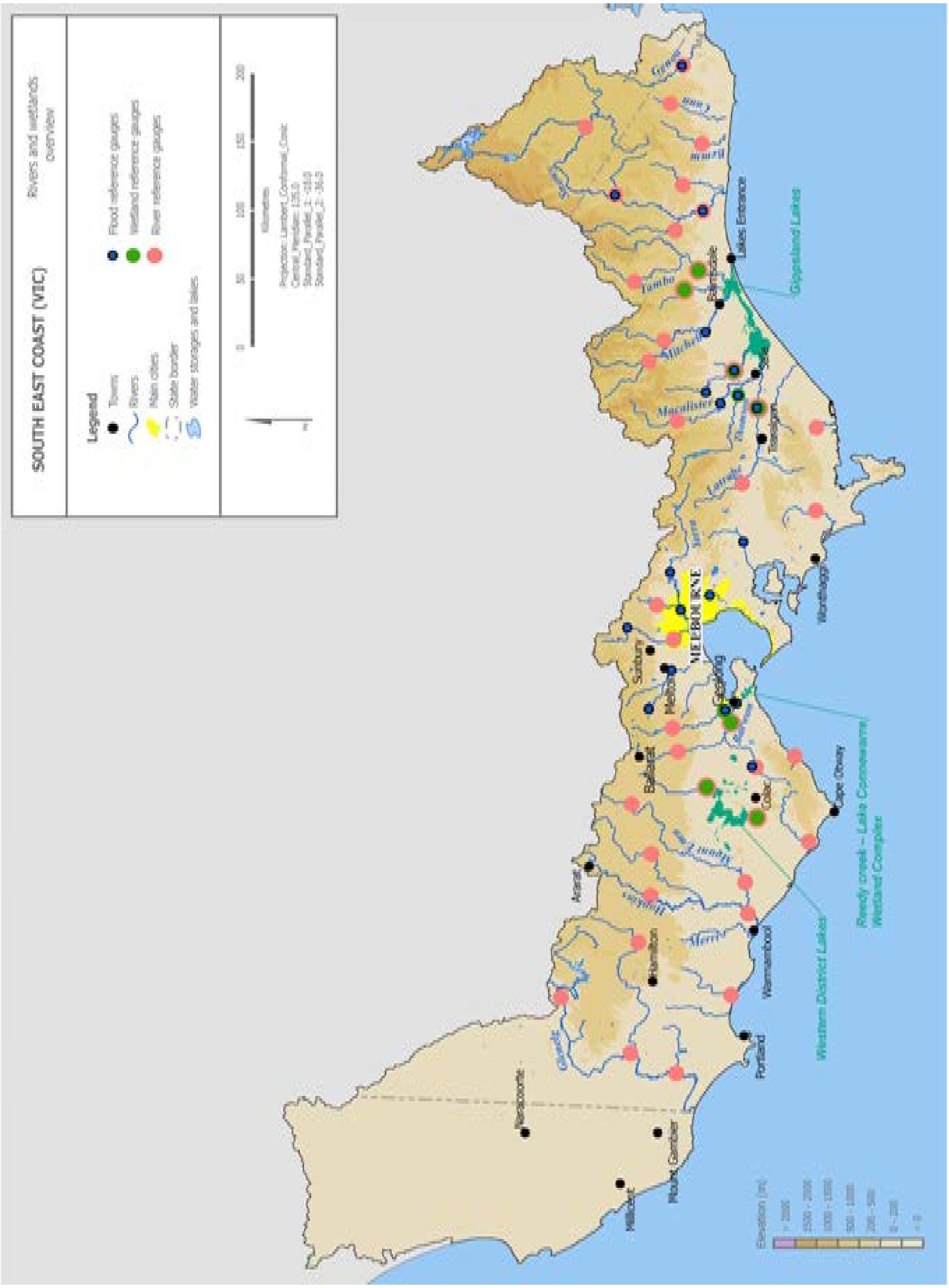


Figure 5-15. Stream gauges selected for analysis in the South East Coast (Victoria) region

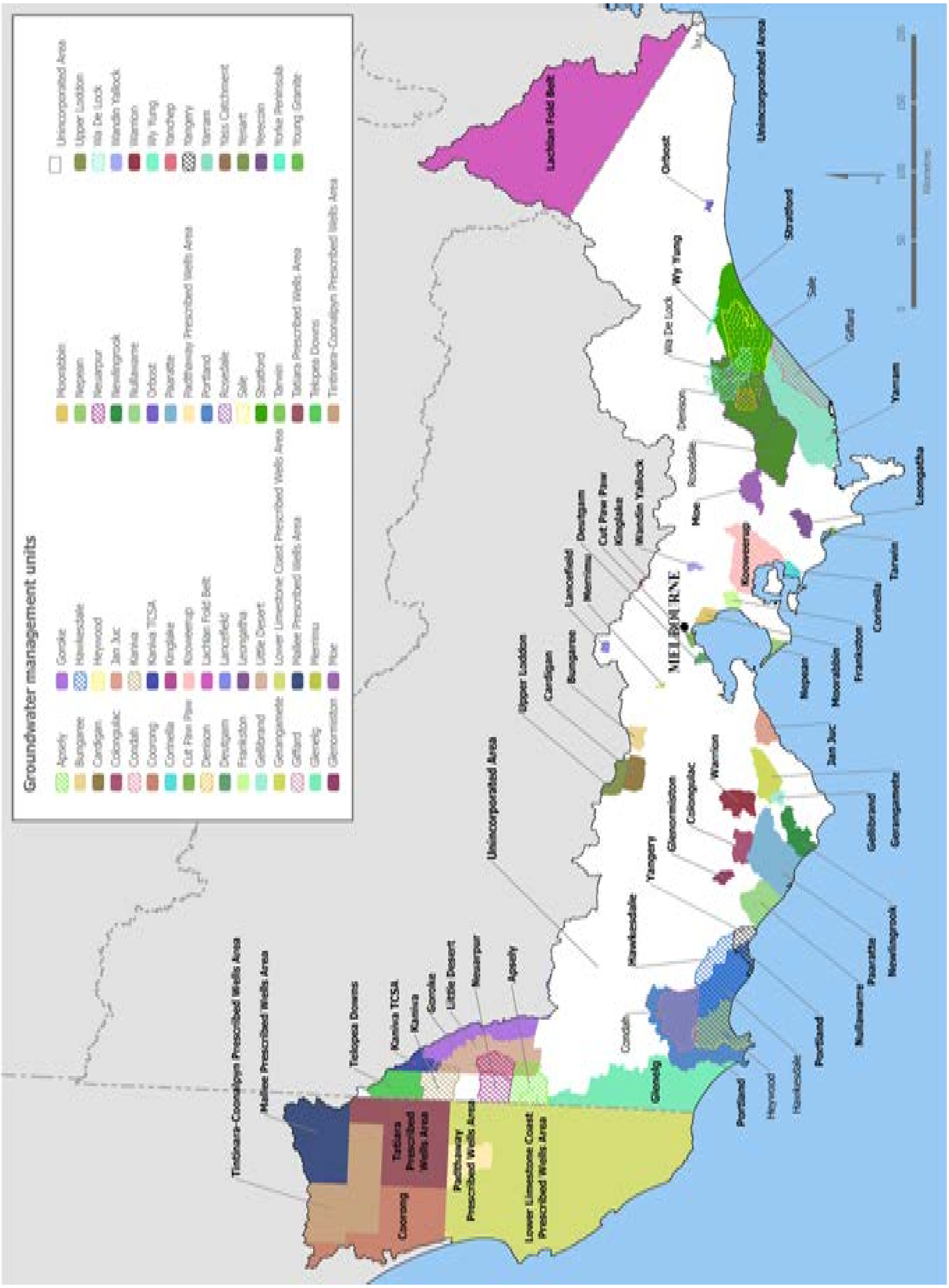


Figure 5-16. Major groundwater management units in the South East Coast (Victoria) region (Bureau of Meteorology 2011e)

5.5.1 Streamflow and flood report

Figure 5-17 presents an analysis of river flows over 2009–10 relative to annual flows for the past 30 years at 39 monitoring sites throughout the South East Coast (Victoria) region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for the 2009–10 are colour-coded relative to the decile range relative to the 1980 to 2010 period at each site.

With regard to total annual discharge for 2009–10, Figure 5-17 shows that observations from monitoring gauges across the region generally reflected the below average to very much below average modelled landscape water yield results shown in Figure 5-12 (b). The estimated above average landscape water yield around the southwest of the region (Otway coast) in Figure 5-12 (b) is represented as normal (average) by streamflow data for 2009–10 from the monitoring gauge in that region. The normal flows recorded in the upper Mitchell River and upper Thomson River are not reflected in the modelled landscape water yield results. Broadly, Figure 5-17 shows:

- streamflow over 2009–10 was very much below average in the southeast of the region as well as in some rivers in the central headlands west of Melbourne
- the larger rivers in the northeast of the region had average flows, consistent with the average landscape water yields of Figure 5-12
- predominantly average flows occurred in the west of the region, which are not fully reflected by the landscape water yield results.

Closer comparison between Figure 5-12 and Figure 5-17 generally shows a common pattern of below average to very much below average decile results, which is typical when compared to the rainfall deciles of Figure 5-6 (b). Rainfall totals are predominantly above average over the region and evapotranspiration totals are consistently lower than rainfall totals. The key factor is the very dry soil moisture status at the beginning of the year, absorbing most of the winter rainfall. During summer, evapotranspiration levels were higher than rainfall levels, which means that soil moisture levels were drawn down again. In the last part of the year the average rainfall totals started filling up the soil again, not allowing much water to be released as landscape water yield or streamflow.

Through flood monitoring partnership arrangements, data were available for a number of flood gauges allowing reporting on flood occurrence and severity at those sites. The 20 gauges selected as indicative stations for the South East Coast (Victoria) region are situated on rivers along the Victorian coast from the Barwon River in the west to Genoa River in the east (Table 5-2). The stations were also selected on the basis of data quality and coverage for the 2009–10 period.

September 2009 saw above normal rainfall across much of Victoria, in spite of the tropical Pacific Ocean temperatures remaining warmer than average in all of the key El Niño monitoring regions and continuing to exceed thresholds considered typical of an El Niño event. A very intense cyclonic system moved across Victoria on 22–23 September 2009. Some stabilisation occurred on the day after but a new front moved through Victoria on 25 September, followed by development over the Tasman Sea on 26–27 September. The month concluded with an anticyclone once again exerting its stabilising influence across Victoria. Rainfall associated with the cyclonic system and subsequent cold front led to increased river levels in the Yarra and Latrobe rivers with minor flooding observed at Yarra Glen and Rosedale.

A low formed on 12 February 2010 and this system intensified over the next few days as it moved towards the Tasman Sea. The resulting moist and strengthening south-easterly flow, which became established over Victoria, resulted in record rainfall totals for this time of the year at a number of places in Gippsland and the north-eastern ranges. Consequently minor flooding was observed on the Snowy River at McKillops Bridge and Jarrahmond.

During May 2010, above average rainfall (for the month) over the headwaters of the Snowy River catchment led to minor flooding once more at McKillops Bridge.

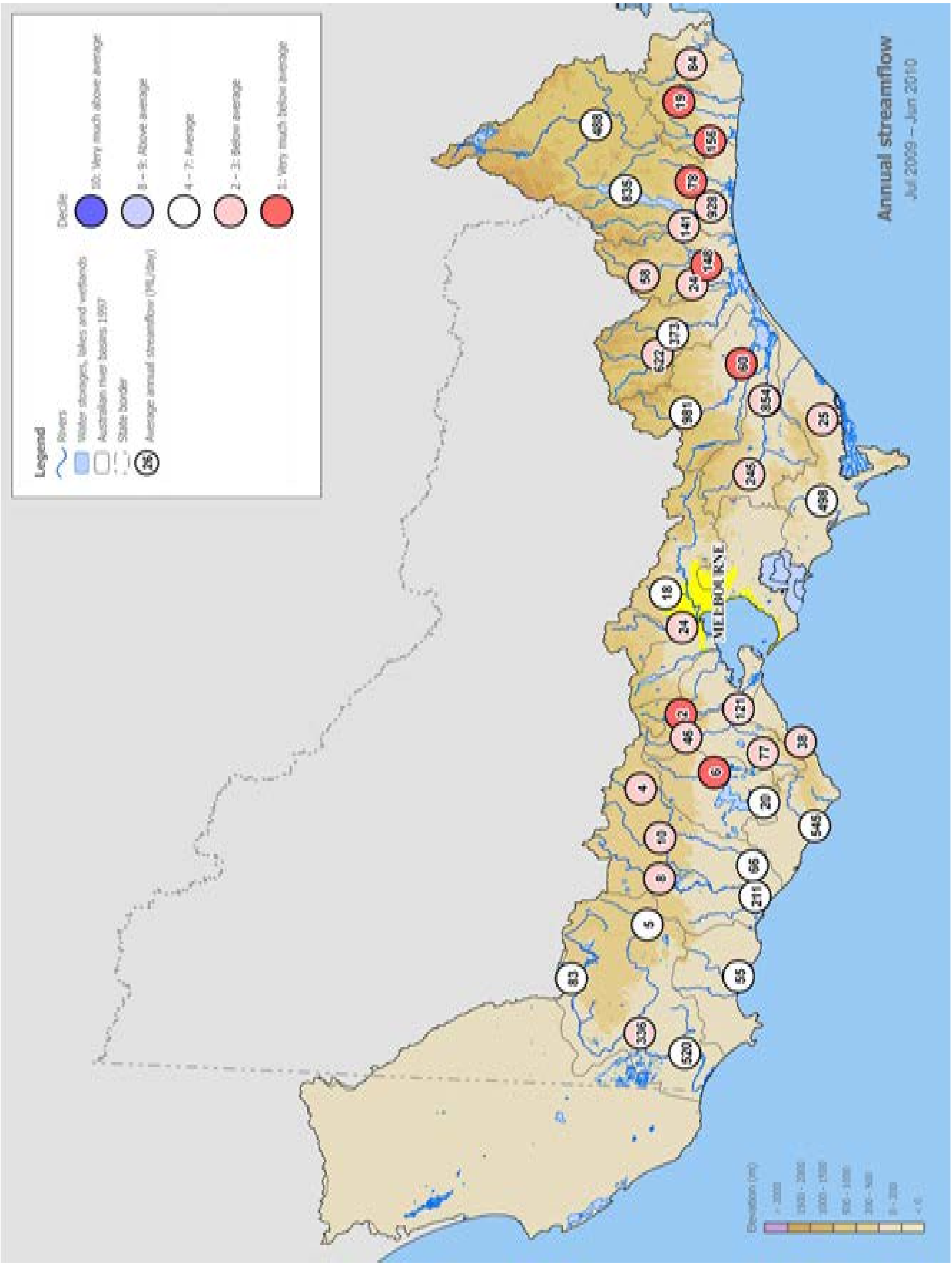
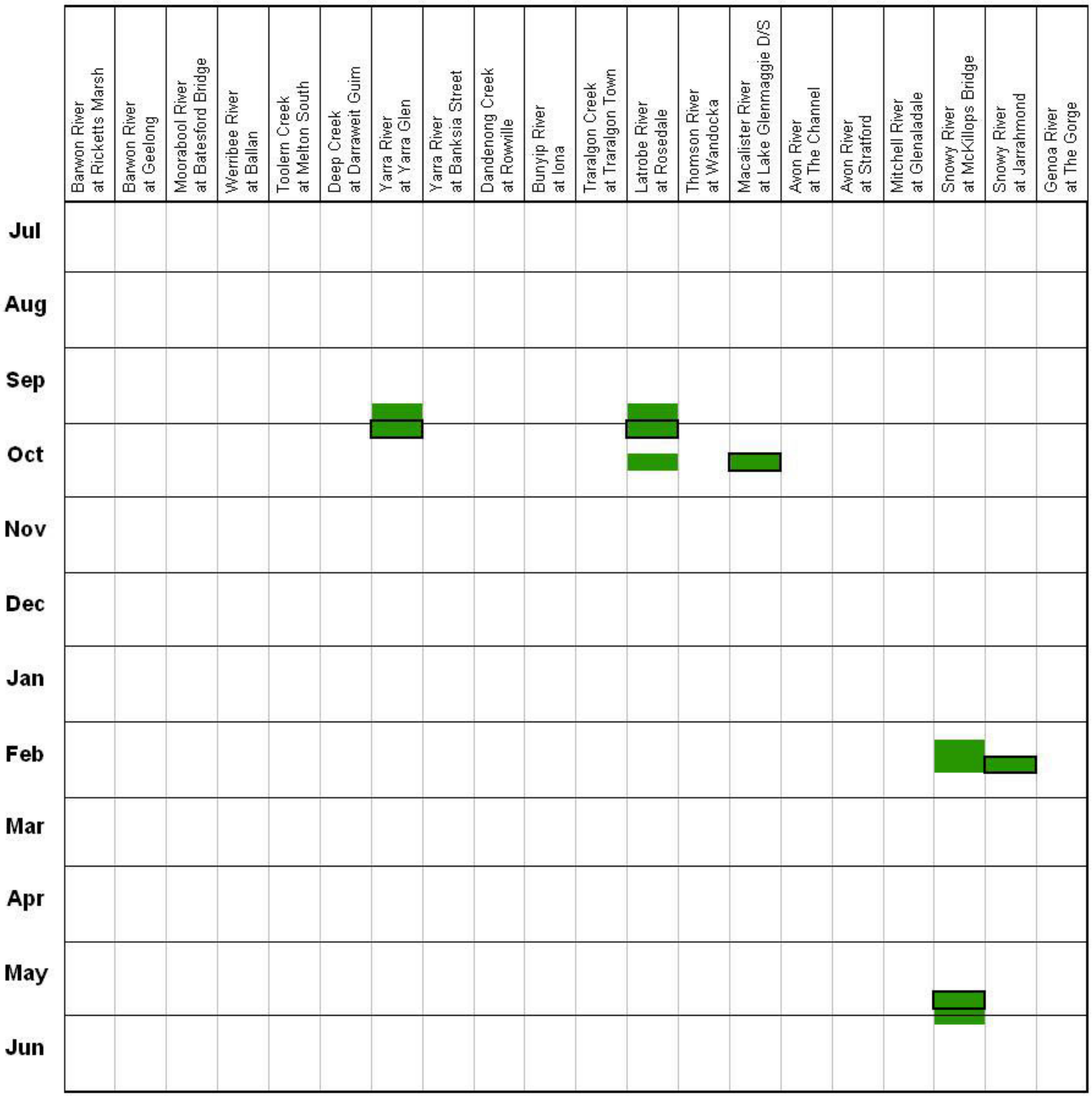


Figure 5-17 Annual streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the South East Coast (Victoria) region

Table 5-2. Weekly flood classifications for key flood warning sites within the region (flood classes are derived in consultation with emergency services and local agencies; the peak height for the year is also included)

South East Coast (Victoria) region
Weekly River Height Peaks from July 2009 to June 2010



Peak flood level (m)

Barwon River at Ricketts Marsh	Barwon River at Geelong	Moorabool River at Batesford Bridge	Werribee River at Ballan	Toolern Creek at Melton South	Deep Creek at Darraweit Guim	Yarra River at Yarra Glen	Yarra River at Banksia Street	Dandenong Creek at Rowville	Bunyip River at Iona
-	-	-	-	-	-	on 01/10/2009	-	-	-
-	-	-	-	-	-	4.4	-	-	-

Traralgon Creek at Traralgon Town	Latrobe River at Rosedale	Thomson River at Wandocka	Macalister River at Lake Glenmaggie D/S	Avon River at The Channel	Avon River at Stratford	Mitchell River at Glenaladale	Snowy River at McKillops Bridge	Snowy River at Jarrahmond	Genoa River at The Gorge
-	on 01/10/2009	-	on 15/10/2009	-	-	-	on 01/06/2010	on 17/02/2010	-
-	4.2	-	2.3	-	-	-	4.0	4.0	-

River height classes (m)

	Barwon River at Ricketts Marsh	Barwon River at Geelong	Moorabool River at Batesford Bridge	Werribee River at Ballan	Toolern Creek at Melton South	Deep Creek at Darraweit Guim	Yarra River at Yarra Glen	Yarra River at Banksia Street	Dandenong Creek at Rowville	Bunyip River at Iona
Major	6.5	4.3	4.9	3.0	7.2	6.5	5.0	9.2	5.5	5.5
Moderate	4.8	3.1	4.0	2.1	6.0	6.1	4.5	8.3	5.0	5.0
Minor	3.0	2.5	2.7	1.2	2.2	5.5	4.1	6.0	4.3	2.1

	Traralgon Creek at Traralgon Town	Latrobe River at Rosedale	Thomson River at Wandocka	Macalister River at Lake Glenmaggie D/S	Avon River at The Channel	Avon River at Stratford	Mitchell River at Glenaladale	Snowy River at McKillops Bridge	Snowy River at Jarrahmond	Genoa River at The Gorge
Major	4.5	5.5	6.7	5.2	7.5	6.5	5.5	8.0	7.4	4.4
Moderate	4.0	4.8	6.5	4.0	6.9	6.0	4.5	6.0	6.2	3.2
Minor	3.5	4.0	6.2	2.3	5.0	4.5	3.0	2.5	3.9	2.2

Colour codes:
- Below flood level
- Annual flood peak
- Major flooding
- Moderate flooding
- Minor flooding

5.5.2 Inflows to wetlands

This section considers water flows into important wetlands in the South East Coast (Victoria) region. Two of the eight internationally recognised Ramsar wetland sites in the region (Western District lakes and Gippsland lakes) and a nationally important freshwater wetland site (the Reedy Creek–Lake Connewarre wetland complex) were selected for examination.

Nine reference gauges were chosen to illustrate patterns of river inflows to the selected wetlands. Figure 5-18 presents a comparison of 2009–10 monthly flows with flow deciles over the 30-year period 1980 to 2010 for each of these gauges.

While river discharge observations at the nine selected gauges do not represent the total volume of freshwater water inflow to the wetlands under consideration, the reference gauge discharges are assumed to be representative of the variation of actual freshwater inflows to the wetlands.

With this in mind, the following may be observed with respect to water supply to these wetlands in 2009–10 relative to the 30-year record:

- For the creeks entering Western District Lake (gauges 1 and 2), average to below average inflows were recorded in the high flow winter period, and below average inflows were recorded over the summer period.
- For the Reedy Creek–Lake Connewarre wetland complex, average to below average inflows were also recorded on the Barwon River (gauge 3) during the high flow winter period, with below average flows observed over the summer period. Flows in the smaller Moorabool River (gauge 4) were below average throughout the year.
- For the various rivers feeding the Gippsland lakes (gauges 5 to 9), flows during the high flow winter period were average or above average only in October 2009 and June 2010. In the summer period, inflows were mostly above average in February and March, but flows were generally below average in most other months at most gauges.
- The overall outcome observed for 2009–10 was of average to below average inflows in the traditionally wetter winter period at all three wetlands and below average inflows in the traditionally drier summer period for the two wetlands west of Melbourne. The Gippsland lakes had somewhat higher inflow volumes, receiving above average inflows during February and March 2010.

Figure 5-19 shows the historic pattern of inflows to the three selected wetlands over the 30 years from 1980 to 2010. A five-year moving window was applied over daily streamflow data to produce the 10th, 50th and 90th flow percentiles for each of the nine reference gauges.

The 10th, 50th and 90th flow percentiles were selected to approximate patterns of low, median and high flows, respectively. Low flows are associated with a base level environmental inflow needed to ensure a minimum level of ecological function during dry periods of the year. Median river flows sustain wetland hydrology and ecological function throughout most of the year. High flows are associated with the lateral movement of water into floodplains, and are necessary to sustain a high level of wetland function.

Note that any variability in the flow percentiles of Figure 5-19 can be a result of changing climatic conditions as well as human interference. However, the purpose of the graphs is not to analyse the cause of the variability.

With respect to the 30-year period, the plots show:

- a strong correlation between the high, median and low flow percentiles in all of the more major rivers (gauges 2 and 3; 5 to 9) and a weaker correlation between low flow and the other flow percentiles in the minor rivers (gauges 1 and 4) due to the more ephemeral nature of these smaller streams
- a rise in median and high flows to a peak around 1992–95 followed by a distinct fall for the Western District lakes (gauges 1 and 2) and the Reedy Creek–Lake Connewarre wetland complex (gauges 3 and 4)
- a similar pattern with respect to inflows to the Gippsland lakes (gauges 5 to 9), though the post-1995 decline in high and median flows is generally less marked.

These flow percentiles suggest that inflow patterns have changed over the past 30 years, which could have had consequences for the ecosystem function and health in all three wetlands. This impact may have been more severe in the Western District lakes and the Reedy Creek–Lake Connewarre wetland complex than in the Gippsland lakes.

5.5.3 Groundwater status

Groundwater status for the South East Coast (Victoria) region was not able to be addressed in this report. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available.

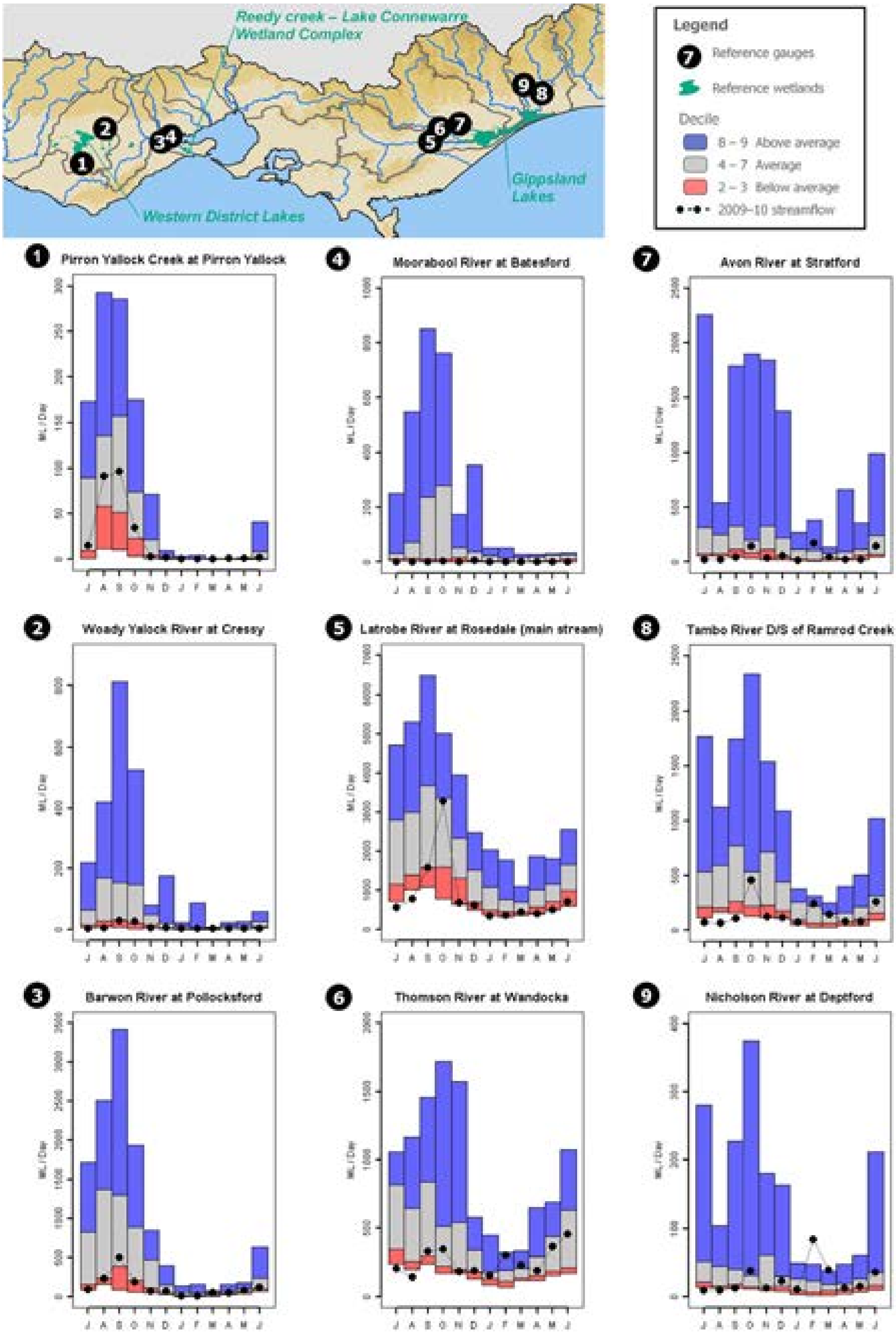


Figure 5-18. Monthly discharge hydrographs for 2009–10 compared with the period of 1980 to 2010 for reference gauges on rivers flowing into selected wetland sites of the South East Coast (Victoria) region

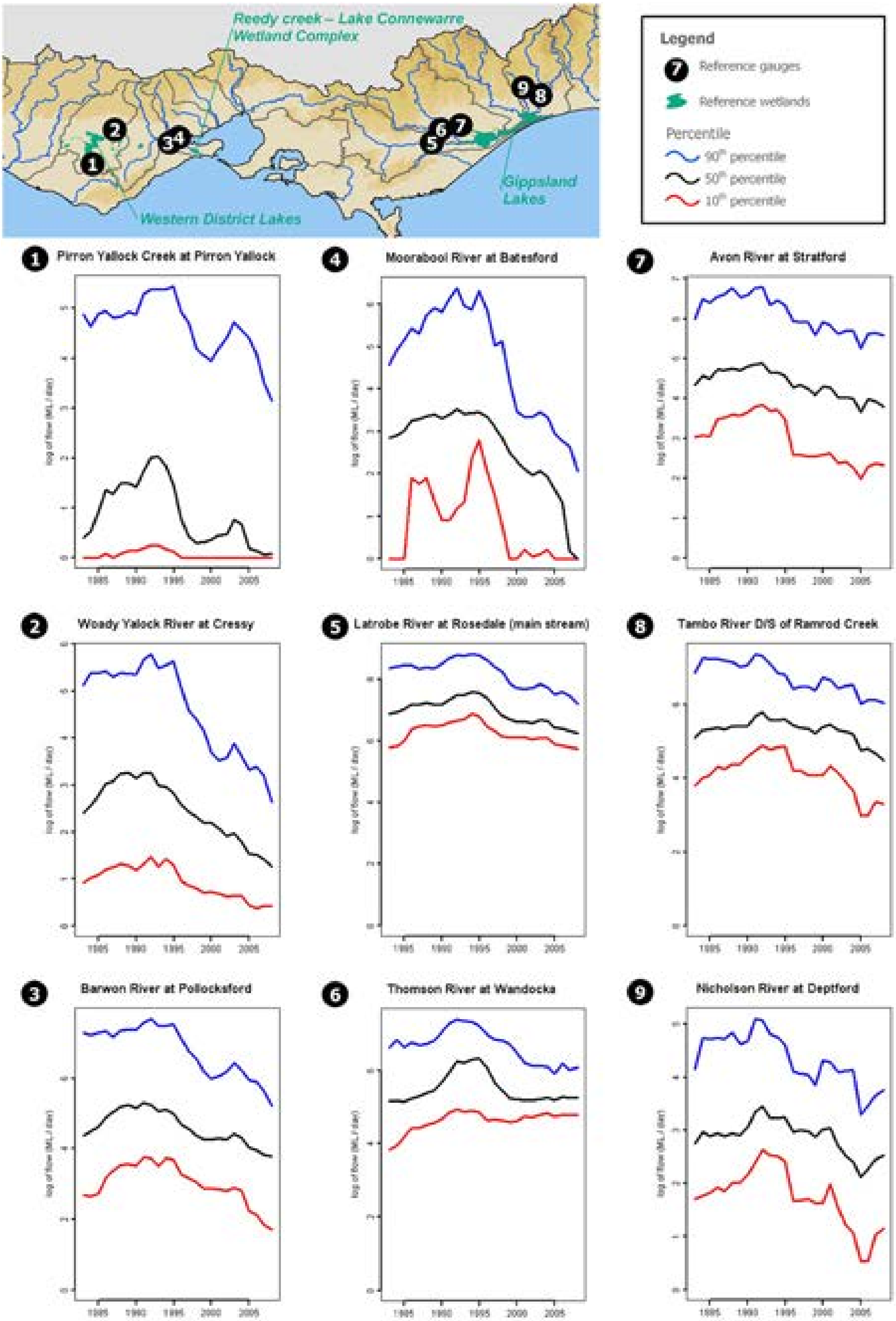


Figure 5-19. Daily flow percentiles extracted from a five-year moving window at reference gauges on rivers flowing into selected wetland sites of the South East Coast (Victoria) region

5.6 Water for cities and towns

5.6.1 Regional overview

The population of the South East Coast (Victoria) region is concentrated in Melbourne (more than 3 million) with a large proportion of the remaining population concentrated in five other major urban centres. These urban centres with populations of greater than 25,000 people are identified in Table 5-3 together with the river basin in which they are located and their main urban supply storages.

Major surface water supply sources in the region are shown in Figure 5-20 with river catchments in the Melbourne area highlighted. This includes the catchments of the Yarra, Werribee, Maribyrnong and Bunyip rivers. The major water storage for Melbourne, the Thomson Reservoir, is situated on the Thomson River east of Melbourne.

Major storages in the region include the Thomson, Upper Yarra, Maroondah, Silvan, O'Shannassy, Yan Yean and Sugarloaf, Cardinia and Tarago reservoirs. These storages provide urban water supply to the Melbourne area. Other water supply storages near Melbourne include Pykes Creek, Merrimu and Rosslynne reservoirs, which supply irrigation and urban water to the west of Melbourne (Department of Primary Industries 2011b).

Surface water is the major source of water for urban use in region. Most of this water comes from mountain ash forest areas in the Yarra Ranges east of Melbourne. More than 15,700 km^2 of these native forests are protected for the primary purpose of harvesting water (Department of Primary Industries 2011a). By 30 June 2012, the commissioning of a first desalination plant in Melbourne will provide up to an additional 150 GL of desalinated water to its water resources.

In the western part of the region (western Victoria and southeast of South Australia), most of the towns are more reliant on groundwater, including the cities of Mount Gambier and Portland.

The following sections focus on the Melbourne water supply area. Variation in water storage during the period 1985 to 2010 is illustrated in Figure 5-21 for three of the major water storages in the region.

Table 5-3. Cities and their water supply sources in the South East Coast (Victoria) region

City	Population*	River basin	Major supply sources
Melbourne	3,900,000	Yarra, Werribee, Maribyrnong and Bunyip	Thomson, Upper Yarra, Cardinia
Geelong	175,000	Barwon	Wurdee Boluc
Ballarat	94,000	Moorabool	Coliban storages, Lake Eppalock
Melton	46,000	Werribee	Melton Reservoir
Sunbury	35,000	Mulgrave–Russell	Western Water supply water after receiving from Melbourne Water
Warrnambool	33,000	Hopkins	Via pipeline from the Gellibrand River and various diversion weirs on creeks in the Great Otway National Park
Mount Gambier	25,200		Blue Lake

* Australian Bureau of Statistics (2010b)

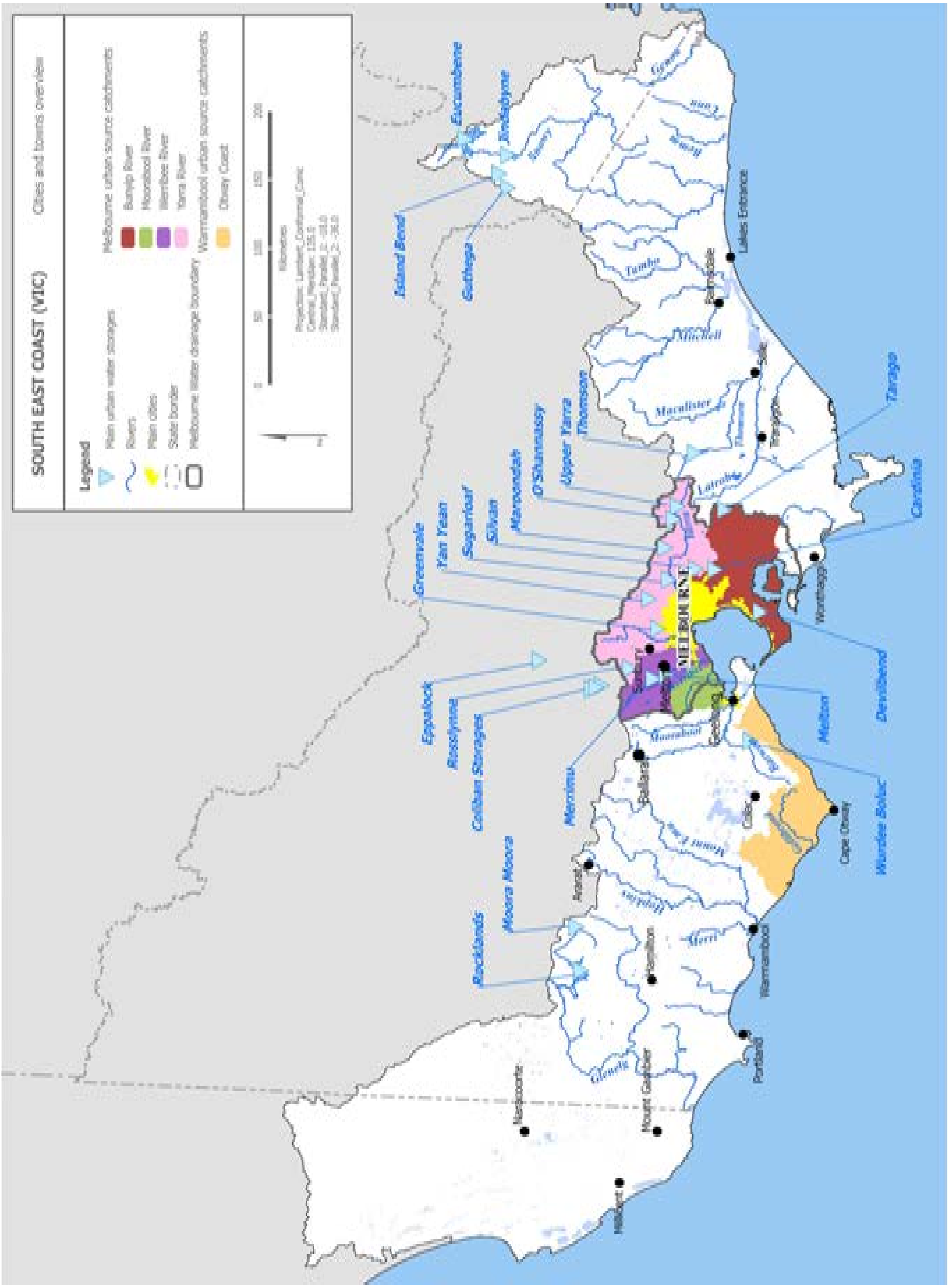


Figure 5-20. Urban areas and supply storages in the South East Coast (Victoria) region

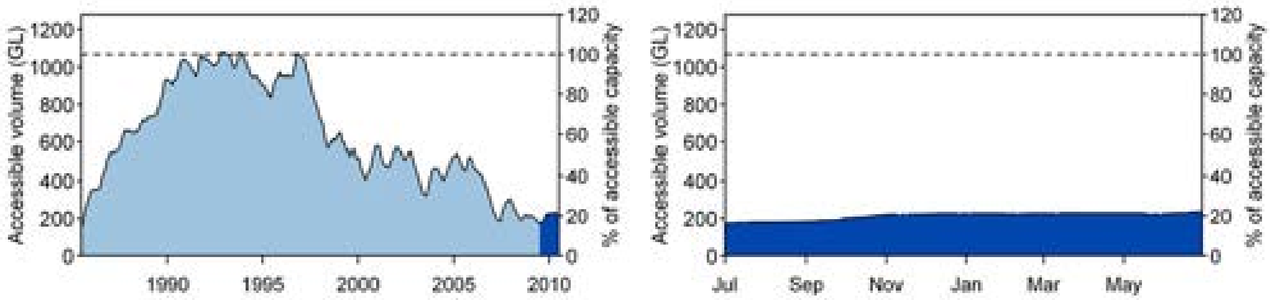
5.6.2 Melbourne region

The surface water flow and transfer system in the Melbourne region is complex (Figure 5–22). It includes natural waterways, some of which incorporate major storages, stormwater management infrastructure and water reticulation, and sewerage systems. The region covers four water supply catchments: the Yarra, Bunyip, Maribyrnong and Werribee river basins.

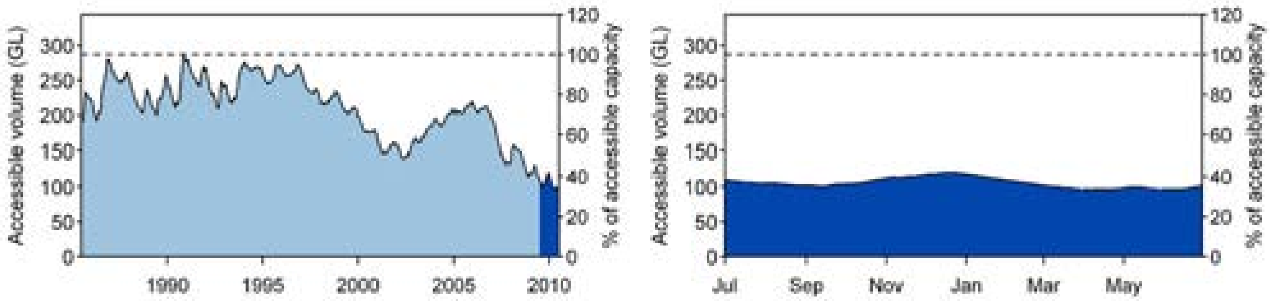
The Yarra River basin begins on the southern slopes of the Great Dividing Range in the forested water supply catchments of the Yarra Ranges National Park.

The Yarra River's catchment area covers 4,110 km^2 and includes seven major storages. The Upper Yarra, O'Shannassy and Maroondah reservoirs all harvest surface water. Sugarloaf Reservoir is an off-stream storage with a dual role to harvest water and act as a seasonal balancing water storage. The Silvan, Yan Yean and Greenvale reservoirs are off-stream storages that serve as seasonal balancing water storages (Department of Primary Industries 2011c).

Thomson Reservoir



Cardinia Reservoir



Upper Yarra Reservoir

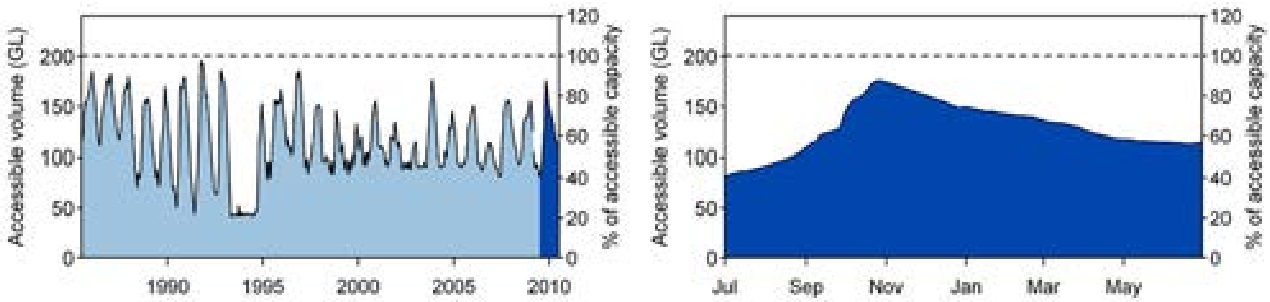


Figure 5-21. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for cities in the South East Coast (Victoria) region

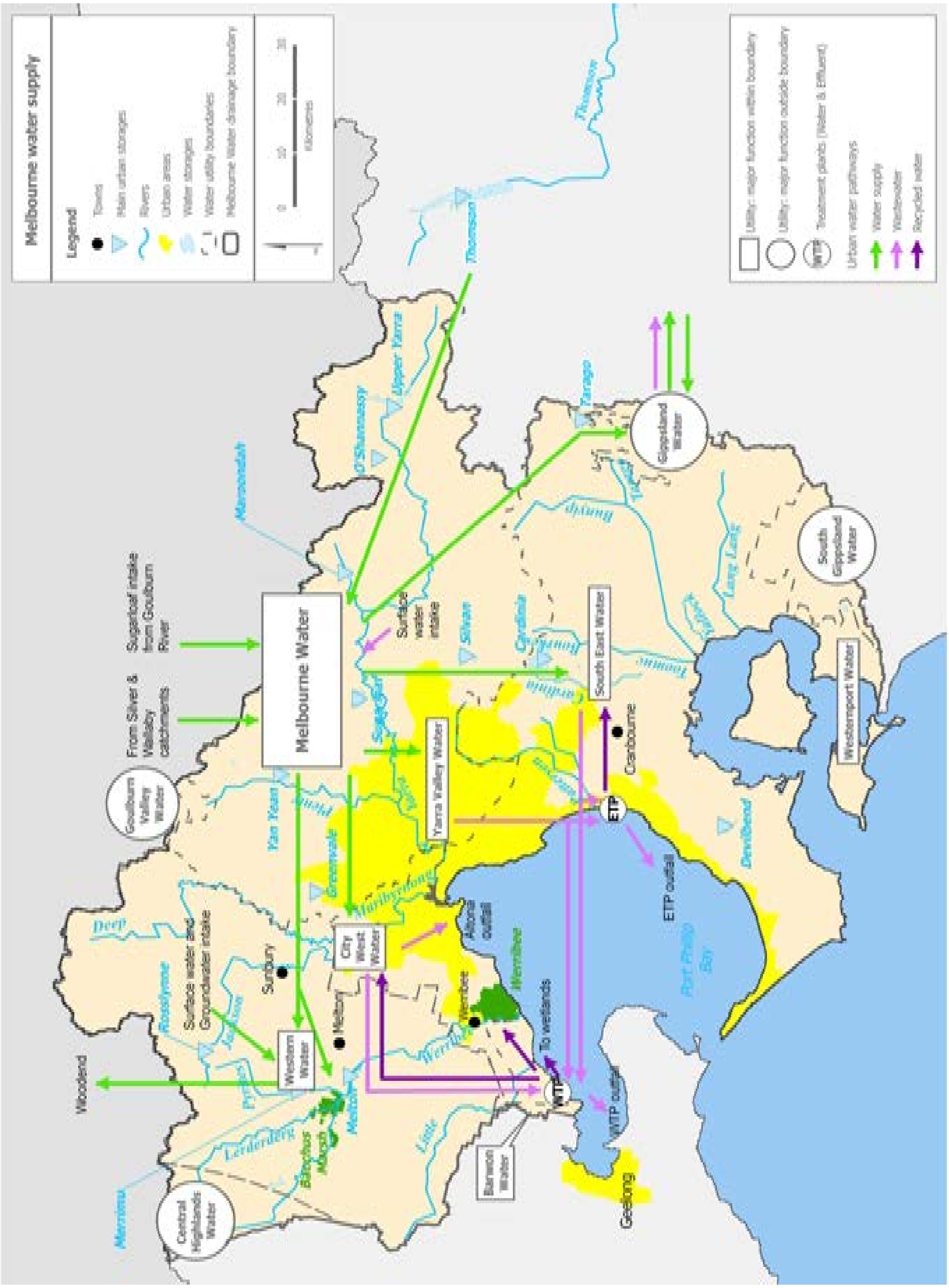


Figure 5-22. Water supply schematic for the Melbourne region

5.6.2 Melbourne region (continued)

The Bunyip River basin covers the southeastern suburbs of Melbourne and the Mornington Peninsula. The catchment extends from Western Port Bay in the south to the Eastern Highlands in the north and covers an area of 4,078 km^2. There are several separate river systems in the basin, including the Patterson River, Cardinia and Toomuc creeks, Bunyip and Tarago rivers, Yallock Creek and Lang Lang River. There are two major storages in the Bunyip River basin: Tarago Reservoir, the only on-stream storage in the catchment, and Cardinia Reservoir, an off-stream storage that stores water transferred from the Yarra River (Department of Primary Industries 2011a).

The Maribyrnong River basin covers an area of 1,453 km^2. It extends approximately 70 km north of Melbourne to the Great Dividing Range. The Maribyrnong River flows through suburban Melbourne before joining the Yarra River estuary just upstream of Port Phillip Bay. Rosslynne Reservoir is the only major storage in the catchment (Department of Primary Industries 2011a).

The Werribee River basin is located directly to the west of Melbourne and covers an area of 1,978 km^2. It is bound to the north by the Great Dividing Range and to the south by Port Phillip Bay. The Werribee River and Lerderderg River meet upstream of Melton Reservoir and then flow through Werribee before entering Port Phillip Bay (Department of Primary Industries 2011c).

Urban water infrastructure and management in the Melbourne region

Melbourne Water is the bulk water supplier in the Melbourne region and is owned by the Victorian State Government. It manages surface water supply catchments, treats and supplies drinking and recycled water, removes and treats most of the sewage, and manages waterways and major drainage systems in the Port Phillip and Westernport area.

There are ten major water storages that serve the Melbourne region. Thomson Reservoir is the largest and has a capacity of 1,068 GL. It comprises approximately 60 per cent of the total accessible storage capacity in the supply area. The Thomson Reservoir was completed in 1984 and was designed to build up water reserves in wet years for use in dry years. It also provides environmental flows to the Thomson River and water for irrigated agriculture and hydro-power generation.

There are five urban water utilities in the Melbourne region that buy water from Melbourne Water. The three main retail water authorities are City West Water, Yarra Valley Water and South East Water. Western Water and Gippsland Water also buy bulk water from Melbourne Water. Western Water has its major service area within the Maribyrnong and Werribee river catchments and a minor service area outside the Melbourne region. Gippsland Water delivers water to a small area in the south-eastern part of the Melbourne region and has its major service area outside the Melbourne region.

The area within the Melbourne region in which the water is delivered by the three main urban retail water authorities – City West Water, Yarra Valley Water and South East Water – is the focus of the following sections and is referred to as the Melbourne water supply area.

Yarra Valley Water is the largest of the three retail water utilities providing water supply and sewerage services to over 1.6 million people and over 50,000 businesses in the Yarra River catchment area of the Melbourne water supply area. It is owned by the Victorian Government and is managed by an independent Board of Directors.

City West Water is the second largest of the three retail water utilities in the Melbourne water supply area and is also owned by the Victorian Government. It provides drinking water and recycled water services to customers in Melbourne's central business district as well as the inner and western suburbs, and manages sewerage and trade waste. It provides services to the local government areas of Brimbank, Hobsons Bay, Maribyrnong, Melbourne (north of the Yarra River), Moonee Valley, Wyndham, Yarra and parts of Melton and Hume. Each year City West Water supplies about 93 GL of drinking water to its customers and transfers approximately 94 per cent of the sewage and trade wastewater collected to Melbourne Water's Western Treatment Plant in Werribee (City West Water 2011).

South East Water provides water supply services to residents, businesses, large industries and local councils in the southeast part of the Melbourne water supply area. It manages and maintains the water and sewerage networks and some treatment plants. It also manages a network of parks as well as cultural assets, bays and waterways (South East Water Limited 2010).

5.6.2 Melbourne region (continued)

Surface storage levels and volumes in recent years

The total accessible water storage capacity of all the water storages servicing the Melbourne water supply area is 1,812 GL. The accessible capacity of the three largest water storages (Thomson, Upper Yarra and Cardinia) is 1,555 GL or about 86 per cent of the total (Melbourne Water 2011a).

Figure 5-23 (top) shows the combined accessible storage volumes of these three water storages from 1984 to 2010. The increase in accessible storage volume between 1984 and 1990 reflects the filling of the Thomson Reservoir, which was completed in 1984.

The storages were full in 1990, 1991, 1992 and 1997. Since 1997, the amount of accessible water stored progressively declined as a result of low rainfall and below average inflows. The accessible storage volume fell from 1,460 GL in 1997 to below 400 GL in 2009.

Figure 5-23 (bottom) shows the combined accessible storage volumes in the three dams from July 2009 to June 2010. Due to above average rainfall, the accessible storage increased from 375 GL in June 2009 to 507 GL in November 2009. From November 2009 to June 2010, the accessible storage volume declined slowly to about 450 GL.

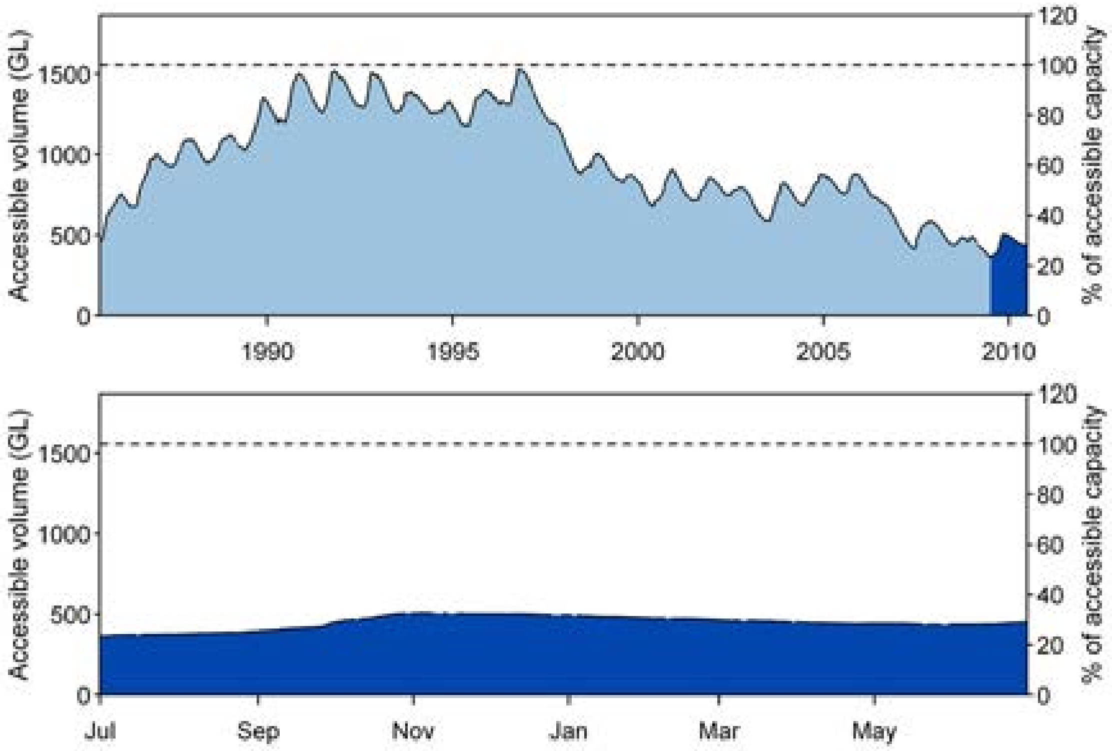


Figure 5-23. Combined surface water storage volumes for the Thomson, Upper Yarra and Cardinia reservoirs since 1985 (top) and during 2009–10 (bottom)

Water restriction in recent years

Melbourne Water and Melbourne's three retail water utilities have developed a Drought Response Plan which guides the management of the water supply system. Actions from this plan include water restrictions and permanent water saving rules. Decisions to lift or introduce water restrictions and water saving rules are made by the Victorian Government based on information received from Melbourne Water and the three retail water companies on accessible storage volumes, streamflow into storages, catchment conditions and climate outlooks. In times of severe water shortages, the urban water suppliers can recommend water restrictions ranging from Stage 1 (mild) to Stage 4 (severe). These restriction levels were developed by the Victorian Water Industry Association (2005).

Figure 5-24 shows that there were no water restrictions in the Melbourne water supply area until August 2006. There were three consecutive years of low rainfall before 2006 and in August 2006 Stage 1 restrictions were announced. This was quickly followed by Stage 2 restrictions introduced in spring 2006 and Stage 3 restrictions introduced in summer 2007. Stage 3a restrictions, which increase limitations on residential water use even further, were announced before winter 2007.

Rainfall between 2007 and 2009 was not enough to increase water storage volumes and Stage 3a restrictions remained in place. Because of above average rainfall in the upstream sections of the supply rivers in 2009–10, water restrictions were eased to Stage 3 in April 2010.

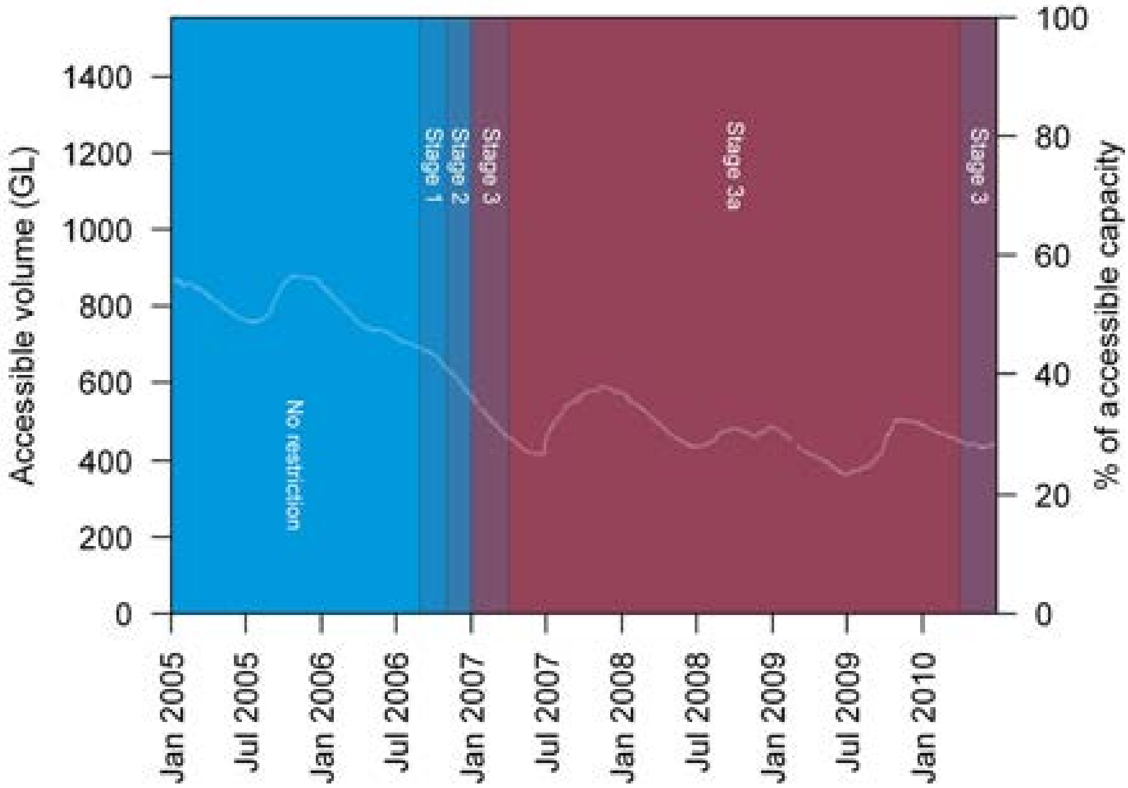


Figure 5-24. Urban water restriction levels across the Melbourne water supply area since 2005 shown against the combined accessible water volume of Thomson, Upper Yarra and Cardinia reservoirs

5.6.2 Melbourne region (continued)

Sources and supply of urban water in recent years

Surface water is the main source of water supplied to the Melbourne water supply area. Figure 5-25 (National Water Commission 2011a) illustrates that about 97 per cent of bulk water delivered is from surface water and three per cent from recycled water. The use of recycled water started in 2005–06. Groundwater and desalinated water were not used up to and including 2009–10.

Water supply in the Melbourne water supply area decreased from 444 GL in 2005–06 to 349 GL in 2009–10 (National Water Commission 2011a). This represents a saving of 83 GL of water mainly due to the restriction on water use. About 14 GL of water has been sourced from recycling each year since 2005–06.

Recycled water is supplied to consumers through various schemes by the three water authorities for a range of activities including irrigated agriculture, market gardens and the maintenance of conservation areas and golf courses. This represents about four per cent of the total water supplied by Melbourne Water to the three main utilities.

Below average rainfall in the region for more than a decade underpinned the decision to construct a desalination plant to secure water supplies for the Melbourne water supply area and Geelong. Melbourne Water is responsible for connecting the desalination plant pipeline at Berwick to their existing water supply network. The desalination plant is expected to be commissioned in June 2012 (Department of Sustainability and Environment 2011).

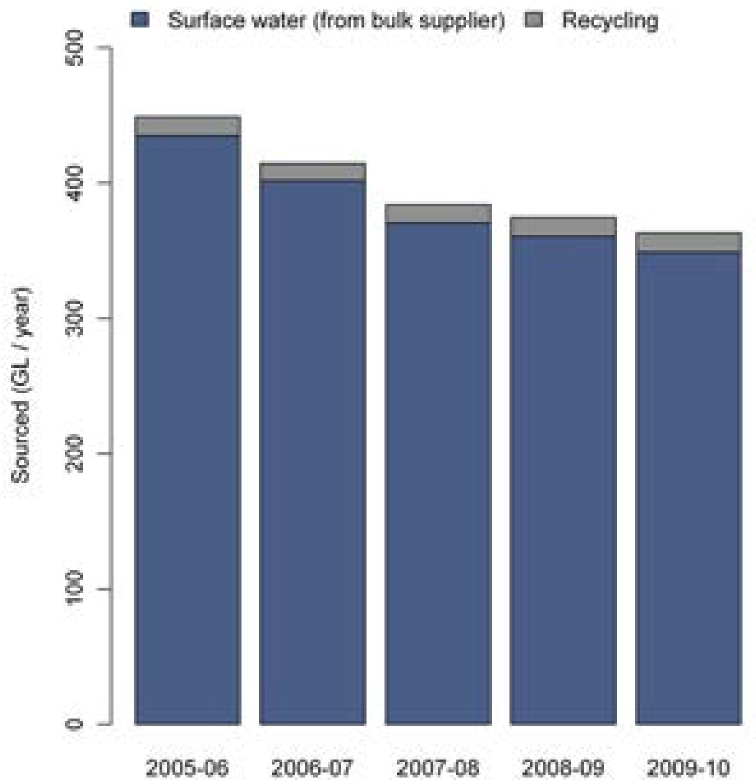


Figure 5-25. Total urban water sourced for the Melbourne water supply area from 2005–06 to 2009–10

5.6.2 Melbourne region (continued)

Figure 5-26 (National Water Commission 2011a) shows the total volume of water delivered to residential, commercial, municipal and industrial consumers by the three utilities from 2005–06 to 2009–10. About 60 per cent of the water was supplied for residential use and 27 per cent for commercial, municipal and industrial use.

Total water use dropped about 20 per cent from 2005–06 to 2009–10 due to water restrictions and resulted in a net saving of 83 GL. The use of water for commercial, municipal and industrial purposes was about 117 GL in 2005–06 and declined by 24 GL to 93 GL in 2009–10. Similarly, the water used for other purposes dropped from 47 GL to 37 GL between 2005–06 and 2009–10. The percentage reduction in these two water use categories over this period was 20 and 24 per cent respectively.

Based on population figures from National Performance Reports ((National Water Commission 2011a)) and total water supplied by the three main utilities, per capita water use, was estimated to be 331 litres/day/capita (L/d/c) in 2005–06 and 238 L/d/c in 2009–10. This represents a water saving of 93 L/d/c that can be attributed to water restrictions and increased public awareness of the need to conserve water.

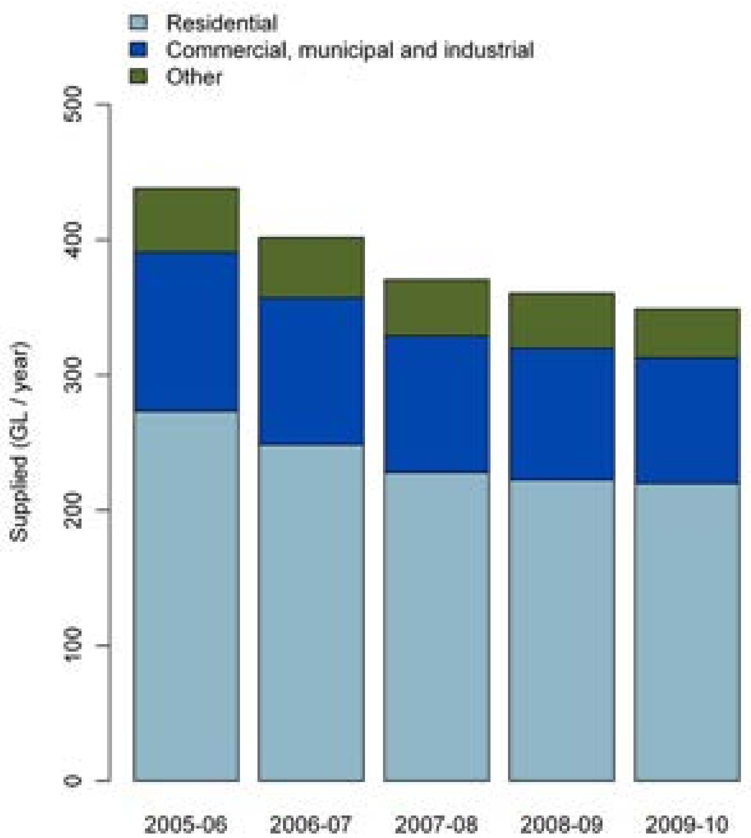


Figure 5-26. Total urban water supplied to the Melbourne water supply area from 2005–06 to 2009–10

5.7 Water for agriculture

More than half the land in the South East Coast (Victoria) region is used for grazing sheep and cattle. Dryland cropping is concentrated in the central and western parts of the region. Hardwood timber production is a major industry in the Snowy, East Gippsland and Barwon river basins. The region contains a green triangle of more than five million hectares with the largest area of plantations in Australia including pine (softwood).

The Macalister Irrigation District is the most significant irrigation area in the region, containing both irrigated pasture and horticulture, while the Werribee irrigation area is important for irrigated agricultural and dairy farming (Figure 5-28). Market gardens are now a dominant industry in both areas.

Management of surface and groundwater resources occurs through water management plans and licensing provisions under the Victorian *Water Act 1989.* Water is provided by two major water corporations in the region: Gippsland and Southern Rural Water and Goulburn–Murray Water ((Department of Sustainability and Environment 2011).

5.7.1 Soil moisture

Upper soil moisture content during summer (November–April) of 2009–10 was generally at an average level across most dryland agricultural areas as a result of average to slightly above average rainfall conditions. In parts of the eastern half of the region, conditions were very much below average. Some areas in the west of the region experienced above average soil moisture conditions (Figure 5-27).

During winter (May–October) 2010 upper soil moisture conditions generally increased across most dryland agricultural areas, particularly following much higher than normal rainfall in August. Average conditions became more prominent across the eastern half of the region, particularly in the areas to the southeast of Melbourne, which were largely below average during the summer period. Western areas were predominantly at an average or above average level. Soil moisture in some dryland agricultural areas in the central-west increased from above average in summer to very much above average in winter (Figure 5-27).

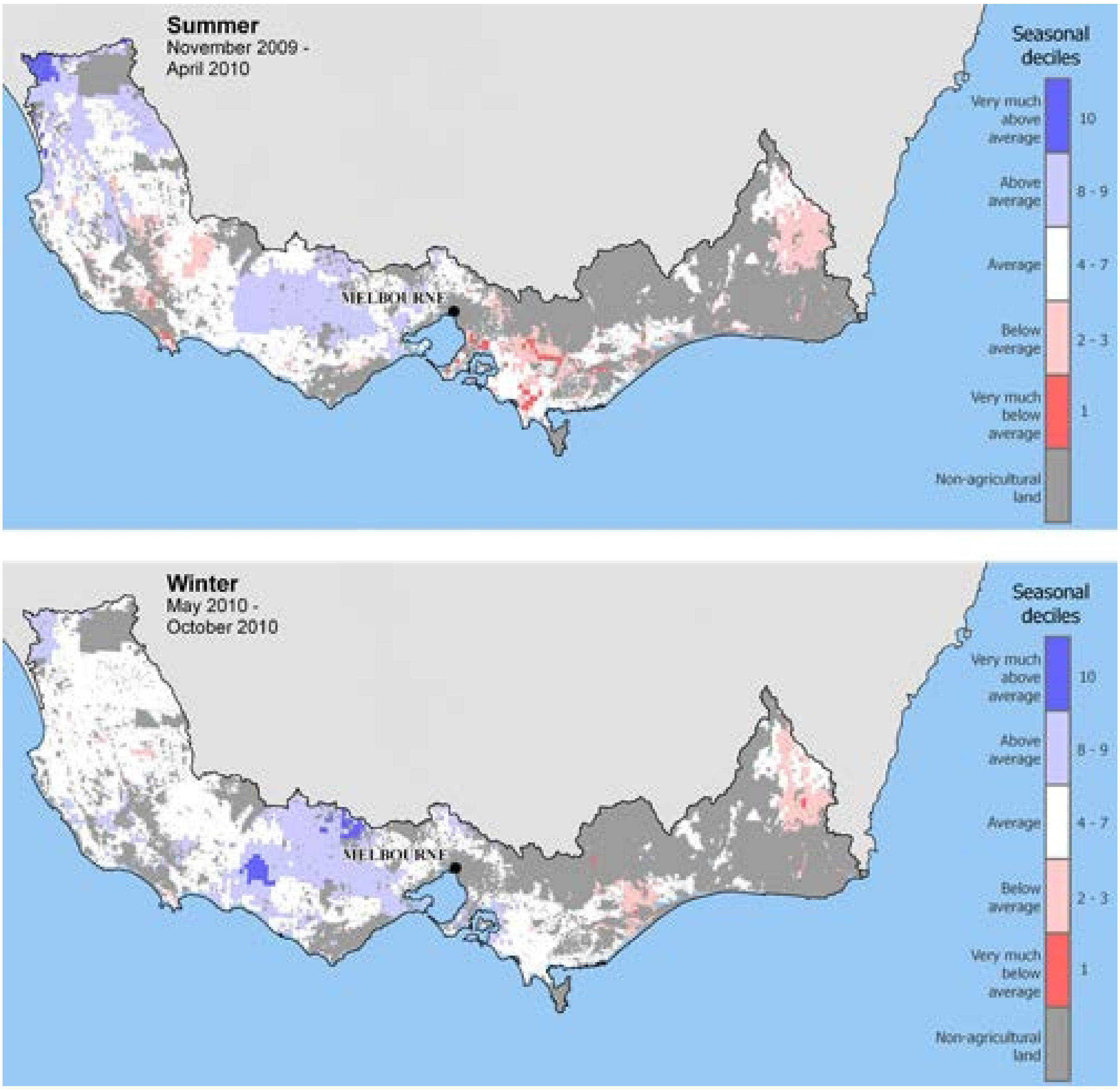


Figure 5-27. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the South East Coast (Victoria) region

5.7.2 Irrigation areas

Irrigated agriculture constitutes only a small portion (0.5 per cent) of the land use in the region. Major irrigation districts are concentrated around Lake Glenmaggie in the Thomson River basin and Bacchus Marsh and Werribee in the Werribee River basin (Figure 5-28).

Irrigation water use in the region between 2005–06 and 2009–10 is shown in Figure 5-29 and Figure 5-30 by natural resource management region. Data were sourced from the *Water Use on Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011). The south east (South Australia) and West Gippsland regions showed the highest irrigation water use during this period. The West Gippsland region includes the Macalister Irrigation District, a major irrigation area in the South East Coast (Victoria) region where irrigated pasture is used for dairying. Water resource availability for this irrigation area and water use in the irrigation area over recent years are examined in more detail in the following sections.

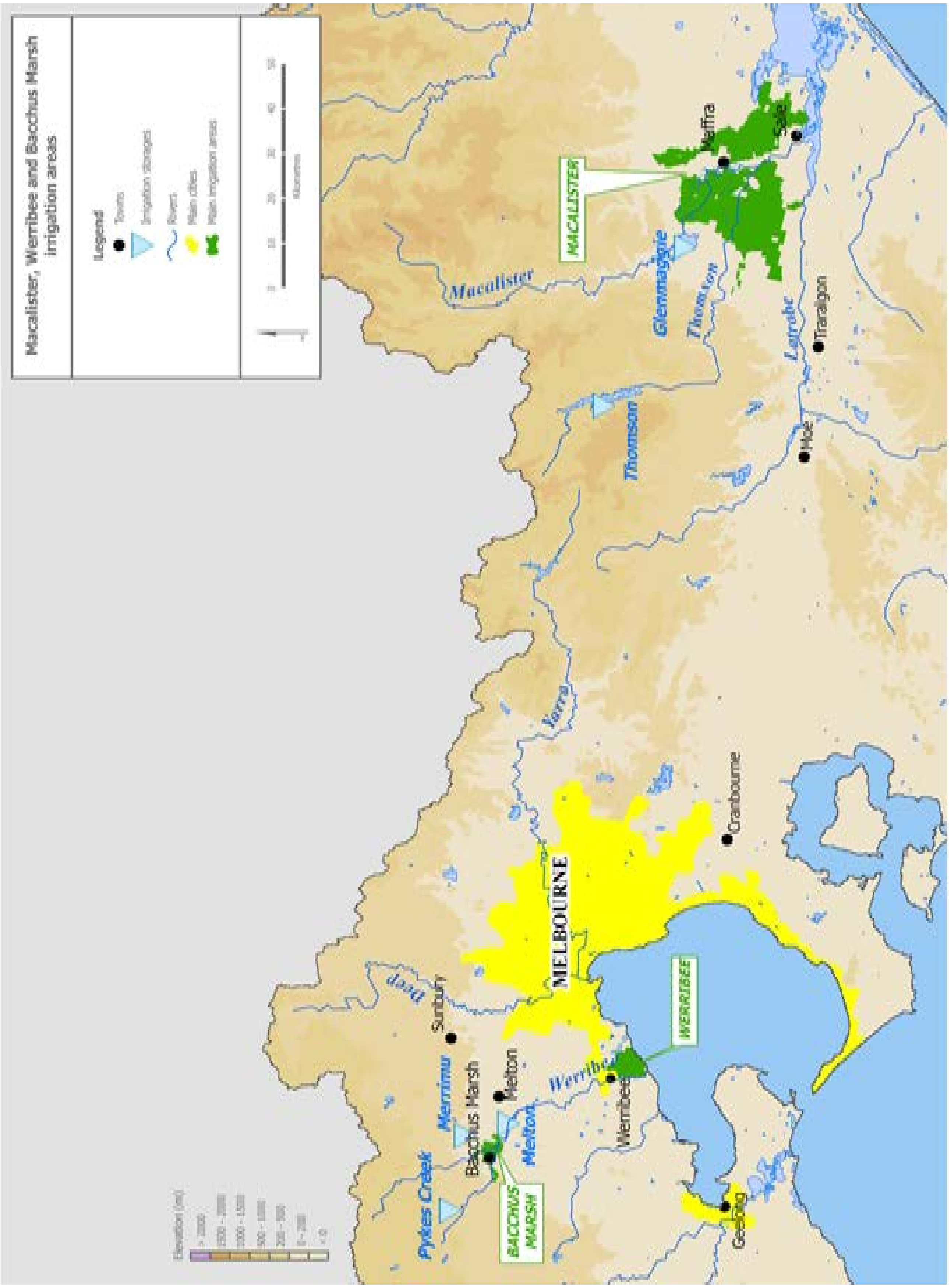


Figure 5-28. Context map of irrigation areas and infrastructure in the South East Coast (Victoria) region

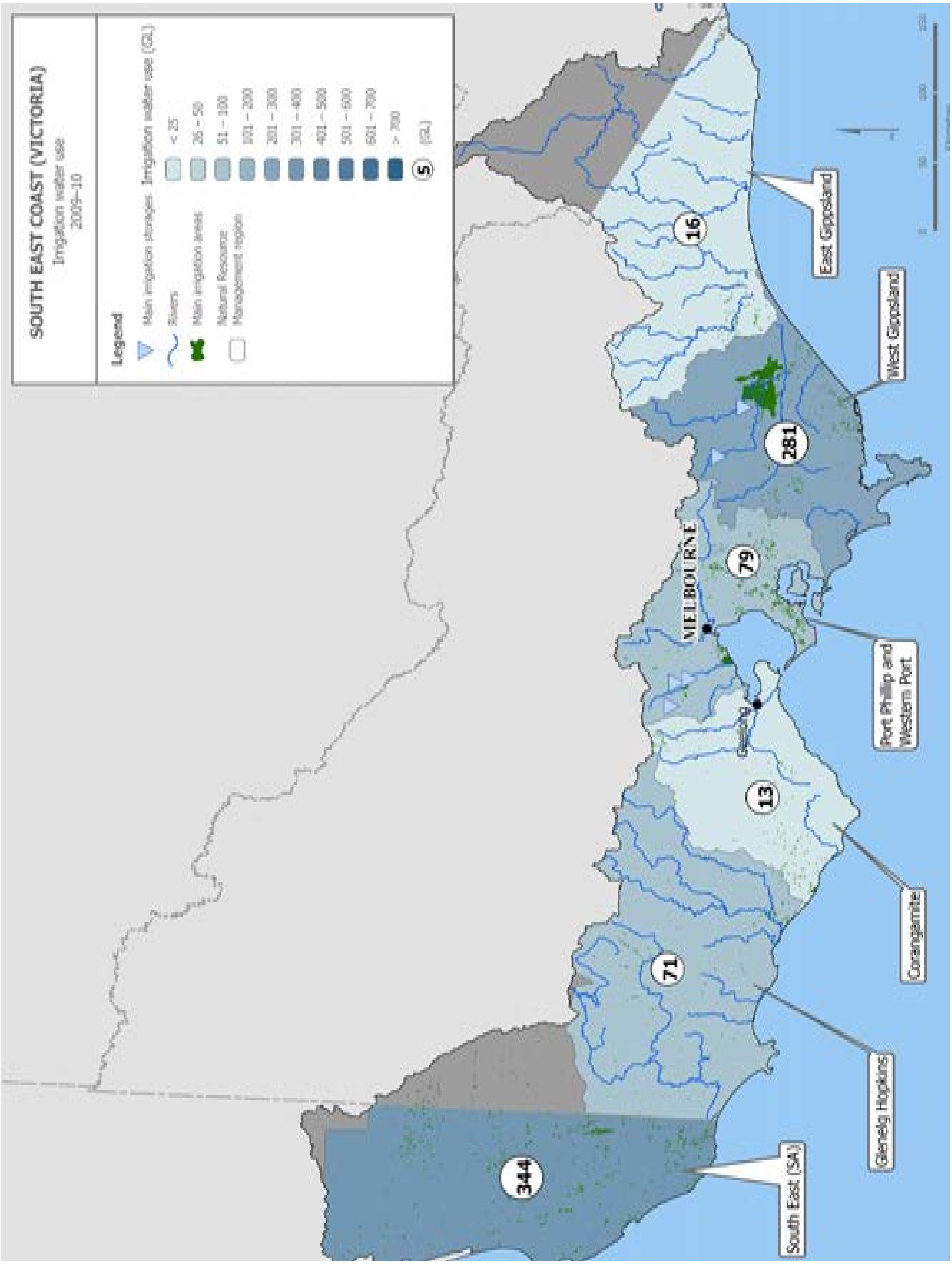


Figure 5-29. Annual irrigation water use per natural resource management region for 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

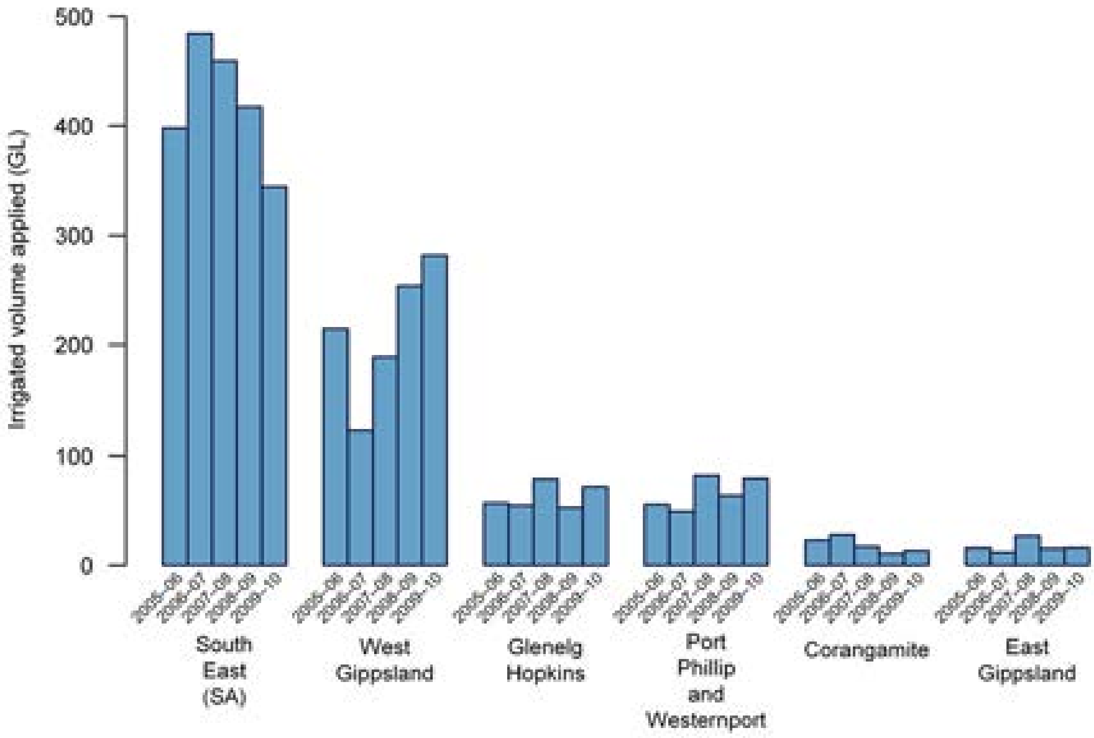


Figure 5-30. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the South East Coast (Victoria) region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

5.7.3 Macalister Irrigation District

The Macalister Irrigation District is the largest irrigation area south of the Great Dividing Range, extending from Lake Glenmaggie to near Sale along the Macalister River. The majority of the land used for irrigation is under pasture. The main business centre in the district is Maffra (Southern Rural Water 2011).

Lake Glenmaggie, situated on the Macalister River, covers an area of 1,760 ha and has an accessible storage capacity of 190 GL. It is the main source of supply for the Macalister Irrigation District. The lake usually fills up during winter and spring (Figure 5-31) and levels decline gradually during the summer months.

Thomson Reservoir, with an accessible storage capacity of 1,123 GL, also partially supplies the Macalister Irrigation District.

Historical data of stored water volume in Glenmaggie Lake show that storage levels reach approximately 100% during winter and spring in most years (Figure 5-31).

Streamflow in the Macalister River peaks during late winter and spring. The flow upstream of Lake Glenmaggie (registered at the river gauge on the Macalister River at Stringy Bark Creek) was around average in total for the winter filling period in 2009 (Figure 5-32). Streamflow over the following 2009–10 summer low flow period was generally above average.

Irrigation allocations from Lake Glenmaggie each year are a function of three phases related to the filling and emptying of the storage: a filling phase between July and September starts at the beginning of the irrigation season on 1 July; a spilling phase begins when the lake has filled (about October or November through to mid-December); and an emptying phase commences when the drawdown of lake levels begins. If the dam spills, all water used from the start of the season is referred to as Spill Entitlement (or off-quota) and allocation use is reset to zero. The maximum volume of Spill Entitlement is 62,000 ML/yr.

5.7.3 Macalister Irrigation District (continued)

During the emptying phase, a High Reliability Water Share and a Low Reliability Water Share are announced depending on the magnitude of the inflows to the storage.

The annual pattern of Water Allocations for the Macalister Irrigation District are shown in Figure 5-33.

Winter and spring inflows are generally sufficient to fill Lake Glenmaggie, and there is usually no need to carry over water from one irrigation season to the next. If Lake Glenmaggie is very low (as in recent drought years) a lower storage volume limit is set and a Maximum Efficiency Rule is applied. This means that water delivery is scheduled so as to conserve water and secure supplies during dry seasons.

There is some groundwater use in the Macalister Irrigation District. Reporting on groundwater levels and conditions is not possible in this report due to a lack of available data.

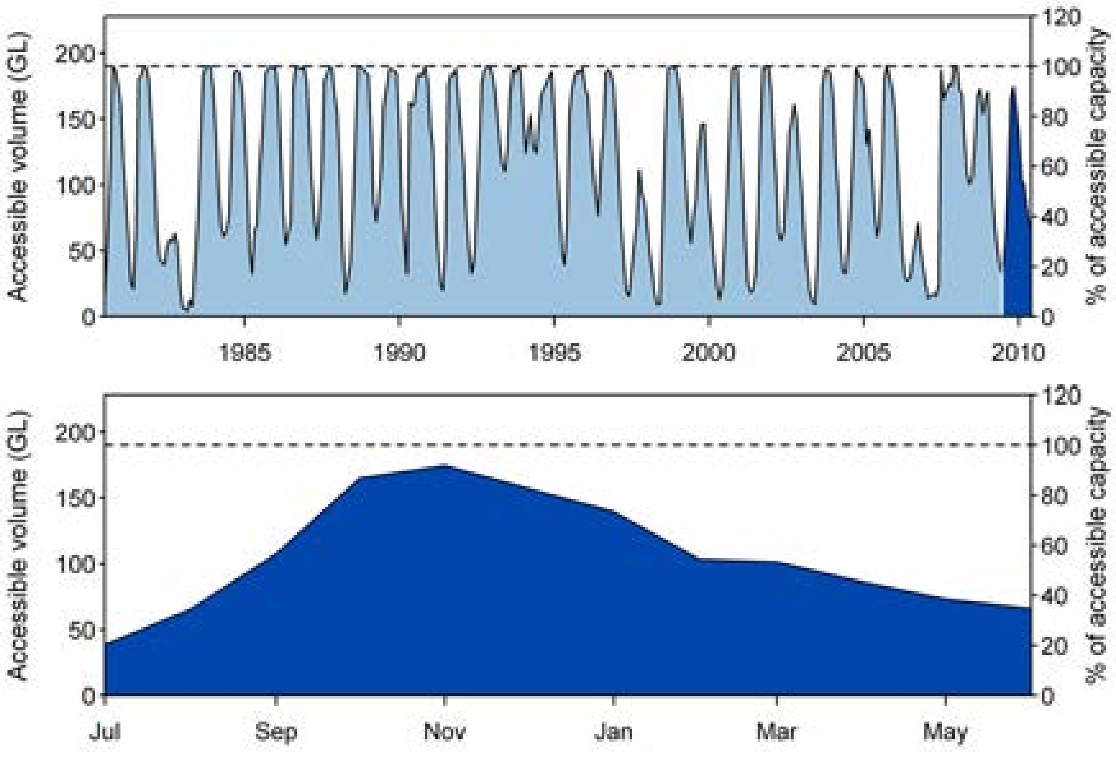


Figure 5-31. Water storage volumes available for irrigation at Lake Glenmaggie since 1980 (top) and during 2009–10 (bottom)

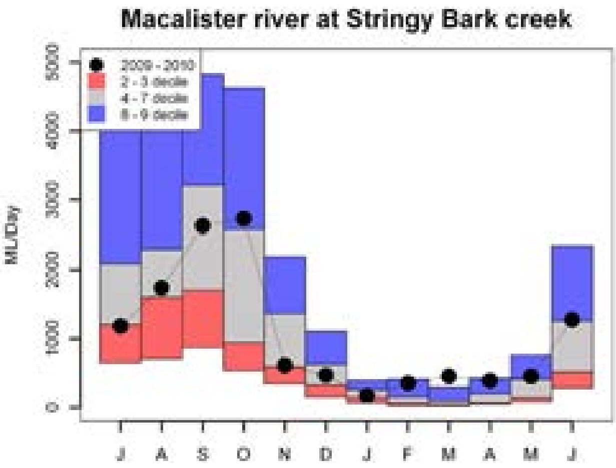


Figure 5-32. Monthly discharge hydrographs compared to discharge deciles at a reference gauge for inflows to Lake Glenmaggie

5.7.4 Werribee and Bacchus Marsh irrigation districts

The Werribee and Bacchus Marsh irrigation districts are long established and are located in the Werribee basin. The Werribee basin has a temperate climate receiving the majority of its rain in winter and spring.

The combined capacity of the Werribee system storages is approximately 69 GL (Melton Reservoir 14 GL, Pykes Creek Reservoir 22 GL and Merrimu Reservoir 33 GL). This capacity is allocated between irrigation (62 per cent) and urban (28 per cent) water use, with the remaining ten per cent retained as an unallocated share.

The Werribee system has some of the highest percentages of water trading in Victoria and trading occurs across the whole system between Werribee and Bacchus Marsh irrigators and river diverters. River entitlements have also been in place in the Werribee basin since 2001 as a further source of water.

The Bacchus Marsh Irrigation District is located on the floodplain of the Werribee River and is a highly developed agricultural district specialising in horticulture and market gardening. Most farms have on-farm dams to store water prior to irrigation, which provides flexibility to manage crop water demands.

The Bacchus Marsh Irrigation District receives its irrigation supply via a weir on the Werribee River east of Ballan as well as a second diversion weir located west of Bacchus Marsh on the Werribee River. The maximum capacity of the supply system is 105 ML/d at the Bacchus Marsh Weir, although during the recent drought it has rarely operated at flows higher than 70 ML/d.

The historic water use in Werribee and Bacchus Marsh irrigation districts is shown in Figure 5-34. Water use has declined steadily since the mid-1990s as water supplies in the Werribee system storage have fallen in response to below average rainfall over this period. Treated recycled water from Melbourne's Western Treatment Plant has been made available to the Werribee district irrigators since December 2004 (Figure 5-34). Melbourne Water supplies up to 65 ML/d of recycled water as a supplementary water source. Recycled water is mixed with river water to reduce salinity levels before it is supplied to irrigators. Heavy rainfall, turbidity-related issues caused by wind, and algal outbreaks affect reliability of river water for mixing with the recycled water.

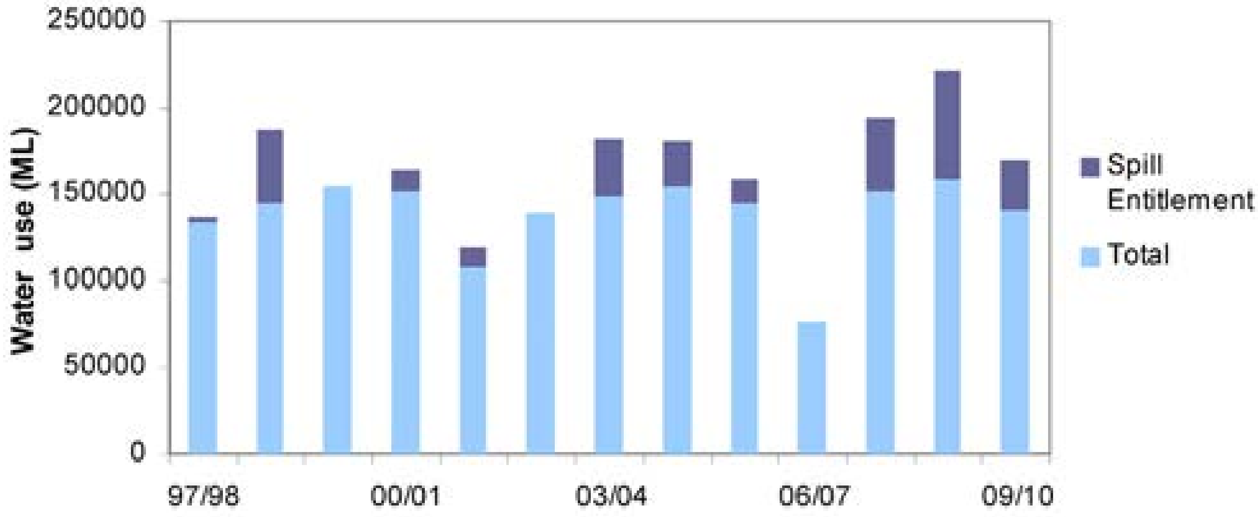


Figure 5-33. Water allocations in the Macalister Irrigation District from 1997–98 to 2009–10, including both high and low reliability water shares

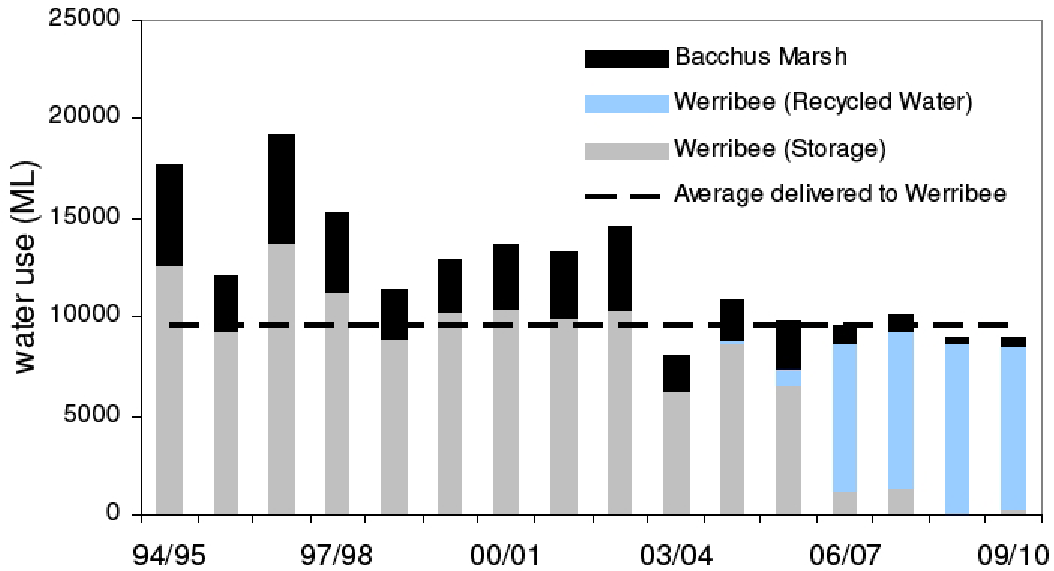


Figure 5-34. Annual water use in Werribee and Bacchus Marsh irrigation districts

6. Tasmania

6. Tasmania

6.1 Introduction

This chapter examines water resources in the Tasmania region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers, wetlands and aquifers. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

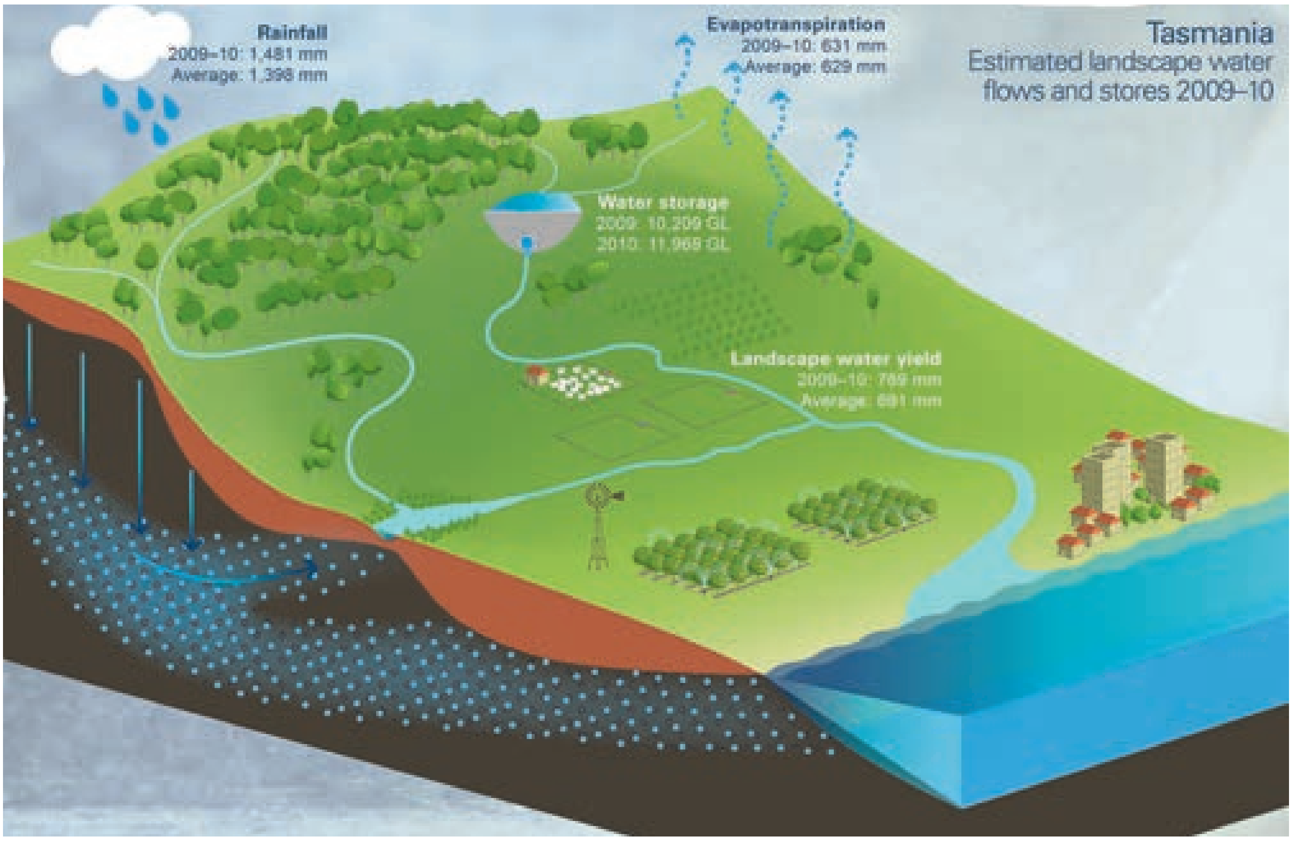


Figure 6-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the Tasmania region

6.2 Key data and information

Figure 6-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the Tasmania region. Higher than average rainfall combined with approximately average levels of evapotranspiration (see Table 6-1) resulted in above average landscape water yield[1] for the year. Soil moisture levels, on the other hand, decreased by six per cent due to local patterns in rainfall and evapotranspiration and soil storage capacities. Surface water storage volumes rose substantially, in line with the landscape water yield result.

Table 6-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

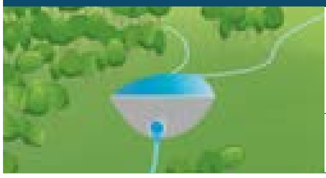
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 6-1. Key information on water flows, stores and use in the Tasmania region

Landscape water balance

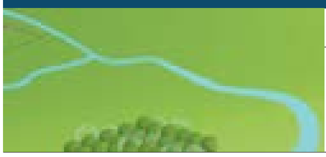
	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	1,481 mm	+6%	69	1,568 mm (2003–04)	1,077 mm (2006–07)
Evapotranspiration	631 mm	0%	53	661 mm (1985–86)	556 mm (1994–95)
Landscape water yield	769 mm	+11%	74	832 mm (2003–04)	432 mm (1987–88)

Surface water storage (comprising approximately 100% of the region's total surface water storage)



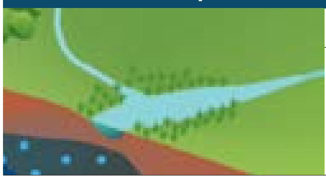
Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
22,141 GL	10,209 GL	46.1%	11,969 GL	54.1%	+8.0%

Measured streamflow in 2009–10



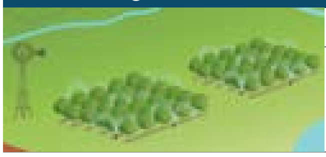
North western rivers	North eastern rivers	South eastern rivers
Above average	Above average to very much above average	Average to above average

Wetlands inflow patterns in 2009–10



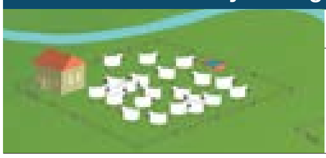
Lower Ringarooma Floodplain	Apsley Marshes estuarine
Above average in winter, average to below average in summer	Predominantly (very much) above average

Annual irrigation water use in 2009–10 for the natural resource management regions



North Tasmania	North West Tasmania	South Tasmania
139 GL	84 GL	59 GL

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Below average in the north and south, average and above average in the east	Generally average in the north and west, below average in the south

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

6.3 Description of region

The island of Tasmania is the smallest of Australia's states with a total land size of approximately 68,000 km^2. It is separated from the Australian mainland by Bass Strait. River basins on the island vary in size from 685 to 11,700 km^2.

The region has a cool temperate climate with average annual rainfall decreasing from the west to the east. Snowfall occurs in late winter and early spring.

Tasmania contains 12 per cent of Australia's freshwater resources. Approximately 150,000 km of waterways, 8,800 wetlands and 94,000 water bodies exist in the region (Department of Primary Industries, Parks, Water and Environment 2009).

Tasmania has more than 48 water storages with accessible capacities greater than 1.5 GL, totalling more than 22,141 GL. The largest is Lake Gordon in the Gordon River basin with an accessible storage capacity of 12,359 GL. Most of the storages are used for hydro-electricity schemes, including the Great Lake–South Esk, Derwent–Nive, Pieman–Anthony, Mersey–Forth, King–Lake Margaret, and Gordon–Pedder power systems (Australian Natural Resource Atlas 2009b).

The population of Tasmania is 500,000 with more than 200,000 residing in Greater Hobart (Australian Bureau of Statistics 2006). Greater Launceston has a population of just less than 100,000, while Devonport and Burnie are other notable centres, both with populations less than 25,000. The water supply to the Greater Hobart urban area is addressed in Section 6.6.

Tasmania is largely comprised of relatively fertile agricultural land, heavily forested environments and rugged pristine mountainous areas. The region contains ten of the 65 Australian Ramsar wetlands. Six of the Ramsar sites are located in the geologically and vegetatively diverse northern regions of Tasmania that include a wide variety of terrestrial, estuarine and marine ecosystems: from the vegetation and wildlife of the mountain plateaus to the wet forests and swamps of the middle elevations, the drier forests and woodlands of the lower-rainfall slopes and sandy coastal hills and plains. Fertile agriculture land is also present. In the west and southwest of the region, rugged mountains, extensive forests and uninhabited coastlines are found. The Tasmanian Wilderness World Heritage Area is located here.

Southern Tasmania is one of the most environmentally diverse areas in Australia. It features four Ramsar-listed wetlands, and three major river-and-estuarine systems in near pristine conditions with high conservation significance (Australian Government 2010).

Land use in the region is illustrated in the Figure 6-2. The majority of Tasmania is under nature conservation (50 per cent). This is followed by forestry (23 per cent) and pasture (21 per cent). Irrigated and dryland cropping and horticulture makes up only a small portion (1.2 per cent) of the land use.

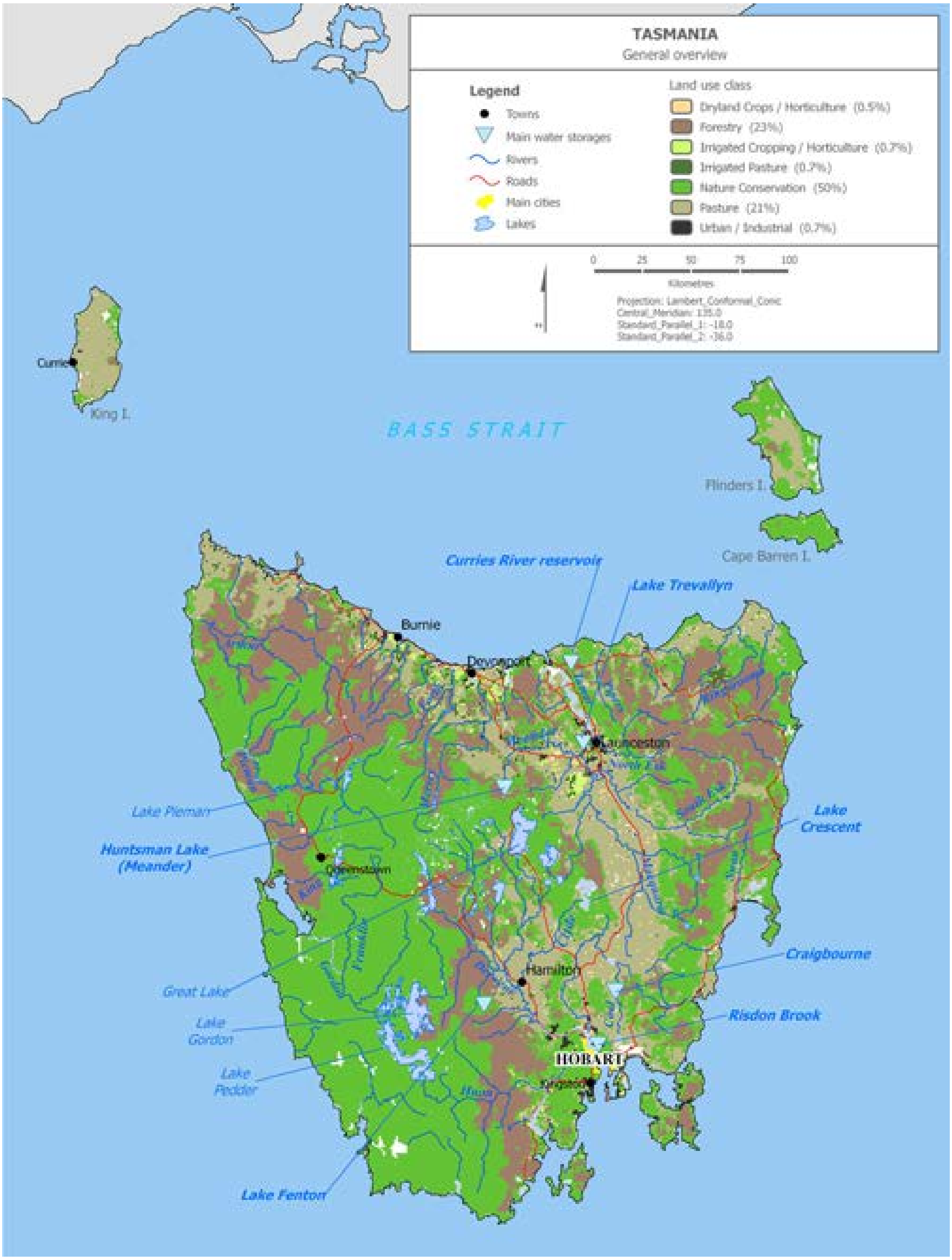


Figure 6-2. Key landscape and hydrological features of the Tasmania region (land use classes based on Bureau of Rural Sciences 2006)

6.3 Description of region (continued)

Tasmania has extensive groundwater resources located in igneous, sedimentary and metamorphic rocks, as well as unconsolidated sediments. The hydrogeology of the region is dominated by large areas of outcropping fractured basement rock. The groundwater systems in fractured rock typically offer restricted low to moderate volume groundwater resources. Groundwater quality and yield is highly variable, depending on the aquifer type, the topographic location and the rainfall. A more detailed description of the groundwater occurrence in the region is given in Section 6.5.

There are more than 8,000 bores in Tasmania supplying water for irrigation, town water, domestic use, stock watering, mining and other commercial purposes. Sustainable annual groundwater yield across the region is of the order of 500 to 2,530 GL. With less than five per cent of the estimated sustainable yield currently in use, Tasmania's groundwater resources are generally under-utilised. However, there are a number of local hotspots around the region where the density of bores and demand on groundwater is relatively high, and pressure on the resource (and connected surface water resources) is occurring. A regulatory framework for managing of groundwater in Tasmania is being developed as a result of the introduction of a water well drillers licensing system and a well works permit system by the Department of Primary Industries, Parks, Water and Environment in 2009.

The classification of watertable aquifers based on the geology within the region is presented in Figure 6-3, drawn from the Interim Groundwater Geodatabase developed by the Bureau. According to the hydrogeological systems within Tasmania, the aquifers can be broadly classified into these groups:

- surficial sediments aquifers, porous media–unconsolidated
- upper Tertiary aquifer, porous media–unconsolidated
- fractured and karstic rocks, local aquifers
- fractured rock aquifers.

Fractured rock aquifers underlie some 85 to 90 per cent of the land surface of the region. Many of these rocks have relatively low porosities and permeabilities and often offer restricted low volume groundwater. Porous sedimentary rock and karstic aquifers can provide high yields and, where they occur, tend to form highly useful supplies to farms, communities and, to a minor extent, industry. Porous unconsolidated aquifers (such as surficial sediments and upper Tertiary aquifers) are present in only in ten to 15 per cent of the region. They provide useful water supplies for farms and small communities (Department of Infrastructure, Energy and Resources 2001).

Figure 6-4 shows the salinity of the watertable aquifer as fresh (below 3,000 mg/L) and saline (above 3,000 mg/L). Data on groundwater salinity is not available for most parts of Tasmania; however, where data do exist, the watertable is mainly fresh.

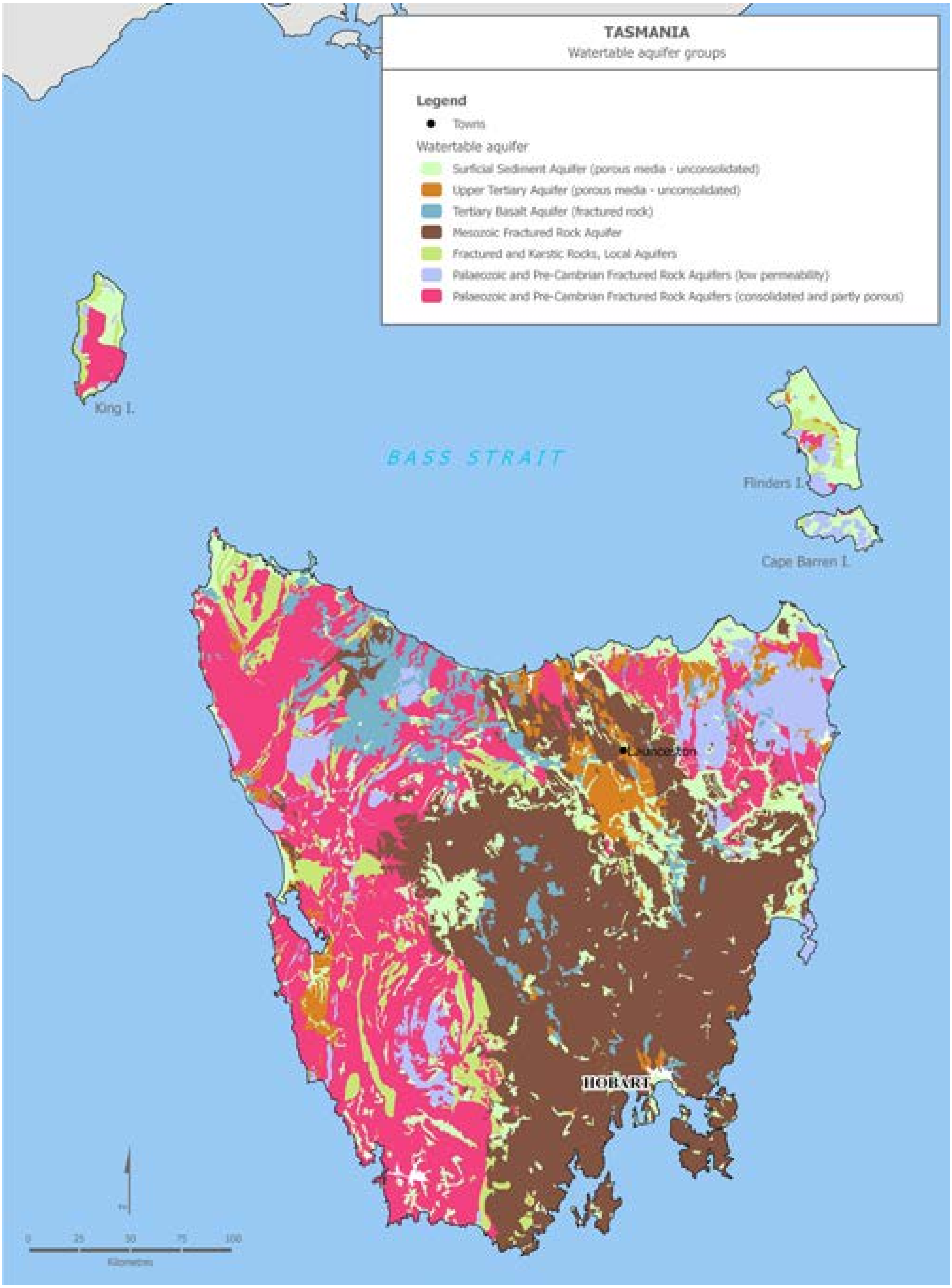


Figure 6-3. Watertable aquifer groups in the Tasmania region (Bureau of Meteorology 2011e)

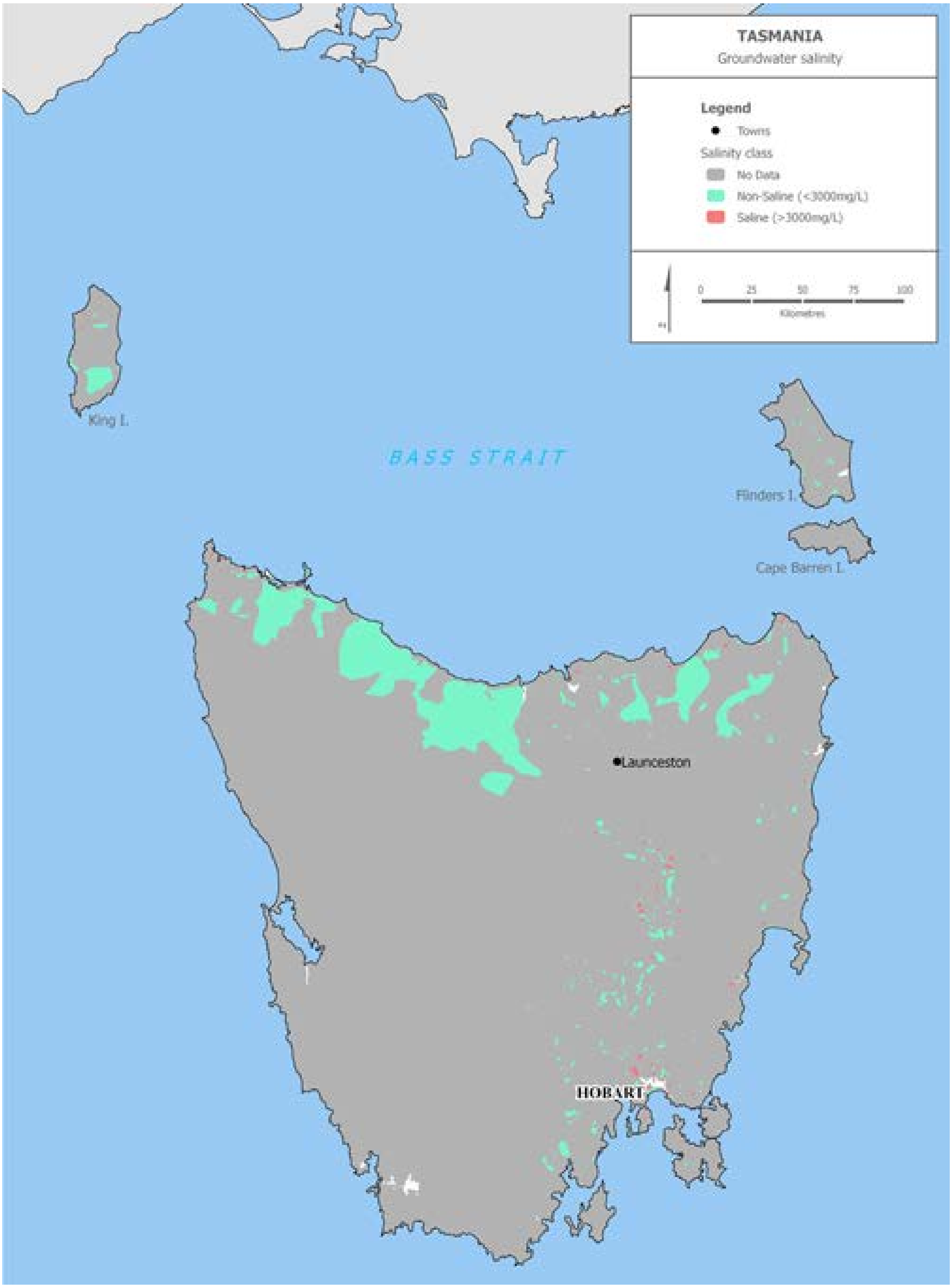


Figure 6-4. Watertable salinity classes within the Tasmania region (Bureau of Meteorology 2011e)

6.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 6-5 shows that the Tasmania region experienced very wet conditions between July 2009 and September 2009 (late winter and early spring). Rainfall for August 2009 was the third highest August total in the long-term (July 1911 to June 2010) record. This period of high rainfall was followed by consecutive months of relatively low rainfall between October 2009 and January 2010. January rainfall was particularly low and was the fifth lowest January rainfall in the long-term record. Rainfall for the last four months of the year was generally around average.

The high levels of rainfall in Tasmania mean that evapotranspiration is largely constrained by energy availability. Therefore, regional evapotranspiration exhibits limited monthly variability with a consistent peak during the summer period when evaporative losses may exceed rainfall inputs.

The general monthly pattern of modelled landscape water yield for the region is closely linked to rainfall, with winter rainfall events generating a significant response at the beginning of the year. Consistently high monthly rainfall resulted in parts of Tasmania being affected by repeated flooding between May and September 2009 (Bureau of Meteorology 2010a). Low monthly landscape water yield was experienced during the drier summer months and persisted through to the end of the year.

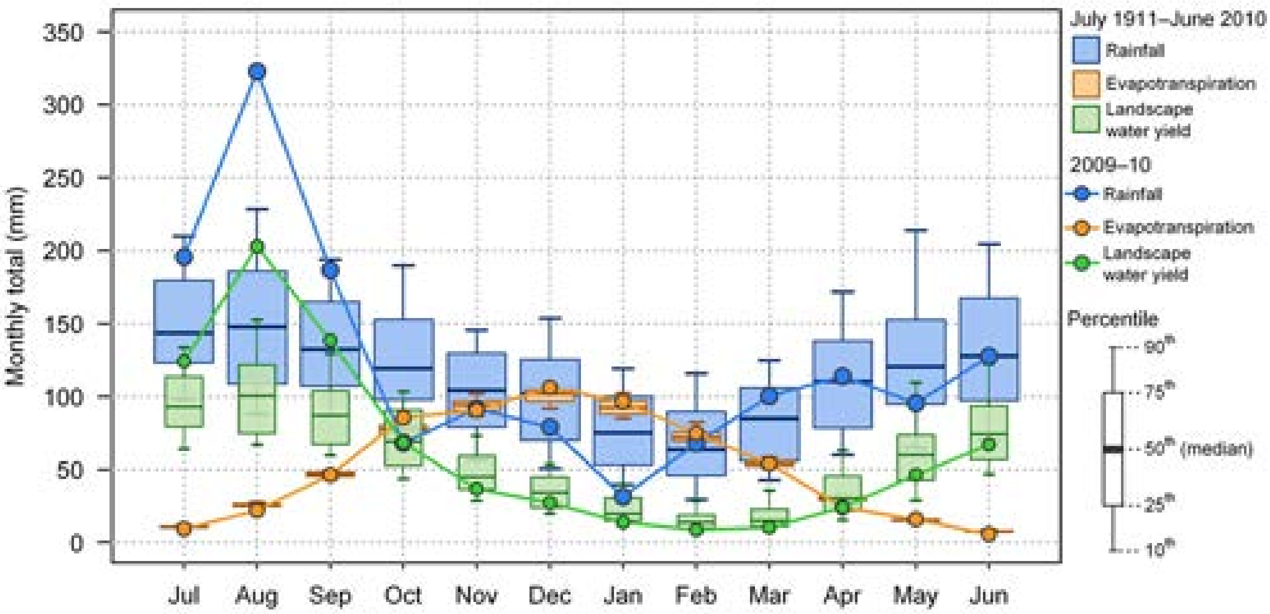


Figure 6-5. Monthly landscape water flows for the Tasmania region in 2009–10 compared with the long-term record (July 1911 to June 2010)

3. The Tasmania region includes small areas that are excluded from the landscape water balance modelling due to absent parameter data (classified as ‘No data’). Typically these represent areas of inland water. More details are presented in the Technical supplement

6.4.1 Rainfall

Rainfall for the Tasmania region[3] for 2009–10 was estimated to be 1,481 mm, which is six per cent above the region's long-term (July 1911 to June 2010) average of 1,398 mm. Figure 6-6 (a) shows rainfall during 2009–10 was highest in the upland areas to the west of the region, declining to generally much lower rainfall totals in the centre and east, excluding the northeast which recorded large rainfall totals resulting in above average rainfall for the area. Tasmania is located in the path of the 'Roaring Forties' winds which are consistent with weather systems predominantly passing across the region in a west to east direction. The higher altitude areas on the west coast of Tasmania experience the highest rainfall, while Hobart and the east coast are in the rain shadow.

Rainfall deciles for 2009–10, shown in Figure 6-6 (b), indicate that the north of the region generally experienced a wetter than average year with very much above average rainfall in the northeast. Most of the south of the region experienced average rainfall conditions, with below average annual rainfall in some areas.

Figure 6-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 1,077 mm (2006–07) to 1,568 mm (2003–04). The annual average for the period was 1,334 mm. The above average annual rainfall of 2009–10 follows three below average years between 2006–07 and 2008–09.

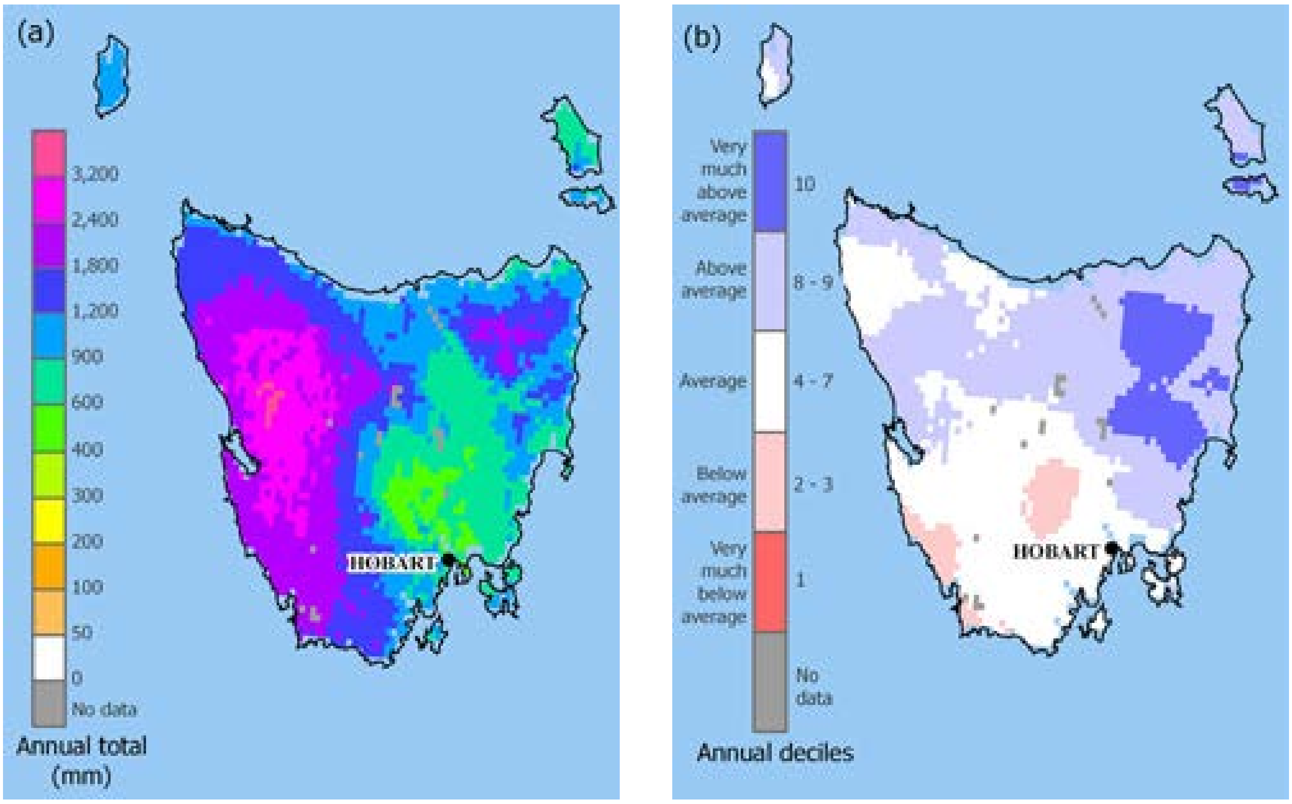


Figure 6-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tasmania region

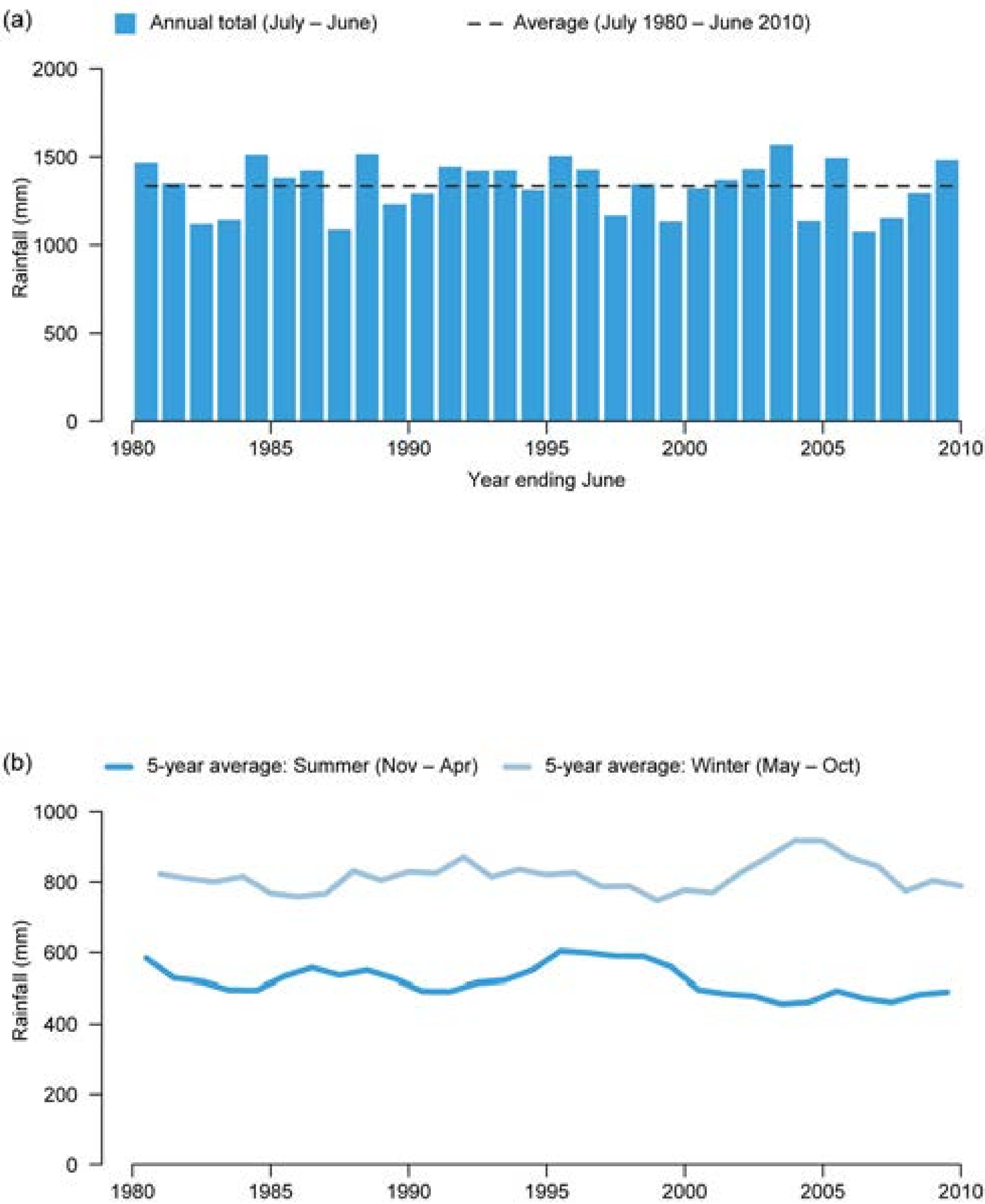


Figure 6-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Tasmania region

6.4.1 Rainfall (continued)

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) is presented using moving averages in Figure 6-7 (b). The graph illustrates the seasonal pattern of rainfall in Tasmania, with wetter winters and lower summer rainfall.

Figure 6-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

This analysis indicates that over the past 30 years there are contrasting patterns of change in rainfall for summer and winter periods, particularly in the west of the region. Summer rainfall shows decreasing trends across most of Tasmania, with the strongest negative trends across the higher rainfall areas on the western side of the region. The magnitudes of reductions in rainfall identified along the far south-western coastal areas are relatively high compared to the average summer rainfall in these areas. The equivalent winter analysis shows positive trends across much of the west of Tasmania, but also indicates decreasing trends in rainfall along the southwest coastal zone.

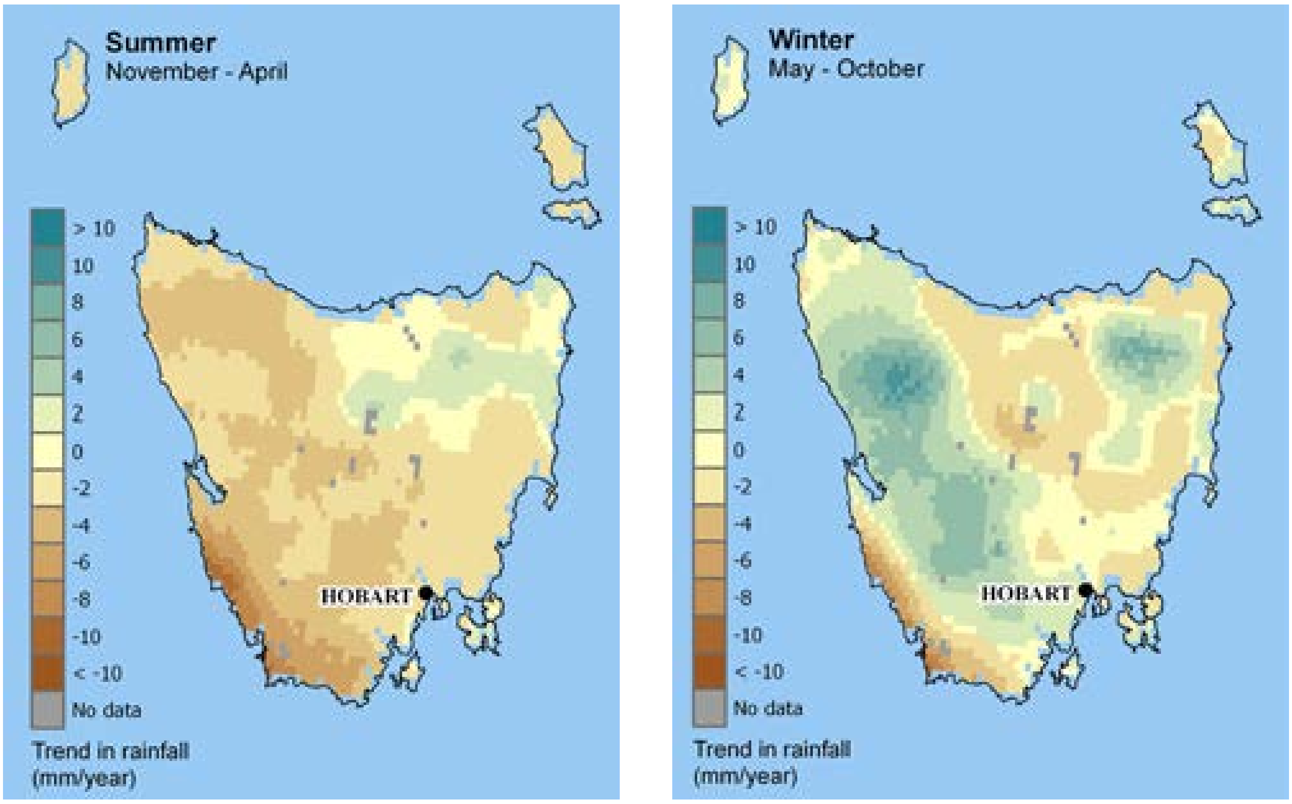


Figure 6-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Tasmania region. The statistical significance of these trends is often very low

6.4.2 Evapotranspiration

Evapotranspiration for Tasmania for 2009–10 was estimated to be 631 mm, which is approximately equal to the region's long-term (July 1911 to June 2010) average of 629 mm. Figure 6-9 (a) indicates that evapotranspiration for 2009–10 was relatively evenly distributed across Tasmania. This suggests that evapotranspiration across the region is largely limited by energy availability rather than water availability.

Evapotranspiration deciles for 2009–10, shown in Figure 6-9 (b), indicate evapotranspiration was below average across much of the western half of Tasmania and above average levels were experienced across the eastern side of the region.

Figure 6-10 (a) shows evapotranspiration over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 556 mm (1994–95) to 661 mm (1985–86). The annual average for the period was 615 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 6-10 (b). Across the region, evapotranspiration for the summer period is consistently much higher than for the winter period, reflecting the distinct seasonal nature of rainfall and energy availability in Tasmania. Both seasonal averages and the annual totals show that there was very limited interannual variability in regional evapotranspiration for Tasmania over the past 30 years.

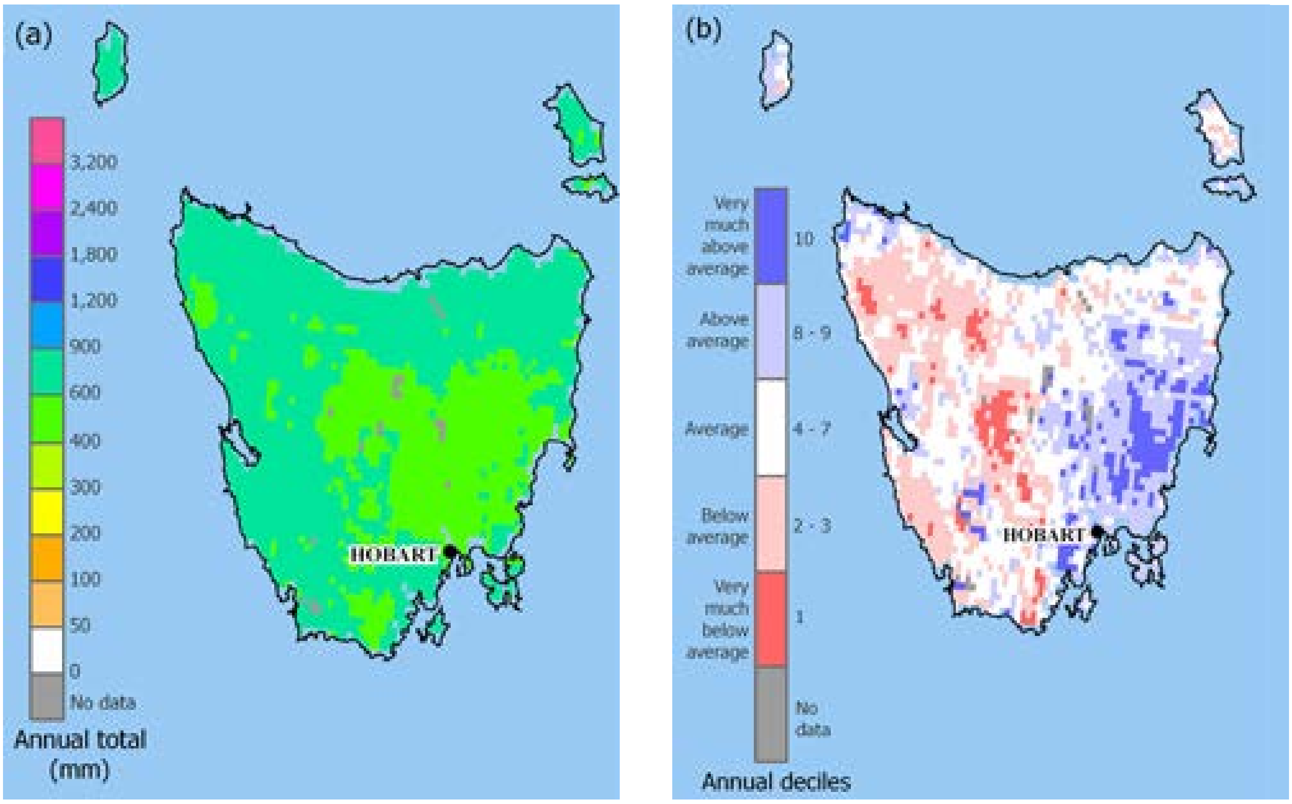
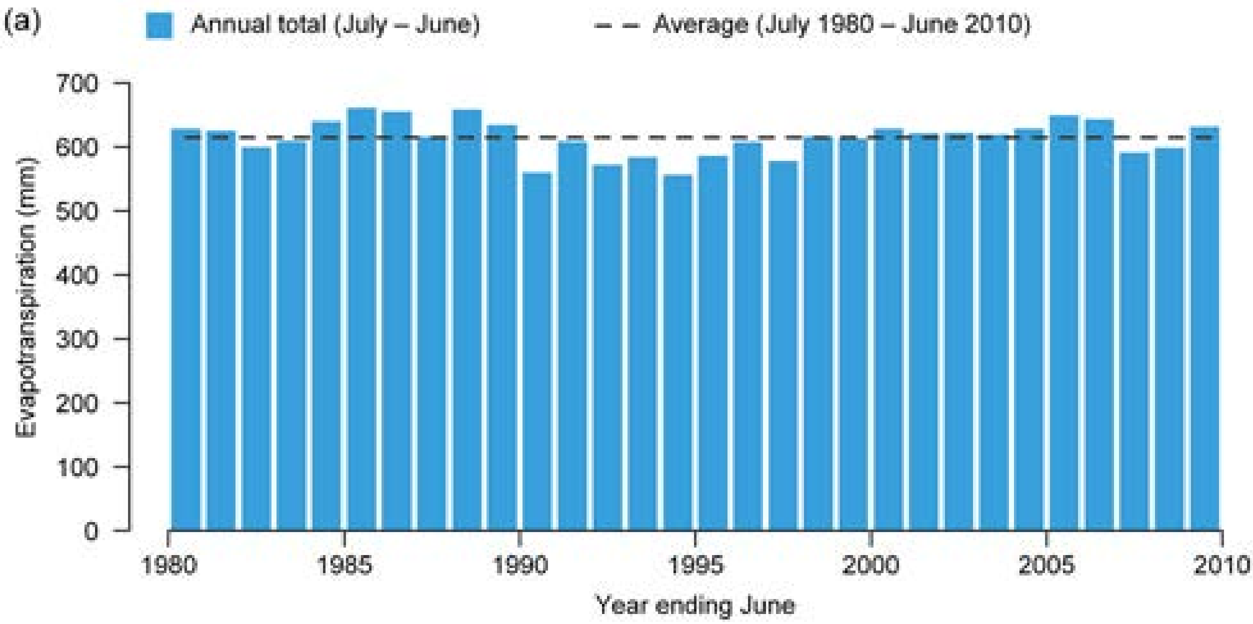


Figure 6-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tasmania region



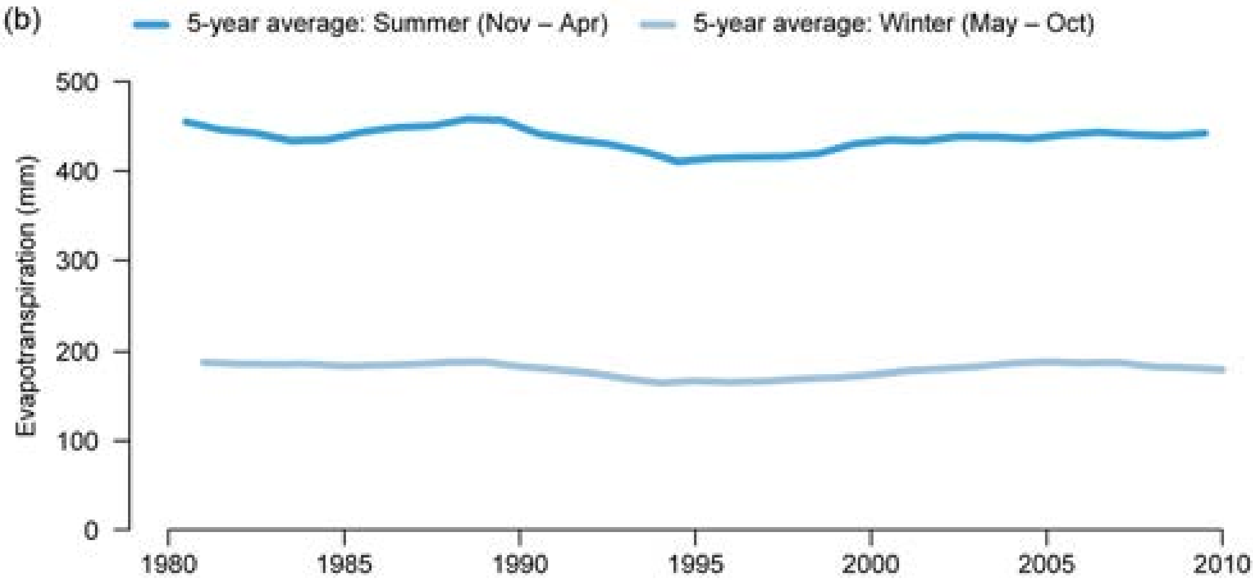


Figure 6-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Tasmania region

6.4.2 Evapotranspiration (continued)

Figure 6-11 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

Summer period evapotranspiration shows a generally mixed pattern of trends observed across the region over the 30-year period, with slight negative trends observed in areas across the centre, east and far southwest of Tasmania. Winter period evapotranspiration shows a more consistent spatial pattern with no clearly defined changes or very slight decreases for almost the entire region.

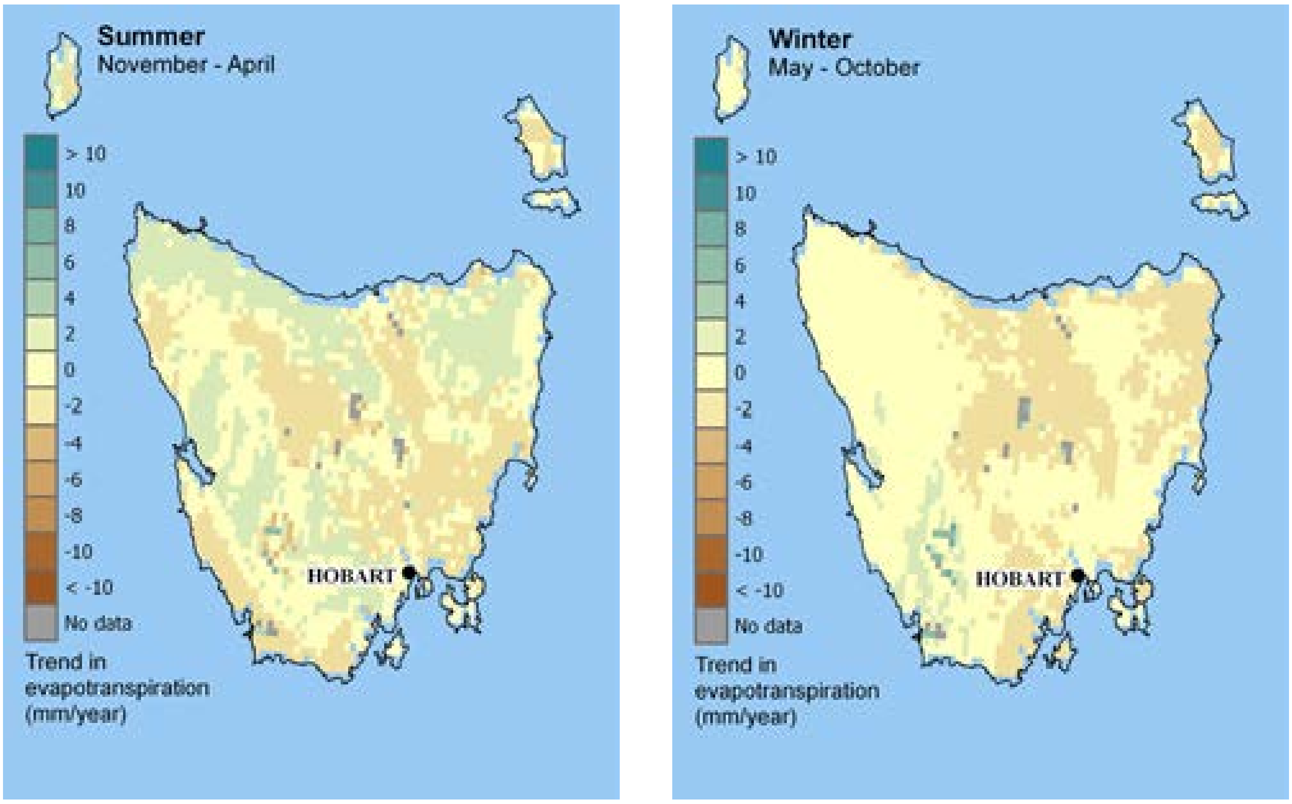


Figure 6-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Tasmania region. The statistical significance of these trends is often very low

6.4.3 Landscape water yield

Landscape water yield total for the Tasmania region for 2009–10 was 769 mm, which is 11 per cent above the region's long-term (July 1911 to June 2010) average of 691 mm. Figure 6-12 (a) shows that landscape water yield for 2009–10 was highest across the high rainfall, upland areas on the western side of Tasmania and very much lower across the lower lying areas of the centre and east of the region.

Landscape water yield deciles for 2009–10, shown in Figure 6-12 (b), indicate areas of above average and very much above average yield across the east and north of the region. Average conditions were experienced across much of the southwest of Tasmania with limited areas of below average yield.

Figure 6-13 (a) shows landscape water yield over the past 30 years (July 1980 to June 2010). Over the 30-year period, landscape water yield ranged from 432 mm (1987–88) to 832 mm (2003–04). The annual average for the period was 651 mm. As with rainfall, the above average total landscape water yield for 2009–10 follows three below average years between 2006–07 and 2008–09. The data clearly show the relatively high level of interannual variability in regional landscape water yield.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 6-13 (b). Landscape water yield in winter is consistently very much higher than in summer, reflecting regional response to seasonal patterns of rainfall and evapotranspiration in the region. Landscape water yield for winter period appears to exhibit the greater level of interannual variability compared to the summer period.

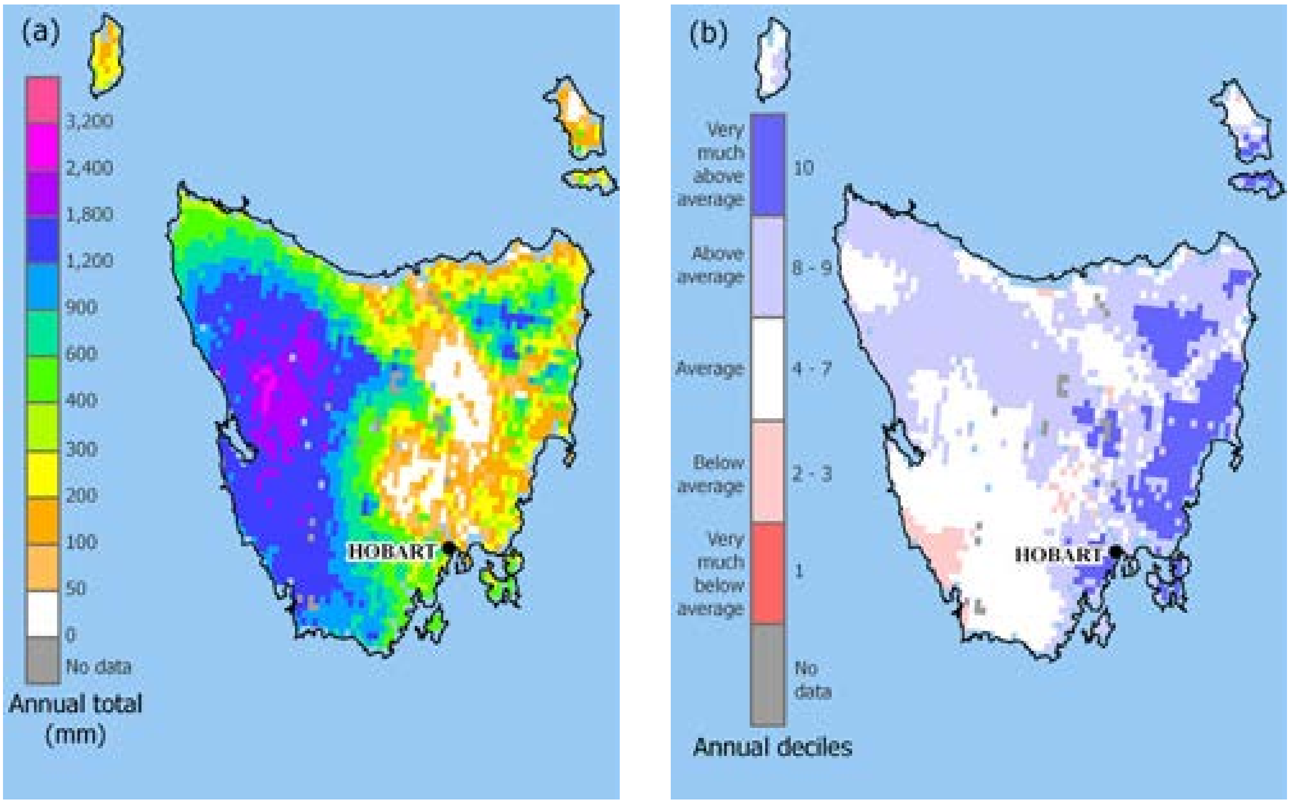


Figure 6-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tasmania region

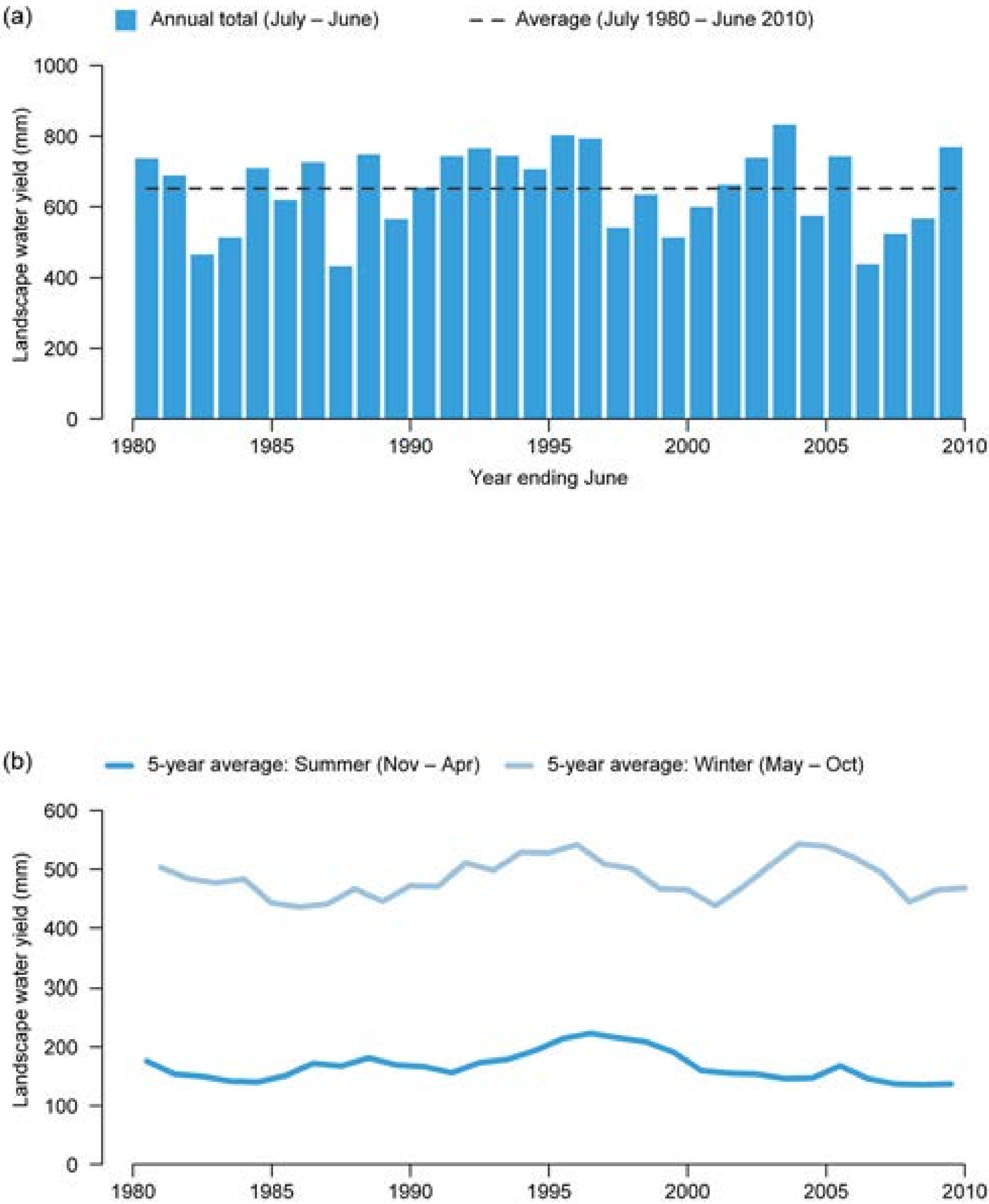


Figure 6-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Tasmania region

6.4.3 Landscape water yield (continued)

Figure 6-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period analysis shows decreases in landscape water yield across much of the western side of the region. The magnitudes of these negative trends, particularly in the coastal areas to the far southwest, are high relative to the area's average summer landscape water yield. The strong positive trends identified in discrete areas in the southwest and centre of the region are caused by issues with the effective representation of large open water bodies within the landscape model.

The winter period analysis shows increases in the west and northeast of the region, in contrast to decreasing trends in landscape water yield in the far southwest and northwest. The spatial pattern of trends in summer and winter landscape water yield is closely related to those observed for the seasonal rainfall trend analysis (see Figure 6-8).

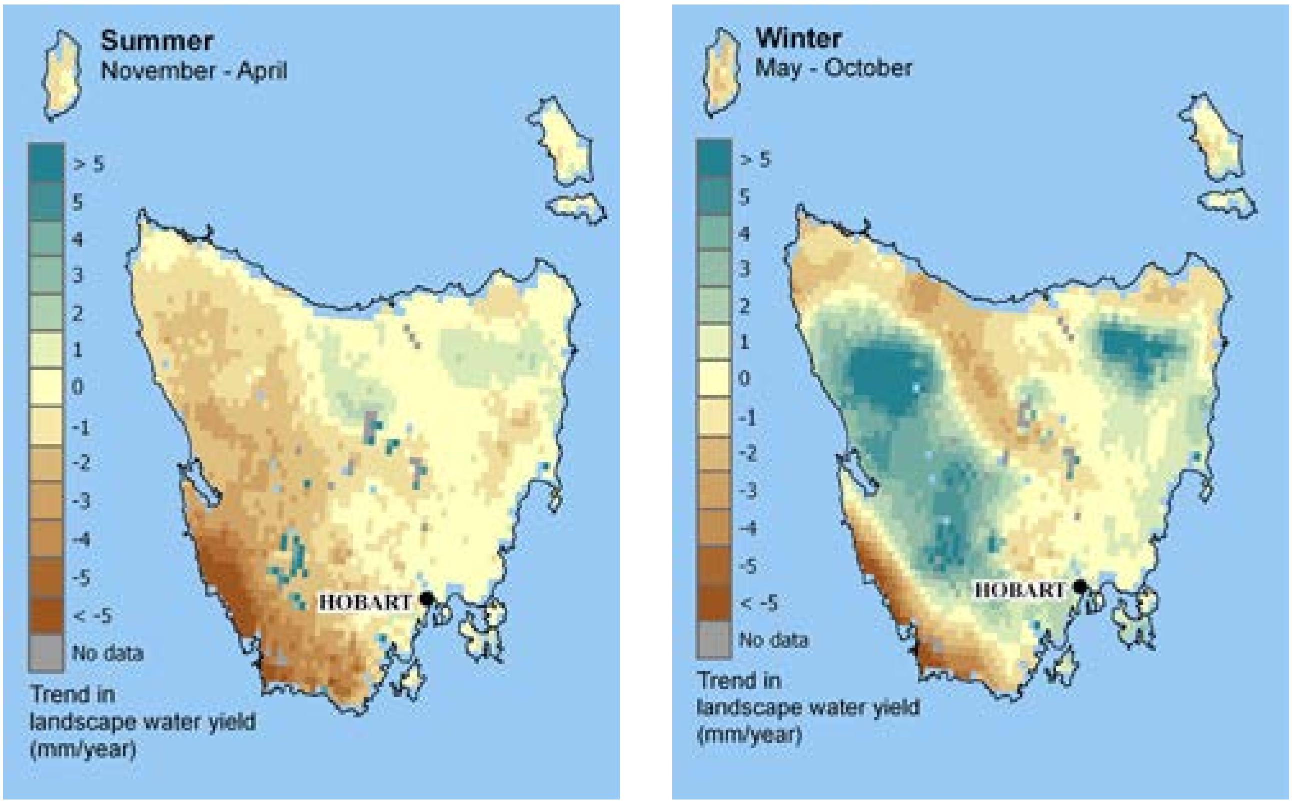


Figure 6-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Tasmania region. The statistical significance of these trends is often very low

6.5 Rivers, wetlands and groundwater

The 25 reliable stream gauges with relatively long records across 11 river basins were considered for examination of regional streamflow in this report (see Figure 6-15). Streamflow at these gauges in 2009–10 was analysed in relation to long term averages of annual and monthly flow.

The groundwater management units within the region are presented in Figure 6-16. Many of these are relatively small in area and are located near the coast with a few exceptions, most notably the Longford, Legerwood, Winnaleah and Ringarooma units.

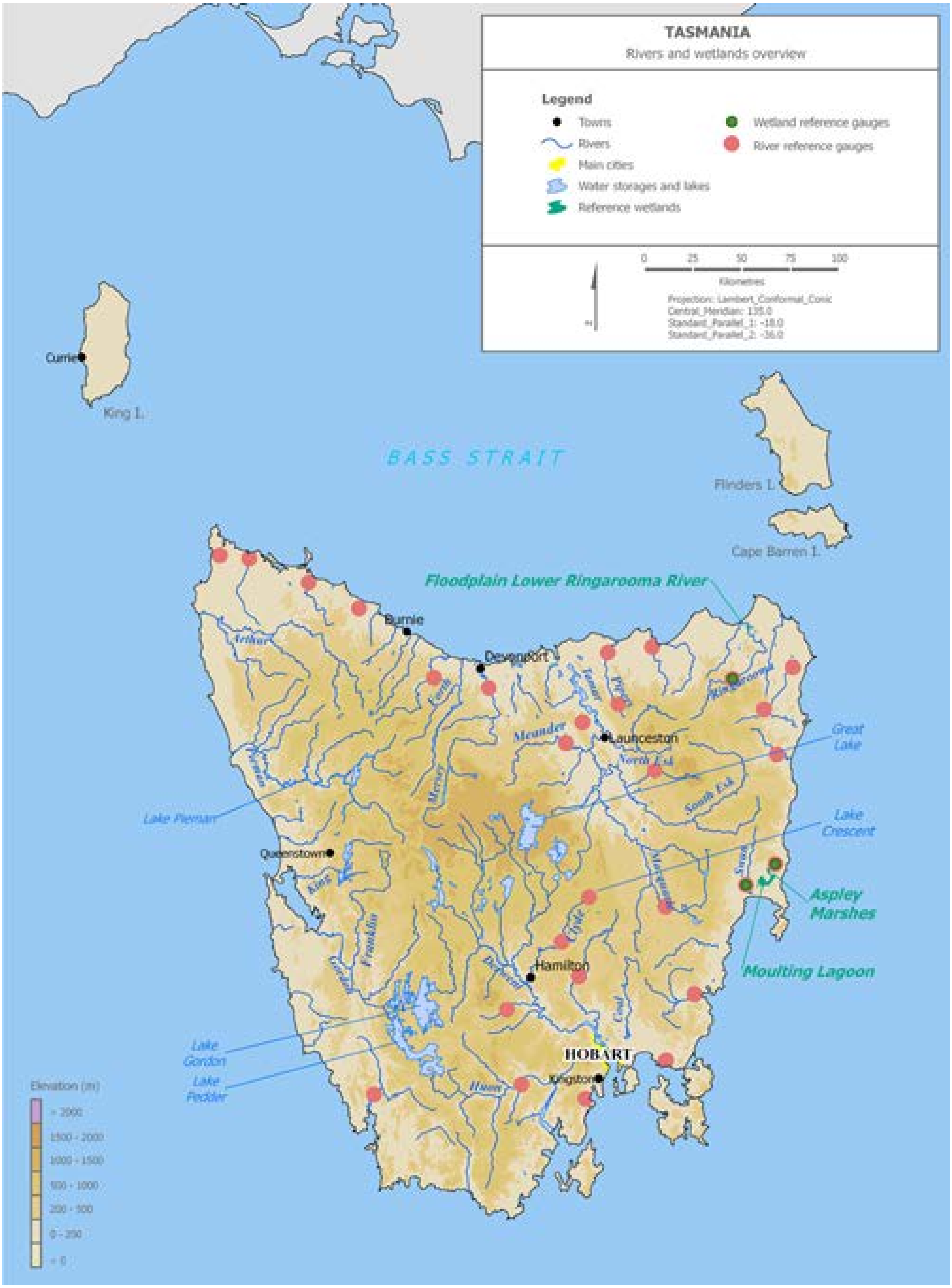


Figure 6-15. Stream gauges selected for analysis in the Tasmania region

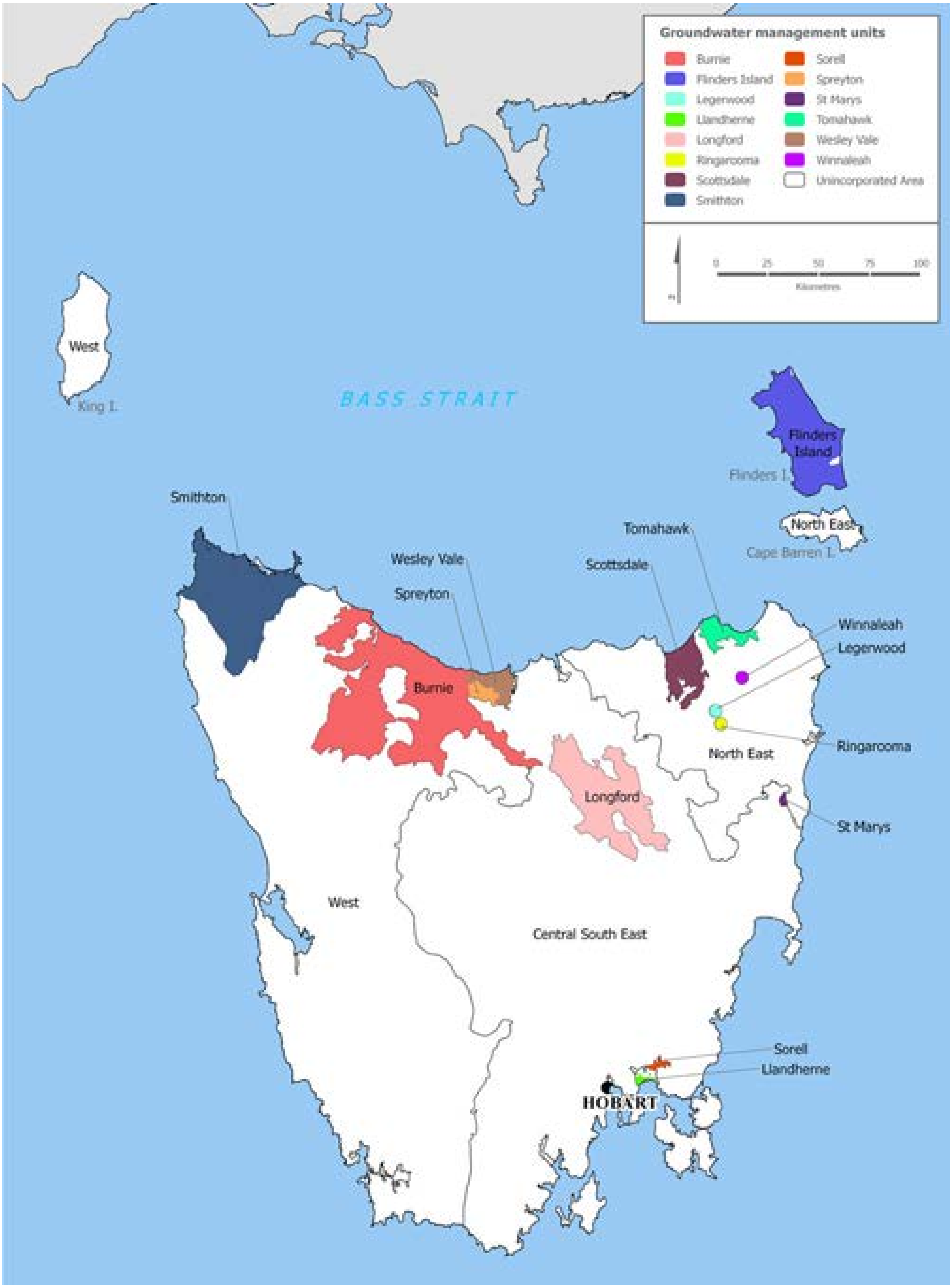


Figure 6-16. Major groundwater management units in the Tasmania region (Bureau of Meteorology 2011e)

6.5.1 Streamflow and flood report

Figure 6-17 presents an analysis of river flows over 2009–10 relative to the last 30 years at 24 monitoring sites throughout Tasmania. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for 2009–10 are colour-coded relative to the decile rank over the 1980 to 2010 period at each site.

With regard to total annual discharge for 2009–10, Figure 6-17 shows that observations from streamflow monitoring gauges along the north coast of Tasmania and in the Tamar River basin clearly reflect the generally above average modelled landscape water yield results for headwater run-off generating areas in the northwest of Tasmania (Figure 6-12 [b]). In general there is good agreement between analysis of flow in Figure 6-17 and modelled landscape water yield in Figure 6-12.

Broadly, Figure 6-17 shows:

- higher streamflow values are usually generated in the headwaters of rivers and their tributaries where rainfall totals were higher
- the slightly contrasting patterns in the Clyde River downstream of Lake Crescent (centre of the map, gauge values 19 and 182) were a consequence of restrictions on flow releases from the lake for ecological benefits (Tasmanian Government Communications Unit 2008)
- suitable monitoring sites were not available at this stage for the majority of the Tasmania west coast.

The flood report is not included in this chapter. At the time of writing, suitable information was not available. In future reports, this aspect will be dealt with more thoroughly as information becomes more accessible.

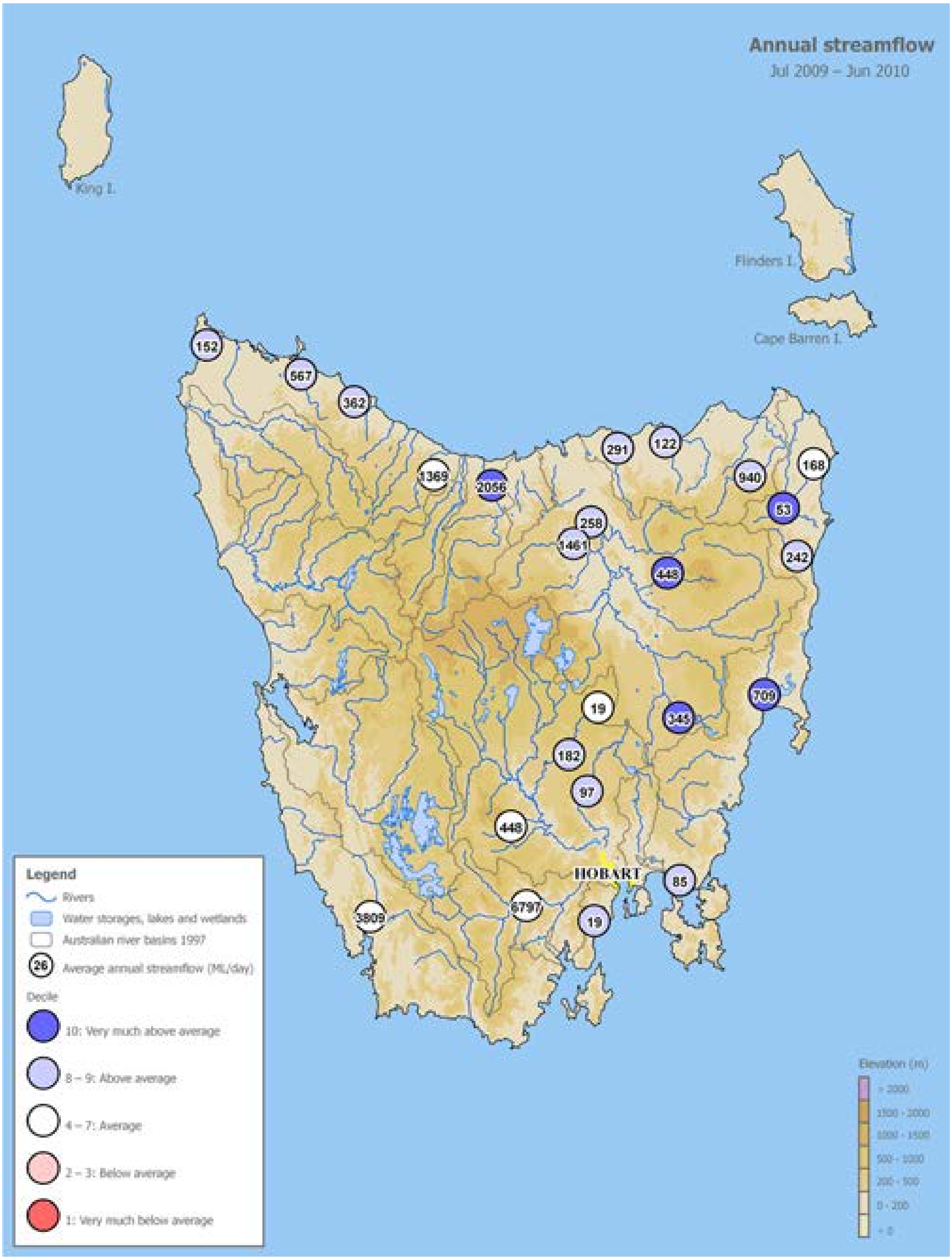


Figure 6-17 Annual streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the Tasmania region

6.5.2 Inflows to wetlands

This section looks at water flows into regionally important wetlands. Two of the ten internationally recognised Ramsar wetland sites, the Lower Ringarooma Floodplain freshwater wetland and the Apsley Marshes estuarine wetland, were selected for examination.

Three reference gauges were chosen to illustrate patterns of river inflows to the selected wetlands (Figure 6-15). Figure 6-18 presents a comparison of 2009–10 monthly flows with monthly flows over the 30-year period 1980 to 2010 for each of these gauges.

While river discharge observations at the three gauges do not represent the total volume of freshwater water inflow to the wetlands under study, the reference gauge discharges are assumed to be representative of the variation of the pattern of actual freshwater inflows to the wetlands.

With this in mind, the following two points may be observed with respect to freshwater supply to these wetlands in 2009–10 relative to the 30-year record:

1. For the north eastern coastal Ringarooma Floodplain (gauge 1), peak spring inflows (August to September 2009) were extremely high (above the 90th percentile). Early summer (November to January 2009) inflows were below average, while inflows from February to June 2010 were above average.
2. For the mid-east coast Apsley Marshes (gauges 2 and 3), the same extremely high peak spring (August to September 2009) inflow pattern (above the 90th percentile) can be seen, particularly for the Swan River at The Grange. This was followed by above average inflows from October to December 2009 and average inflows from January to June 2010 for both these monitoring gauges.

Figure 6-19 shows the range of inflows to the two selected wetlands over the 30 years from 1980 to 2010. A five-year moving window was applied over daily streamflow data to produce the 10th, 50th and 90th flow percentiles for each of the three reference gauges. Unfortunately a large gap in the data exists for the Apsley River (gauge 2).

The 10th, 50th and 90th flow percentiles were selected to approximate patterns of low, median and high flows, respectively. Low flows are associated with a base level environmental inflow needed to ensure a minimum level of ecological function during dry periods of the year. Median flows sustain wetland hydrology and ecological function throughout most of the year. High flows are associated with the lateral movement of water into floodplains, and are necessary to sustain a high level of wetland function.

Note that any variability in the flow percentiles of Figure 6-19 can be a result of changing climatic conditions as well as human interference. However, the purpose of the graphs is not to analyse the cause of the variability.

With respect to this 30-year period, the plots show:

- no notable patterns or trend in the median or high flows on the Ringarooma River (gauge 1) over the past 30 years. A slight decrease in low flows may be evident, particularly after 1995
- a sustained period of declining low, median and high flows in the Apsley River (gauge 2) after 2000, although the past two years tended towards increasing high and median flows
- a more notable trend of decreases in median and low flow volumes in the Swan River (gauge 3) over the past 20 years.

6.5.3 Groundwater status

Groundwater status for the Tasmania region is not addressed in this report. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available.

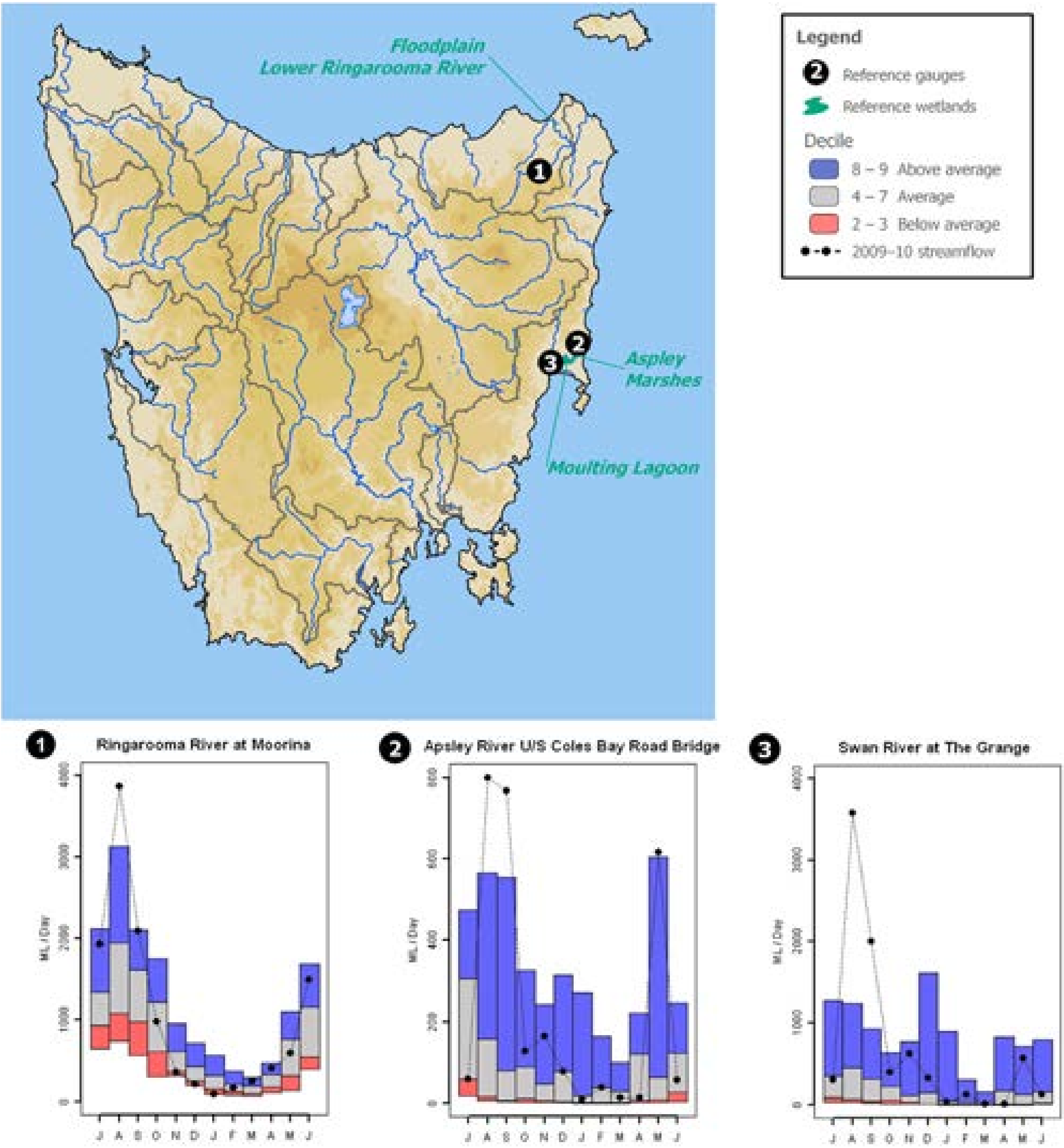


Figure 6-18. Monthly discharge hydrographs for 2009–10 compared with the period of 1980 to 2010 for reference gauges on major rivers flowing into selected wetland sites of the Tasmania region

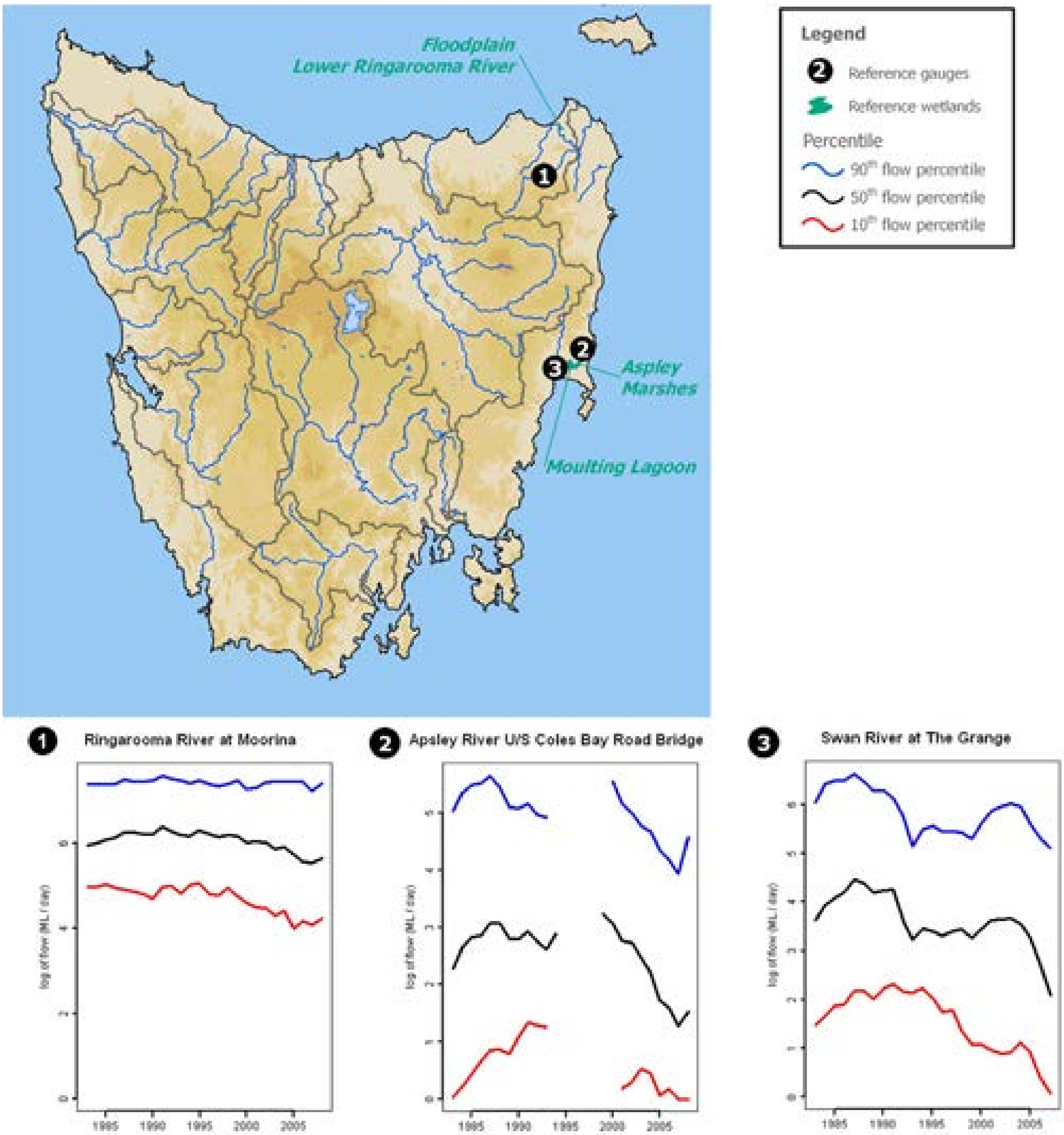


Figure 6-19. Daily flow percentiles extracted from a five-year moving window at reference gauges on rivers flowing into selected wetland sites of the Tasmania region

6.6 Water for cities and towns

6.6.1 Regional overview

The main urban centres (with more than 25,000 people) in Tasmania are Hobart and Launceston. Hobart, the State capital and the largest city, is located in the State's southeast on the estuary of the Derwent River. It is considered the second oldest capital city in Australia after Sydney. The population in Tasmania is mostly concentrated in the Greater Hobart area.

Launceston is the second largest city, situated in the north of the State at the juncture of the North Esk, South Esk, and Tamar rivers. Devonport, situated at the mouth of the Mersey River, and Burnie, a slightly smaller city, are the major regional centres of the north-western part of the State.

On mainland Tasmania, hydro-electricity is generated by 27 hydro-power stations and their associated water resources and infrastructure within the South Esk–Great Lake, Mersey–Forth, Derwent, Pieman–Anthony, King and Gordon river catchments (Hydro Tasmania 2010). Although there are significant water resources to provide water supplies to cities and towns in Tasmania, there are geographic, seasonal and infrastructure factors that can have an impact on the supply of water to where it is needed. Figure 6-20 shows the location of river basins and associated storages providing water supplies to the urban centres of Hobart and Launceston.

Table 6-2 shows the populations of Hobart and Launceston, the river basins in which they are located and the major water supply sources for each city.

Prior to the reform of Tasmania's water and sewerage industry (from 1 July 2009), there were three regional corporations owned by local councils that provided bulk water services: Cradle Coast Water in north-western Tasmania, Esk Water in the northeast, and Hobart Water in southern Tasmania. Hobart Water supplied Hobart and the surrounding areas; Esk Water supplied Launceston and the towns on both sides of the Tamar River out to Georgetown; Cradle Coast Water supplied Devonport, Burnie and the surrounding coastal towns. The reforms involved the amalgamation of bulk water authorities and the water and sewage operations of 29 local councils, resulting in the creation of Southern Water, Ben Lomond Water and Cradle Mountain Water (Southern Water 2009).

Hobart and Launceston are the main urban centres and Hobart is discussed in greater detail in the following sections. The water supply area for Hobart is taken as that served by Hobart Water as the bulk water authority from 1997 to June 2009.

Table 6-2. Cities and their water supply sources in the Tasmania region

City/town	Population*	River basin	Major supply sources
Greater Hobart	212,000	Derwent River, Kingston Coast	Derwent River, Mt Wellington streams, Lake Fenton
Greater Launceston	105,000	South Esk River, North Esk River, Tamar River	North Esk River, St Patricks River, Curries River Reservoir
Devonport	25,500	Forth River, Mersey River	Forth River, Lake Paloona

* Australian Bureau of Statistics (2010b)

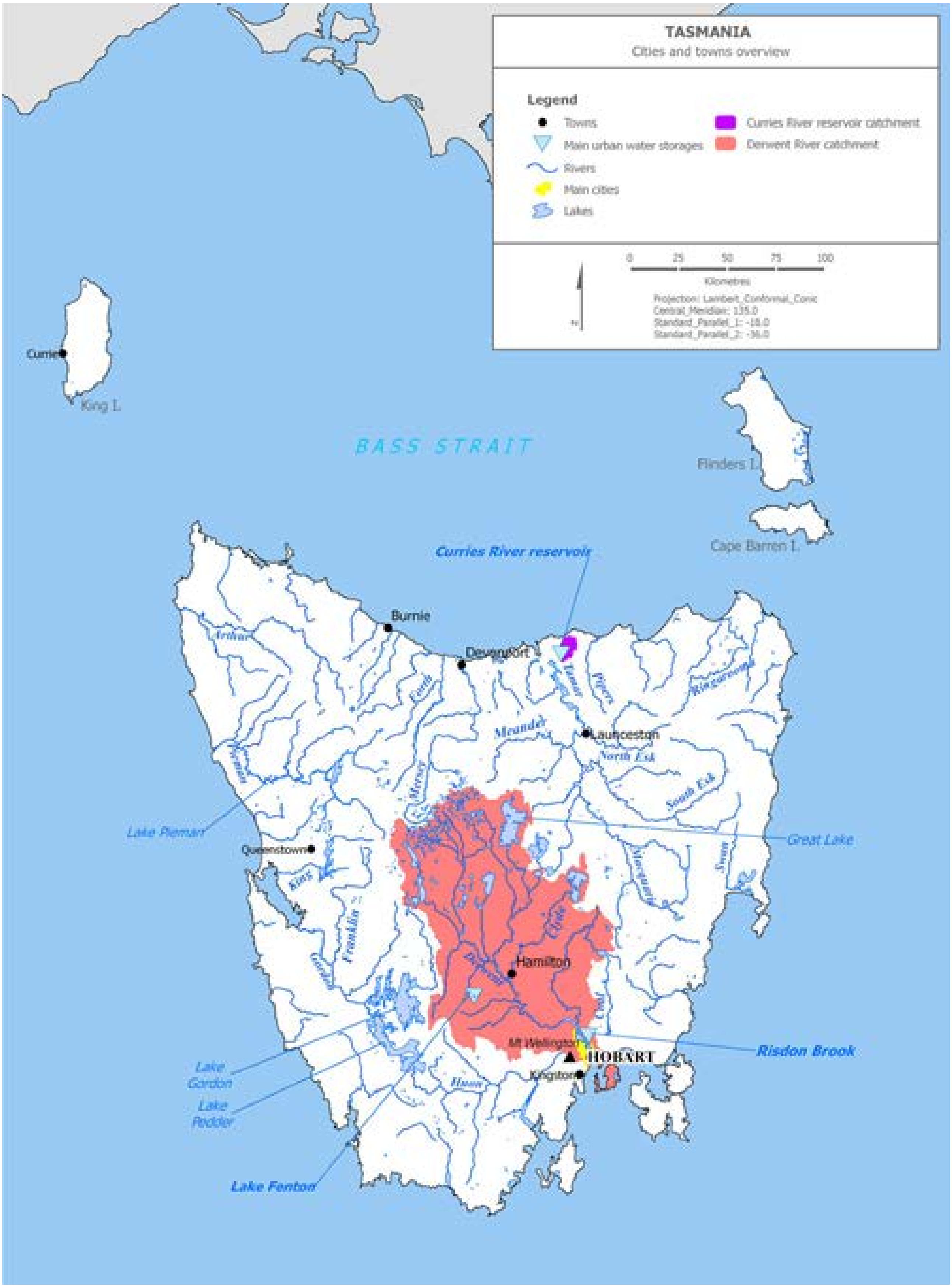


Figure 6-20. Urban areas and supply storages in the Tasmania region

6.6.2 Hobart

Hobart is located on the southeast coast of Tasmania on the estuary of the Derwent River. The Hobart water supply area for this report is within the Derwent and Kingston Coast river basins and encompasses the Greater Hobart suburbs.

The Derwent River basin has an area of 9,160 km^2, contains 35 storages with a total accessible capacity of nearly 5,000 GL, and has 2,860 GL average annual run-off (Whitehead et al. 2010). The Derwent and three of its nine tributaries have been dammed or diverted to over 20 storages for hydro-electricity generation.

Hobart's water supply is obtained from three main sources. The primary source is from the middle reaches of the Derwent River, upstream of New Norfolk. Water is also sourced from Lake Fenton/Lady Barron near Mt Field in the Derwent River basin and from several Mt Wellington streams (Hobart Water 2008).

Urban water infrastructure and management in Hobart

In 1997, the State Government-owned Hobart Regional Water Board was handed to local councils in and around Hobart, and the Hobart Regional Water Authority was formed (Tasmanian Audit Office 1997). This Authority, trading as Hobart Water, was the bulk water distributor supplying eight councils that serviced Hobart and the surrounding areas including Brighton, Clarence, Derwent Valley, Glenorchy, Hobart, Kingborough, Sorell and Southern Midlands.

Under the Tasmanian *Water and Sewerage Industry Act 2008*, from July 2009 the responsibility of the water and sewage services within the above council areas, as well as four additional council areas, was assigned to the newly established regional corporation Southern Water. The additional council areas include Central Highlands, Glamorgan–Spring Bay, Huon Valley and Tasman. The Hobart water supply area for this report includes the eight councils served by Hobart Water as the bulk water authority prior to reforms that came into effect on 1 July 2009.

Hobart's urban water supply infrastructure consists of one water treatment plant, numerous pumping and dosing stations, and eight water storages totalling approximately 11 GL including the Risdon Brook Reservoir and Lake Fenton (Hobart Water 2008).

Water sourced from the Derwent River is treated at the Bryn Estyn plant, transferred to water storages and then delivered to customers throughout Greater Hobart, including the area east of the Derwent River estuary. The water sourced from Mt Wellington and Lake Fenton is used for supply to consumers in Hobart City and Kingborough Councils.

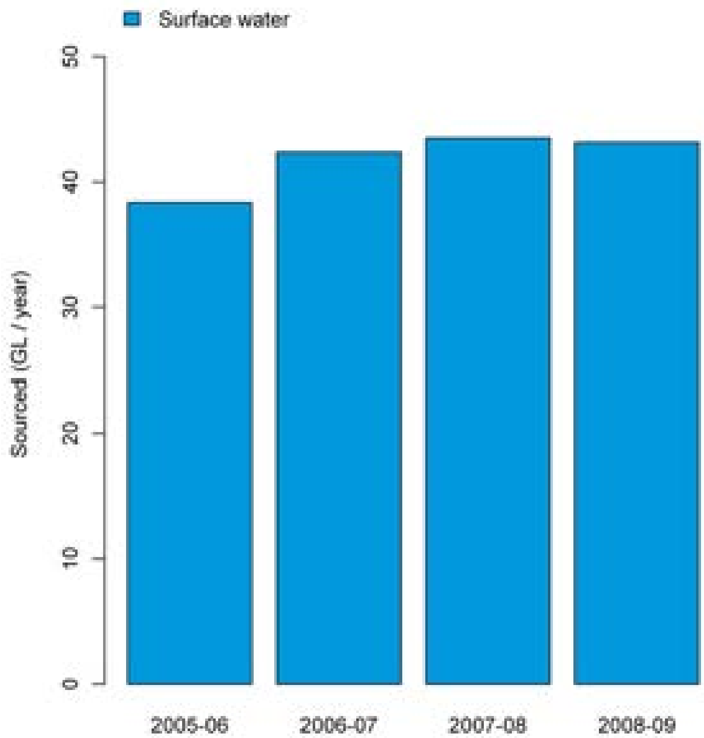


Figure 6-21. Total urban water sourced for Hobart from 2005–06 to 2008–09

6.6.2 Hobart (continued)

A number of recycled water schemes are operating across southern Tasmania. The largest is the Clarence recycled water scheme which supplies recycled water to 28 users (Southern Water 2011a). The Clarence recycled water scheme was developed to remove nutrients from treated effluent outfalls into the Derwent River and provides nutrients and water to agricultural, horticultural and amenity enterprises in the region. The scheme is being upgraded to improve efficiency and increase annual supply to irrigators (Southern Water 2011b).

Water restrictions in recent years

Due to the ample availability of water resources to supply Greater Hobart, water restrictions are rarely enforced. However, restrictions on outdoor watering are automatically imposed during periods of total fire ban so that sufficient water is available for fire-fighting purposes (Southern Water 2010).

Source and supply of urban water in recent years

The following paragraphs contain data relating to the source and supply of water to the Hobart region from 2002–03 to 2008–09. This data were extracted from two National Performance Reports of the Water Services Association of Australia (2007); and National Water Commission (2010). Due to water industry changes that occurred in July 2009, the 2009–10 supply and consumption data for Hobart were not available.

Figure 6-21 shows the total volume of water sourced from surface water for supply to Greater Hobart. Over the period from 2005–06 to 2008–09, the highest volume of water sourced for Hobart was in 2007–08.

Hobart Water reported water supply to three customer groups; bulk water customers, off-peak water customers and wayside customers. The bulk water customers included local councils that supplied water to homes and businesses through local reticulation systems. Off-peak water customers included irrigators and commercial operators that took water into private storages during off-peak periods. Wayside customers were consumers that could not be served by the local council due to their location and were therefore served directly by Hobart Water.

Figure 6-22 shows the annual volume of water supplied to bulk customers and off-peak (irrigators and commercial) customers. The volume supplied to wayside customers was very small by comparison. The bulk water customers – eight local councils – were supplied with approximately 39 GL for all years in the 2002–03 to 2008–09 period except for 2005–06 when 36 GL was supplied. The volume of water supplied to off-peak customers nearly tripled over the period 2002–03 to 2008–09 from 1.8 GL to 5 GL.

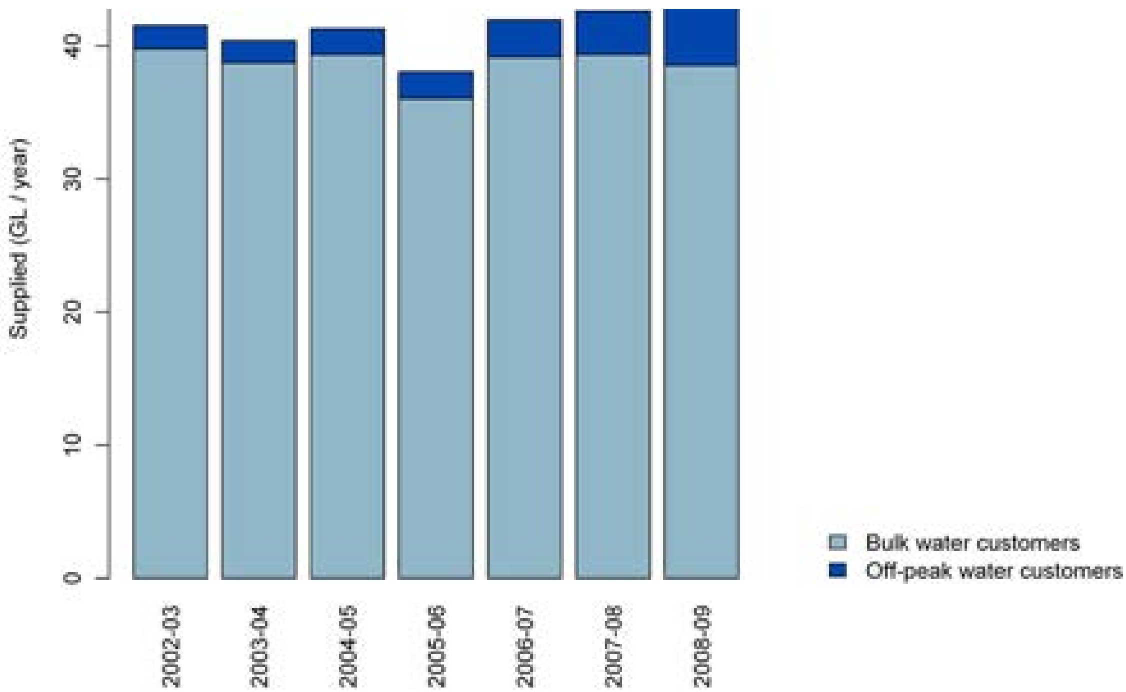


Figure 6-22. Total urban water supplied to Hobart from 2002–03 to 2008–09

6.7 Water for agriculture

Tasmania has a highly uneven rainfall distribution due to its mountainous topography and regional climate drivers. As a result, there is a diverse range of hydrological characteristics, from high-discharge mountain streams in the west to ephemeral streams in the east (Bennet et al. 2010). The majority of Tasmania is under nature conservation (50 per cent). This is followed by forestry (23 per cent) and pasture (21 per cent). Irrigated agriculture is a developing industry in Tasmania through the building and extension of irrigation schemes.

6.7.1 Soil moisture

Upper soil moisture conditions in the agriculture and pastoral lands of Tasmania were very mixed and ranged from generally below average to above average (in the central-east) during summer (November to April) of 2009–10 (Figure 6-23). Over winter 2010 (May to October), upper soil moisture conditions remained generally at similar levels to the preceding summer, although areas of above average conditions to the east of the region in the summer reduced to average levels during the winter period (Figure 6-23).

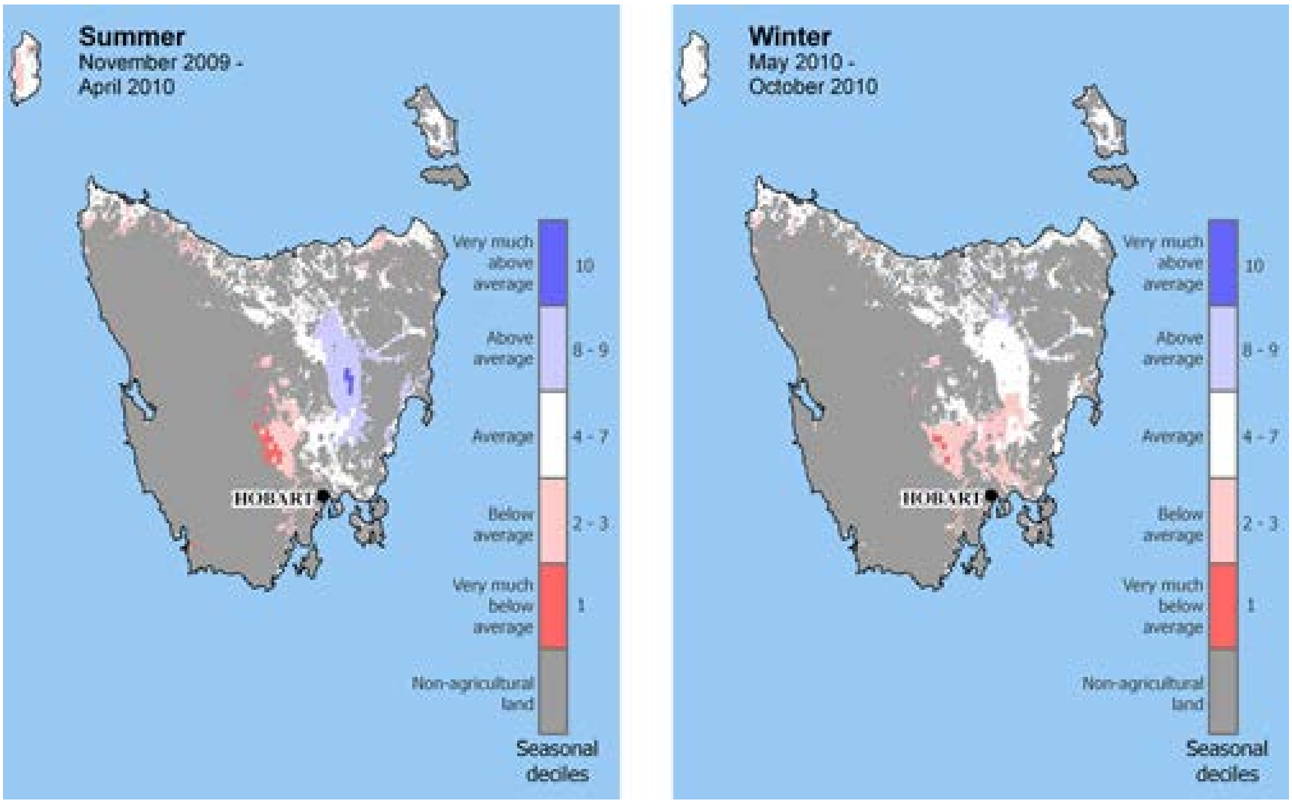


Figure 6-23. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the Tasmania region

6.7.2 Irrigation areas

Agriculture is an important component of Tasmania's economy, contributing to about 16 per cent of the gross state product (Tasmanian Farmers and Graziers Association 2010) and consuming about 60 percent of total water use in the State (Australian Bureau of Statistics 2010a).

Various state, regional and local organisations are responsible for water management in Tasmania and there are a number of irrigation schemes operating in the region. Figure 6-24 gives a broad overview of the irrigation areas in the region. The Tasmanian Irrigation Schemes, a subsidiary of the Rivers and Water Supply Commission, is a Government business enterprise responsible for State Government-owned irrigation schemes. It also oversees irrigation scheme developments through the Tasmania Irrigation Development Board[4].

The Tasmanian Irrigation Schemes manage six irrigation and water schemes. The South East Irrigation Scheme (in the Coal River basin) and Meander Irrigation District (in the Meander River catchment), which are owned and operated by the Tasmanian Irrigation Schemes, are among the largest. Each user within an irrigation district is provided with an irrigation right (the entitlement to take water from the irrigation scheme) that is separated from land title and is transferable within the irrigation district, subject to conditions imposed by the management authority under its transfer rules (National Water Commission 2011b).

Average annual irrigation water use in Tasmania's three natural resource management regions over the period 2005–10 is illustrated in Figure 6-25. Data were sourced from the *Water Use of Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011). Figure 6-26 shows annual irrigation water use in each region.

Water resource conditions and use for irrigated agriculture in 2009–10 in the Coal River basin and Meander River catchments (see Figure 6-24) are described in more detail in the following sections. The Coal River basin in southeast Tasmania occupies an area of approximately 540 km^2 (Department of Primary Industries, Water and Environment 2003a). Land use practices in the river basin include pasture, irrigated cropland, forestry, conservation, recreation and rural-residential development.

The Coal River basin is one of the driest catchments in Tasmania with annual rainfall ranging from 500 mm to 700 mm across the catchment (Department of Primary Industries, Water and Environment 2003a). In-stream and off-stream farm dams traditionally provided most irrigation and stock water supplies over the drier summer period. The groundwater resources of the basin are estimated at 8,200 GL, the bulk of which are saline and not suitable for domestic and irrigation use.

The Meander River catchment in the Tamar River basin has a drainage area of approximately 1,500 km^2. The Meander River originates in the foothills of the Great Western Tiers and flows over 100 kilometres to join the South Esk River at Hadspen to the east. Important tributaries to the Meander River are Western Creek, Quamby Brook and the Liffey River, which collect run-off from the north of the catchment where average annual rainfall exceeds 1,600 mm. Meander Valley is a key dairy, red meat and cropping area in Tasmania. Livestock products make up more than half of the agricultural production and crops make up the remainder.

6.7.3 The South East and Meander Valley Irrigation Schemes

The South East Irrigation Scheme controls water distribution and usage in the Coal River basin through Stages 1 and 2 of the irrigation scheme.

- Stage 1 of the scheme comprises the Craigbourne Reservoir at upper Coal River near Colebrook.
- Stage 2 of the scheme consists of 4,200 ha, of which 3,200 ha is considered suitable for irrigation. Most of the area is located downstream of the Craigbourne Reservoir and has received regulated flows since 1986.

Craigbourne Reservoir was built in 1986 and has a full supply level capacity of 12.5 GL with a lake surface area of approximately 6.2 km^2 and a catchment area of around 247 km^2. The reservoir is primarily for irrigation storage but is an important and popular fishery because of its proximity to Hobart.

4. In July 2011, the Rivers and Water Supply Commission, the Tasmanian Irrigation Development Board and Tasmanian Irrigation Schemes were formally merged into a single State-owned company, known as Tasmanian Irrigation Pty Ltd

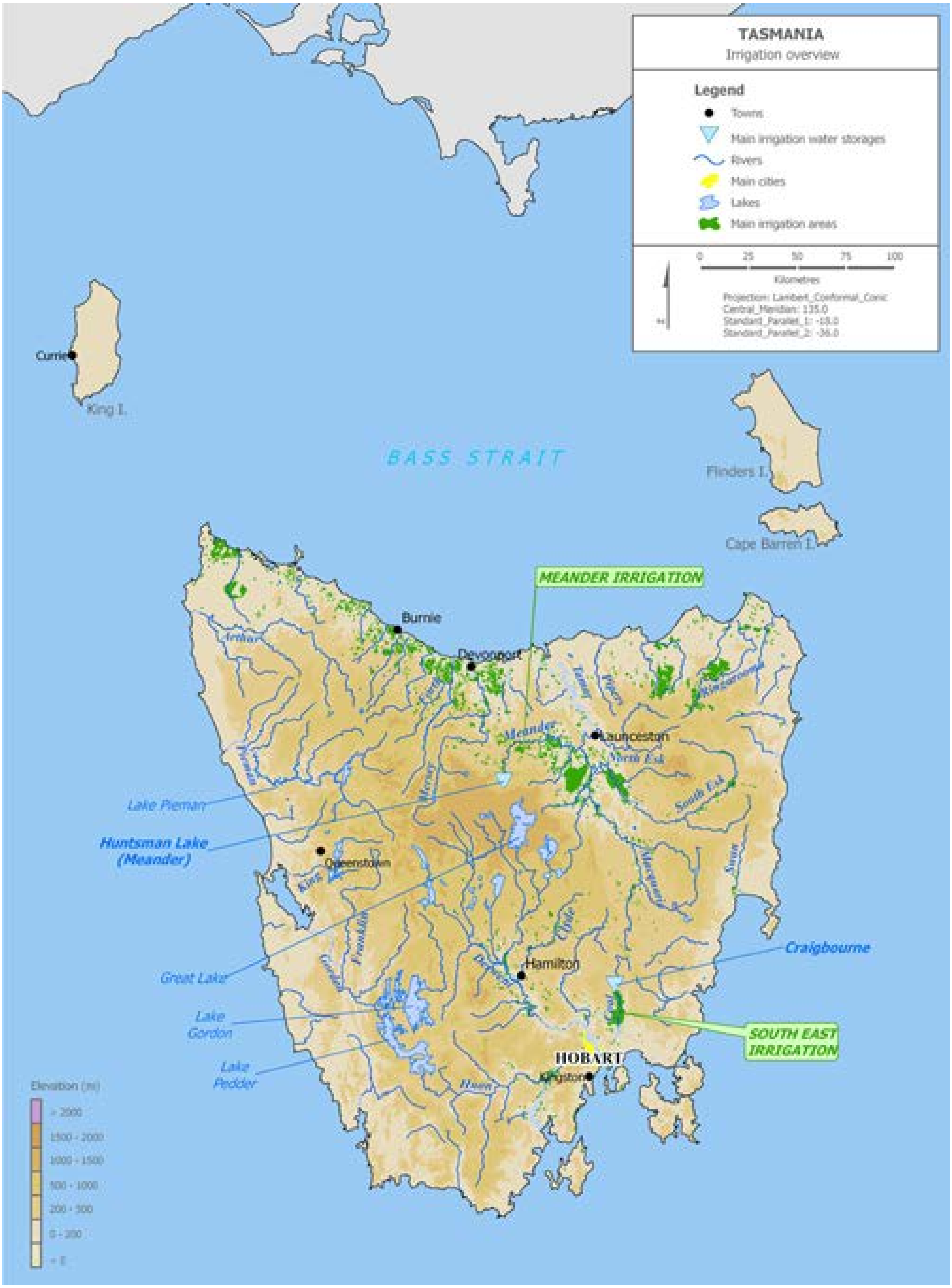


Figure 6-24. Context map of irrigation areas and infrastructure in the Tasmania region

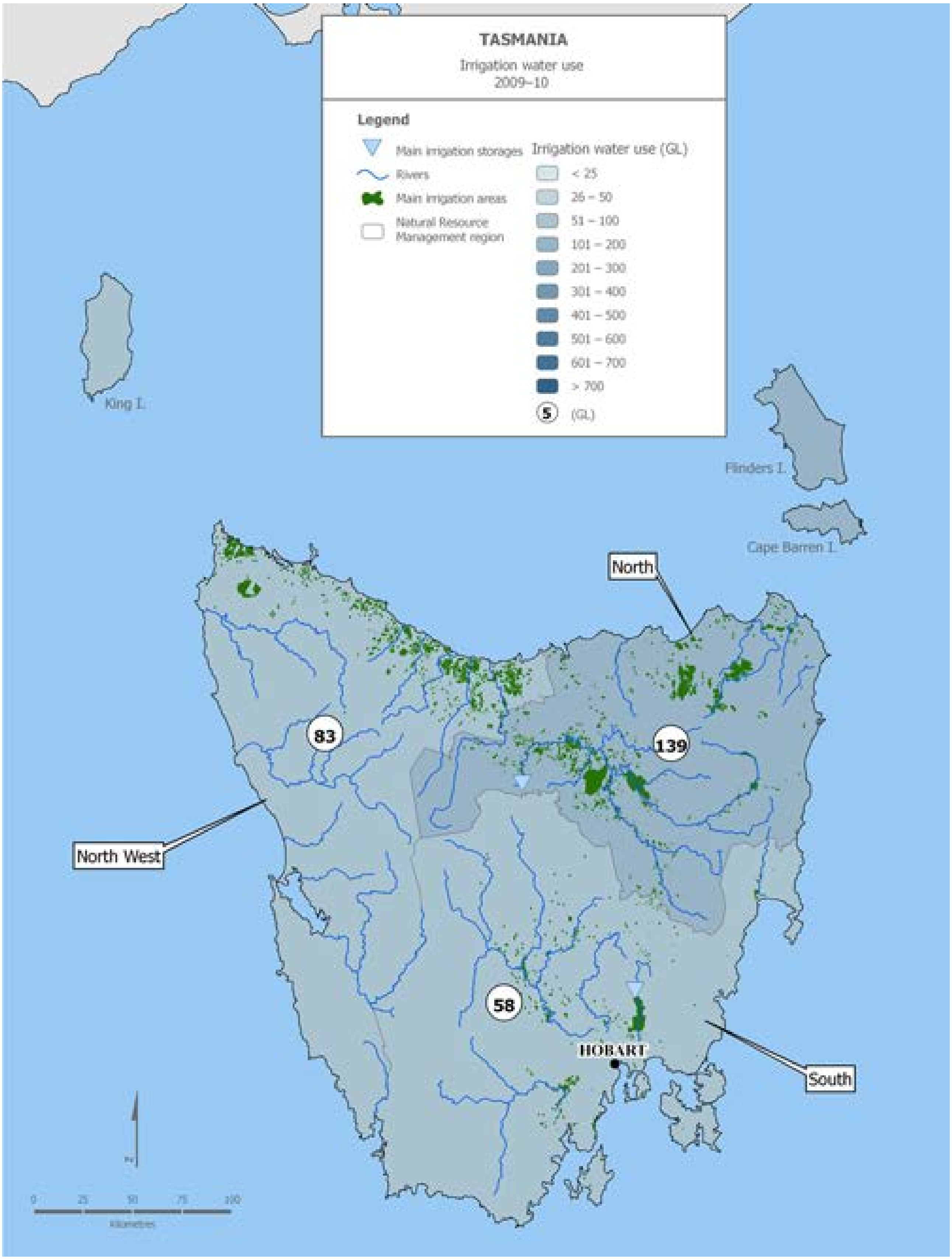


Figure 6-25. Annual irrigation water use per natural resource management region for 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

6.7.3 The South East and Meander Valley Irrigation Schemes (continued)

The seasonal flow patterns in the Coal River are variable (Figure 6-27). Flow volumes are generally low with long periods of zero flow. After numerous drought years and continuing falls in Craigbourne Reservoir storage volumes, significantly above average rainfall from late winter through to spring 2009 resulted in very high flows in the Coal River. As a result, the water volume at Craigbourne Reservoir reached full capacity for the first time in five years.

The Meander Valley Irrigation Scheme was established in 2007–08 (Meander Valley Council 2010). The Meander Dam (and associated Huntsman Lake) was officially opened in 2008. Meander Reservoir has a storage capacity of 43 GL.

River flow data shows that maximum inflows to the Meander Reservoir are during the winter and spring seasons (Figure 6-28). During 2009–10, monthly flow volumes in the Meander River and Liffey Creek were above the 90th percentile in August 2009 and average or better from July to November.

The Meander Reservoir was at full capacity from July to October 2009 (Figure 6-29). Over this time, a total of 247 GL of water was released from the dam, with 126 GL of this going over the spillway. Almost 7 GL was taken up by irrigators.

Water allocations and use in 2009–10 at the Meander Valley and South East Irrigation Schemes are compared in Table 6-3 and Figure 6-30. The low water use compared with allocations in the Meander Valley during 2009–10 was partly due to a very wet winter in 2009 and timely rain within the irrigation district during the summer of 2009–10, which lowered the water requirement for irrigation (Rivers and Water Supply Commission 2010).

In the South East Irrigation Scheme, a wet winter in 2009 resulted in low irrigation water requirements early in the season. However, an exceptionally dry summer and autumn increased irrigation demand late in the 2009–10 season and brought irrigation water use for the year up to the ten-year average (Table 6-3).

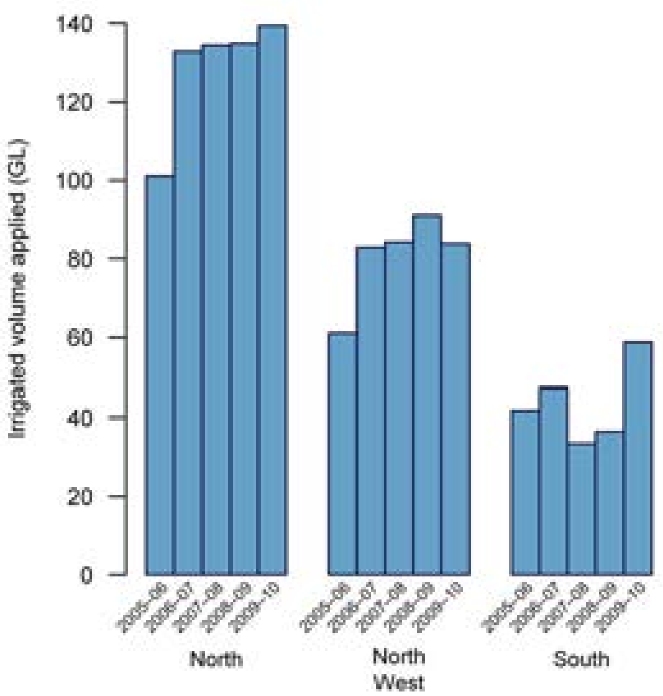


Figure 6-26. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the Tasmania region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

Table 6-3. Water allocation and delivery in the Meander Valley and South East irrigation schemes during 2009–10

Scheme name	Area irrigated (ha)	Water allocation (ML)	Water delivered (ML)	5-year average, ML (delivered)	10-year average, ML (delivered)
Meander Valley Irrigation Scheme	5,200	17,000	6,600	5,800	5,800
South East Irrigation Scheme	1,600	4,500	3,100	3,500	3,200

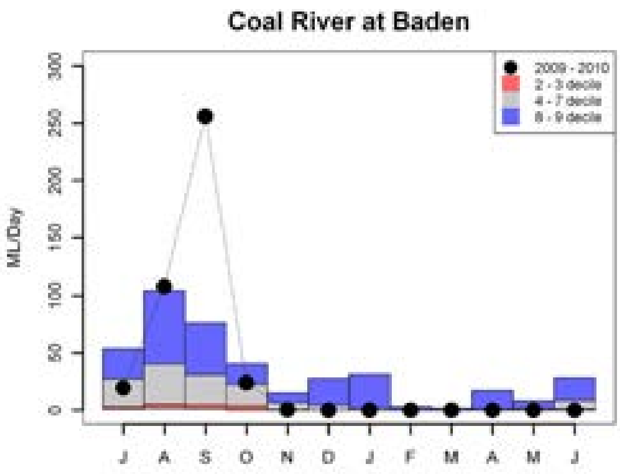


Figure 6-27. Monthly discharge hydrograph compared to discharge deciles for inflows into the Craigbourne reservoir

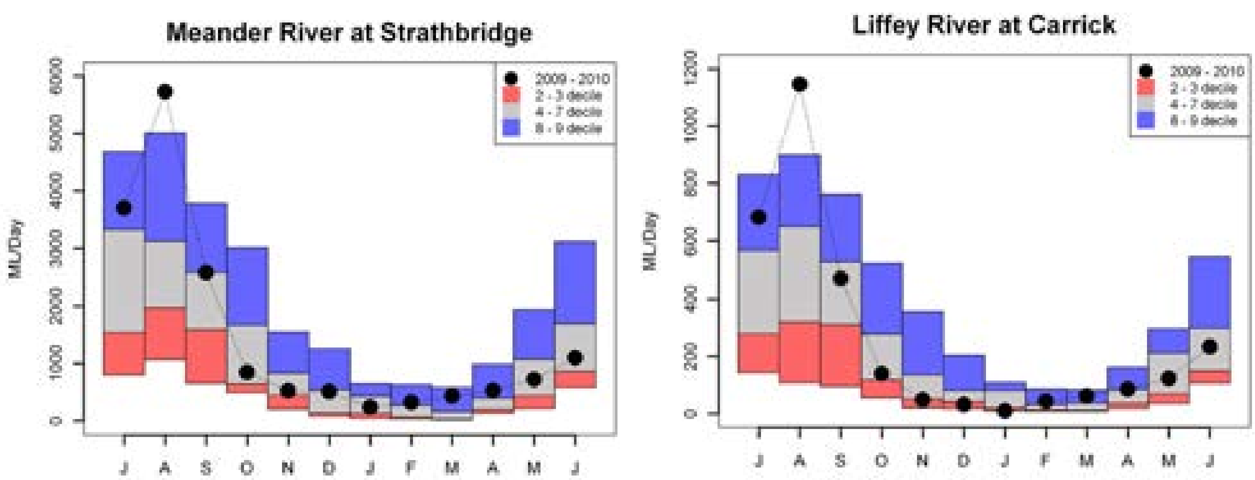


Figure 6-28. Monthly discharge hydrograph compared to discharge deciles for inflows into the Meander Reservoir

Figure 6-29. Water storage volumes available for irrigation at the Meander Reservoir since July 2008 (top) and during 2009–10 (bottom)

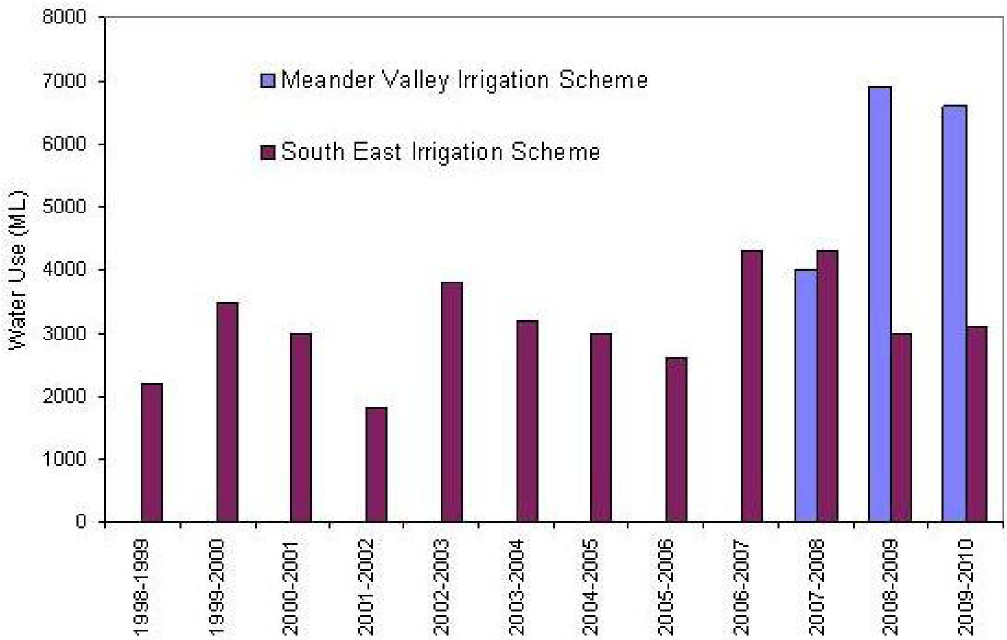


Figure 6-30. Comparison of water use in Meander Valley and South East irrigation schemes

7. Murray–Darling Basin

7. Murray–Darling Basin

7.1 Introduction

This chapter examines water resources in the Murray–Darling Basin region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers, wetlands and aquifers. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Understanding of surface water quality is important to sustainable water resources management; however, it could not be adequately addressed in this assessment. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

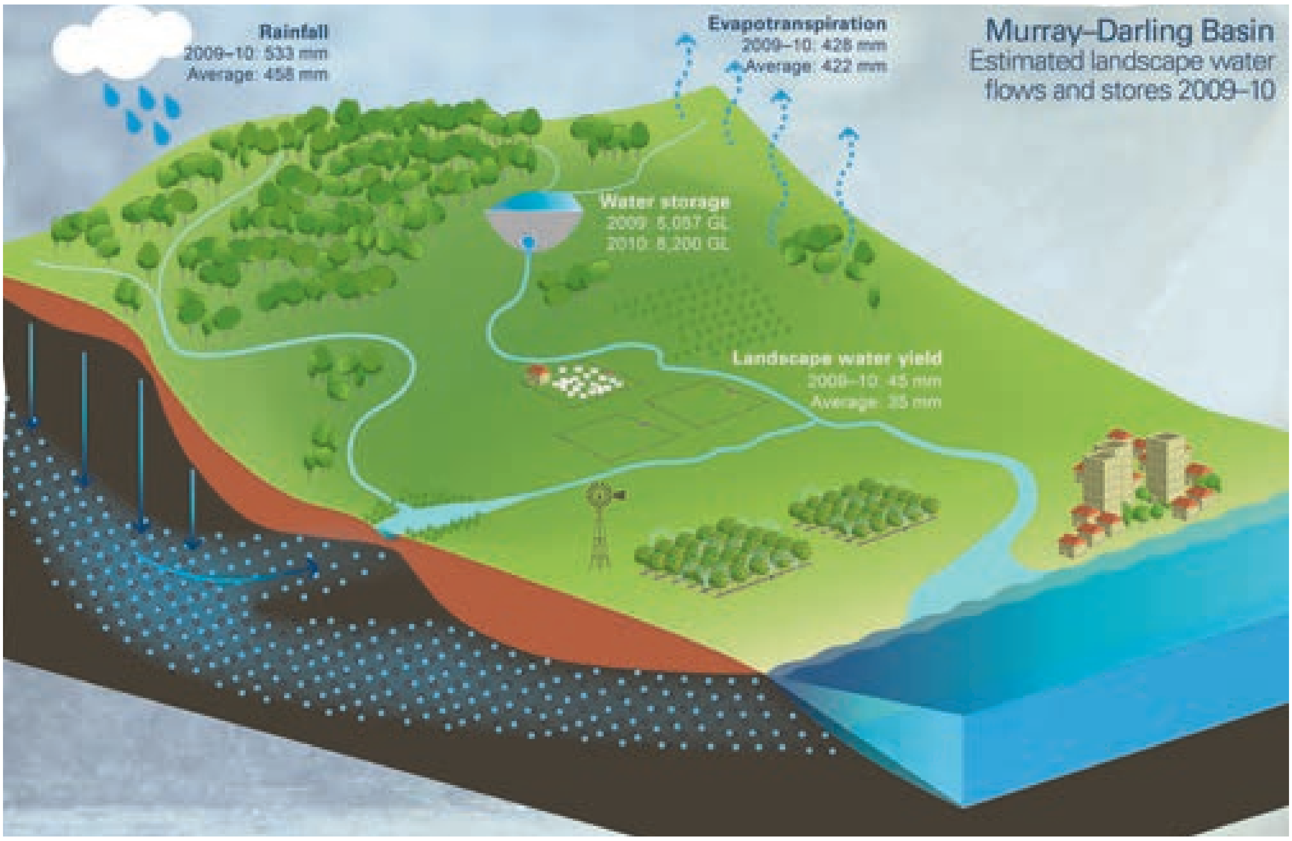


Figure 7-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the Murray–Darling Basin region

7.2 Key data and information

Figure 7-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the Murray–Darling Basin region. The year was wetter than average for the Murray–Darling Basin region (see Table 7-1) and resulted in above average landscape water yield[1]. Evapotranspiration levels were close to the average level, which allowed soil moisture storage to increase across much of the region. Surface water storage volumes also rose substantially (by 12.4 per cent of accessible storage capacity) during the year providing much needed water for both agricultural and environmental purposes.

Table 7-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

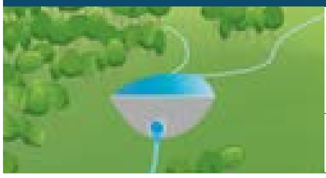
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 7-1. Key information on water flows, stores and use in the Murray–Darling Basin region[2]

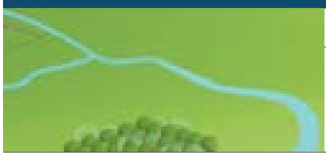
Landscape water balance

	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	533 mm	+16%	81	615 mm (1988–89)	305 mm (2002–03)
Evapotranspiration	428 mm	+2%	55	517 mm (1983–84)	315 mm (1982–83)
Landscape water yield	45 mm	+30%	78	61 mm (1993–94)	13 mm (2006–07)

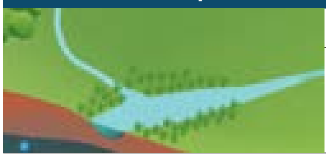
Surface water storage (comprising approximately 95% of the region's total surface water storage)

	Total accessible capacity	July 2009		June 2010		% Change
		Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
	25,210 GL	5,057 GL	20.1%	8,200 GL	32.5%	+12.4%

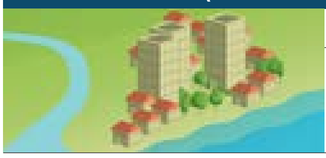
Measured streamflow in 2009–10

	Central-north rivers	Eastern rivers	Southern rivers
	Above average to very much above average	Below average to very much below average	Below average to very much below average

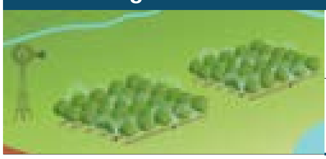
Wetlands inflow patterns in 2009–10

	Currawinya lakes	Gwydir wetlands	Macquarie marshes	Barmah forest
	Extremely high summer inflows	Predominantly below average	Predominantly below average	Predominantly below average

Urban water use (Canberra–Queanbeyan)

	Water supplied 2009–10	Trend in recent years	Restrictions
	42 GL	Steady (low relative to historical levels)	Continued Stage 3 restrictions

Annual irrigation water use in 2009–10 for the natural resource management regions

	Murrumbidgee	Murray	Goulburn Broken	North Central (Vic)	Border Rivers – Gwydir
	585 GL	318 GL	304 GL	363 GL	259 GL

Border Rivers – Maranoa Balonne	Namoi	SA Murray–Darling Basin	Mallee	Lachlan	Central West (NSW)
244 GL	214 GL	288 GL	320 GL	142 GL	117 GL

Lower Murray–Darling	Condamine	Western (NSW)	North East (Vic)	In the Wimmera	South West (Qld)
86 GL	166 GL	99 GL	28 GL	28 GL	5 GL

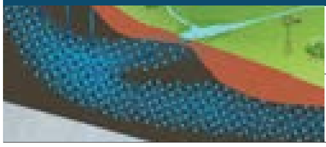
2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

Table 7-1. Key information on water flows, stores and use in the Murray–Darling Basin region (continued)

Soil moisture for dryland agriculture

Summer 2009–10 (November–April)	Winter 2010 (May–October)
Above average to very much above average in the west and centre, average to very much below average in eastern parts of the region	Very much above average over most of the region, average over parts of the far south

Groundwater levels for selected aquifers in 2009–10



Condamine	Narrabri Gunnedah	Cowra Lachlan	Shepparton Calivil	Murray Group	Renmark
Below average	Below average	Below average	Below average	Below average	Below average

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

7.3 Description of region

The Murray–Darling Basin region covers more than one million km^2, one-seventh of mainland Australia, including parts of Queensland, New South Wales (NSW), Victoria and South Australia, and all of the Australian Capital Territory. The Murray–Darling Basin is named after its two major rivers, the River Murray, which drains water from inland areas of southern New South Wales and northern Victoria, and the Darling River, which drains inland southern Queensland and northern NSW. The River Murray and Darling River combine near Wentworth before discharging to the ocean via the Lower Lakes system in South Australia.

The Murray–Darling Basin region is bounded in the south and east by the Great Dividing Range. In the northwest and southwest, the boundaries are much less distinct, particularly in the Wimmera River catchment to the southwest and the border between the Paroo River catchment and the neighbouring Bulloo River catchment which is part of the Lake Eyre Basin region to the northwest. Both of these areas are of low topography and have internal drainage. Elsewhere, areas of low to medium altitude mark the region's limits, including the Mount Lofty Ranges in the southwest, the Grey and Barrier Ranges in the west, and the Chesterton and Warrego Ranges in the north (Murray–Darling Basin Commission 2006).

The region has a great range of climatic conditions and natural environments, from the rainforests of the cool and humid eastern uplands, the temperate Mallee country of the southeast, the subtropical areas of the northeast, to the hot, dry semi-arid and arid lands of the far western plains.

Most of the region's landscape is dominated by vast inland plains and large areas of undulating hills, mostly at 200 m above sea level or below. The largest plains are the Darling Plain in the north, drained by the Darling River and its tributaries, and the Riverine Plain in the south, drained by the Murray and Murrumbidgee rivers and their tributaries.

The Darling River (2,740 km), the River Murray (2,520 km) and the Murrumbidgee River (1,600 km) are the three longest rivers in Australia.

Monsoonal events in the north of the basin contribute to a portion of the flow from the north in the Darling River. Higher rainfall along the Great Dividing Range throughout NSW also contributes to flow in the Darling. The flow in the various rivers and tributaries of the River Murray originate from the rainfall run-off or from snowmelt in the south and southeast of the basin. This includes the headwaters of the Murray, Mitta Mitta, Kiewa, Ovens, Broken and Goulburn rivers in the Victorian Alps. The source of the Murrumbidgee River is the Snowy Mountains area of the Kosciusko National Park.

Streamflow volumes at reference sites in the basin are examined in Section 7.5.1.

It is estimated that there are more than 30,000 wetlands in the Murray–Darling Basin region, including 16 wetlands that are listed as internationally important under the Ramsar Convention on Wetlands. In addition, approximately 220 of the wetlands are listed in the *Directory of Important Wetlands* in Australia.

7.3 Description of region (continued)

Large wetland systems occur along the Darling River and its tributaries, including the Paroo Overflow lakes, Narran lakes, Gwydir wetlands, Macquarie marshes and the Great Cumbung Swamp. The Ramsar designated wetlands of the Lower lakes, Coorong and Murray mouth are at the terminus of the River Murray in South Australia and are important for the breeding and feeding of many species of waterbirds and native fish (Commonwealth Scientific and Industrial Research Organisation 2008). There are major floodplain forests along the River Murray including Barmah–Millewa, Gunbower, Koondrook–Perricoota, Chowilla and the Lindsay–Wallpolla islands. Many of these floodplain wetlands and forests were degraded and some suffered significant loss of area over recent decades due to changes and modifications in flooding regimes and land use (Commonwealth Scientific and Industrial Research Organisation 2008). Recent flows into a selection of wetlands are examined in Section 7.5.2.

The region has a population of over two million (Australian Bureau of Statistics 2010c), approximately ten per cent of Australia's total population. The largest population centre is Canberra in the Murrumbidgee River basin. Other major centres with populations greater than 25,000 include Queanbeyan, Toowoomba, Bendigo, Albury-Wodonga, Wagga Wagga, Shepparton, Tamworth, Orange, Griffith, Dubbo, Mildura and Bathurst. The water supply to these areas is addressed in Section 7.6.

The Murray–Darling Basin Authority, in cooperation with state authorities, is the principal organisation responsible for integrated management of the water resources in the Murray–Darling Basin. Town centres in the region are supplied water from local systems operated by local or State Government organisations. Of the major urban centres, Canberra is served by a dedicated system of four storages while Toowoomba uses water that is imported from the North East Coast region.

Many of the regional water supply systems in the region supply water for both urban consumption and for irrigation. The River Murray system has a number of significant storages that are used for town water supply, irrigation and securing supply to South Australia and southern Victoria. A large portion of water consumed throughout South Australia is sourced from the Murray–Darling Basin region. In Adelaide, for instance, a major component of water consumed can be diverted from the River Murray.

There are 47 major storages in the region which have accessible storage capacity of more than 10 GL. The largest storages are Lake Eildon (accessible capacity of 3,200 GL) on the Goulburn River, and Lake Dartmouth (accessible capacity of 3,800 GL) and Lake Hume (accessible capacity of 3,000 GL) on the upper River Murray.

On the south eastern boundary of the region lies the Snowy Mountains Hydro-electric Scheme, one of the most complex integrated water and hydro-electric power schemes in the world. It provides a net transfer of water from the South East Coast (Victoria) region into the Murray–Darling Basin region. The scheme collects and stores water from the Snowy Mountains that would normally flow east to the coast and diverts it inland through trans-mountain tunnels and power stations to the Murray and Murrumbidgee rivers.

The mix of land use in the Murray–Darling Basin region is illustrated in Figure 7-2. Agriculture is the dominant economic activity in the region. Pasture, predominantly for livestock production, particularly dryland sheep and cattle production, accounts for 75 per cent of the land area of the basin. Important cropping activities include cereals (particularly wheat, barley and rice), oilseed, cotton, and horticulture (particularly citrus, stone and pome fruits, grapes and vegetables). Irrigated agriculture occupies a relatively small proportion of the region (two per cent) but is the major water user in the basin. More than half of all irrigation in Australia takes place in the region, which supports an agricultural industry worth more than $9 billion per annum (Australian Government Department of Sustainability, Environment, Water, Population and Communities 2011).

In 2005–06, it was estimated that the region contained 65 per cent of Australia's irrigated land with a gross value of agricultural production of $15 billion (Australian Bureau of Statistics 2006). Pasture for dairying was traditionally the main irrigation industry in terms of water use. The largest irrigation areas are located in the Murrumbidgee, Murray, Lachlan, Goulburn, Broken, Loddon and Lower Murray basins to the south of the region, and the Condamine, Border, Gwydir, Namoi and Macquarie basins to the north of the region. Water supply to the Coleambally and Murrumbidgee irrigation districts in the Murrumbidgee basin is described in Section 7.7.

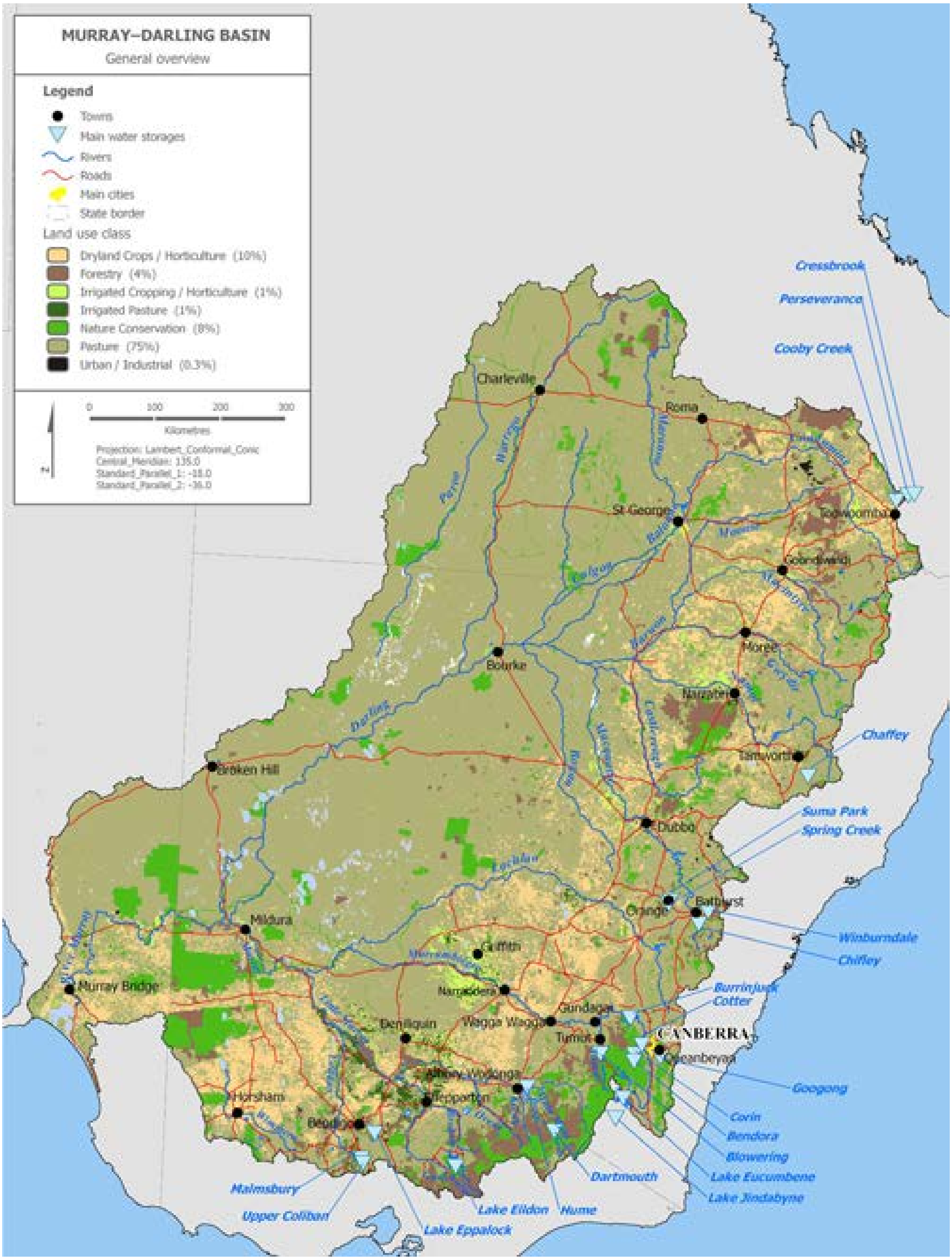


Figure 7-2. Key landscape and hydrological features of the Murray–Darling Basin region (land use classes based on Bureau of Rural Sciences 2006)

7.3 Description of region (continued)

As shown in Figure 7-3, the region is divided into three broad hydrogeological subdivisions (Murray–Darling Basin Commission 2008), namely:

- the basinal aquifers in sedimentary deposits (Murray Basin and Great Artesian Basin) within the flatter landscapes
- the fractured rock aquifers in areas where the basement rock outcrops
- valley-fill alluvium (including the Mid-Murrumbidgee and Upper Namoi) in the highlands bordering the basin.

The Great Artesian Basin is the largest groundwater basin in Australia and underlies the northern portion of the region. It consists of a complex, multi-layered system of water bearing sandstones separated by mostly shale and mudstone confining beds (Murray–Darling Basin Commission 2008). It underlies the sand and clay sequences of the Murray–Darling Basin region that were laid down over the past 50 million years. The Great Artesian Basin provides vital water resources for domestic and town water supply, for stock use by the pastoral industry and water supplies for the operations of the mining and petroleum industries and associated communities.

The sedimentary aquifers within the region cover the main depositional areas of the Murray Geological Basin and the Darling River basin, including upstream reaches of other major rivers such as the Murrumbidgee and Lachlan rivers. The major aquifers within or at the margins of the Murray Geological Basin include the Shepparton, Calivil, Parilla–Loxton Sands, Murray Limestone and Renmark Group aquifers, and the upland alluvium of the Cowra and Lachlan formations. The important alluvial sediments of the Darling River basin include the Gunnedah and Narrabri aquifers.

Fractured rock aquifers occur in the highland areas around the margins of the region. Generally, the groundwater in fractured rock aquifers exhibits a response in level consistent with changes in local climatic conditions (Murray–Darling Basin Commission 2008). In fractured rock aquifers, groundwater is stored in the fractures, joints, bedding planes and cavities of the rock mass. Although fractured rock aquifers are found over a large area, they hold a much lower groundwater volume than sedimentary aquifers. Due to the difficulty in obtaining high yields, the volume of groundwater extracted from any one bore and in a given area is relatively low.

Figure 7-4 shows the salinity of the watertable aquifer in the Murray–Darling Basin region as fresh (less than 3,000 mg/L) and saline (greater than 3,000 mg/L). Generally, the shallow groundwater in the flatter, lower altitude areas of the region is saline, while fresh groundwater resources occur at depth. Groundwater in the deeper sub-systems is typically fresher than the watertable. Watertable aquifer salinity levels have risen significantly since European settlement, following the clearing of native vegetation, irrigation development and the consequent increase in recharge to groundwater systems (Barnett et al. 2004).

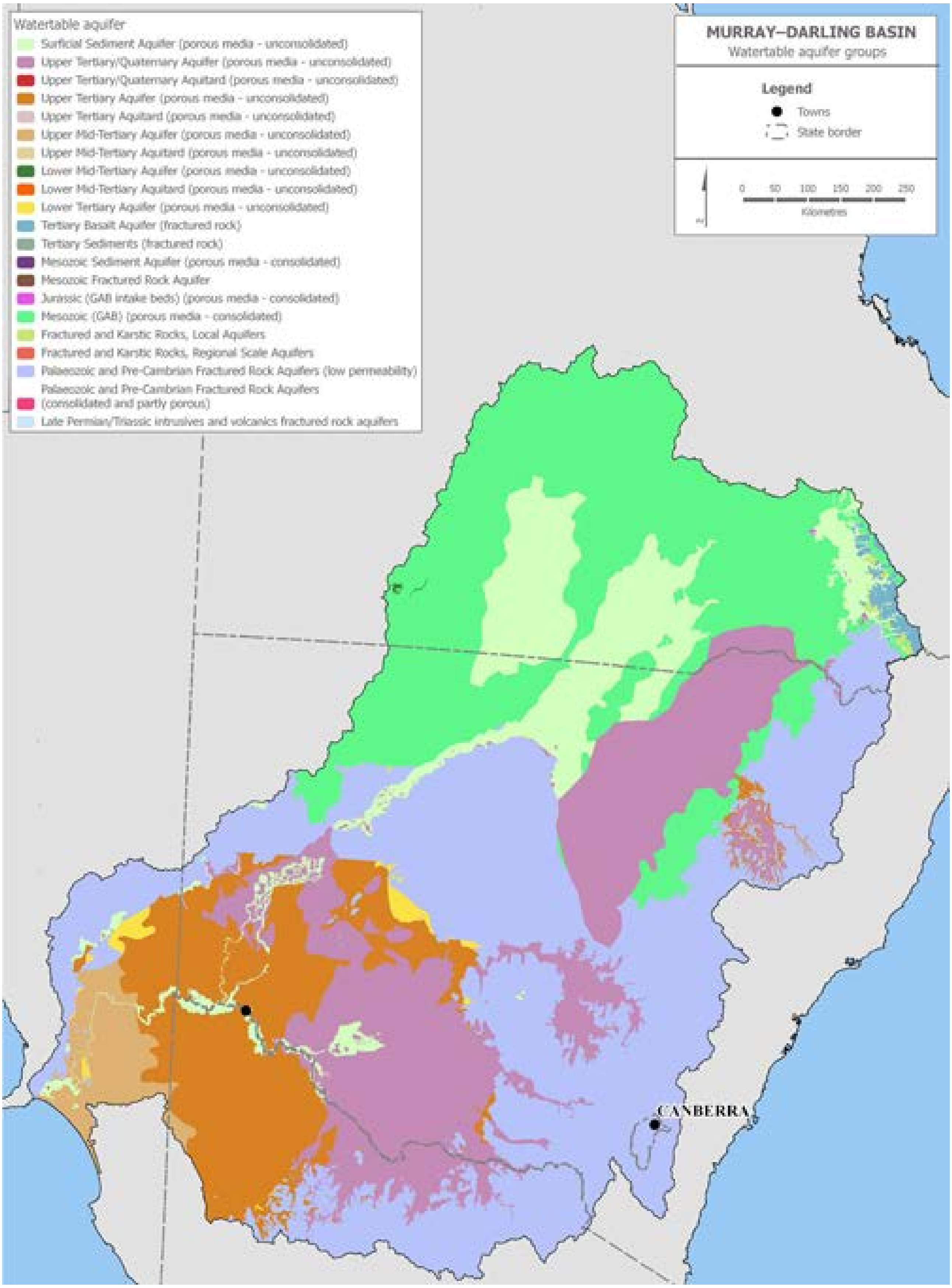


Figure 7-3. Watertable aquifer groups in the Murray–Darling Basin region (Bureau of Meteorology 2011e)

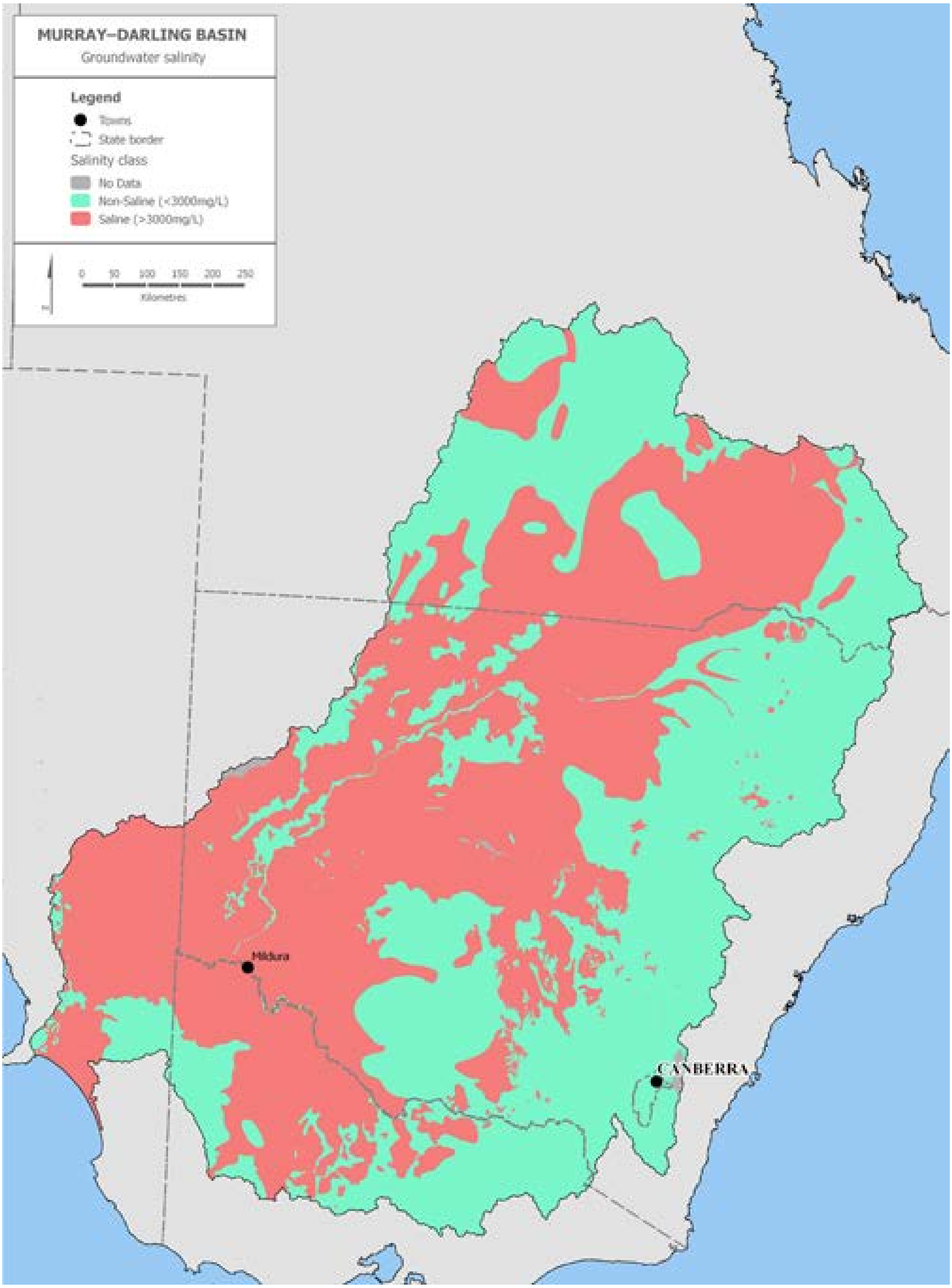


Figure 7-4. Watertable salinity classes within the Murray–Darling Basin region (Bureau of Meteorology 2011e)

7.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 7-5 shows that for the Murray–Darling Basin (the Basin) region, 2009–10 started with much lower than the median rainfall in July and August 2009, followed by approximately median monthly rainfall up to November 2009. These relatively dry conditions were followed by a wetter than usual summer of 2009–10. The wetter than average summer was due in large part to the wetter than normal December 2009 in the northern part of the Basin, and February 2010, the wettest February averaged across the Basin since 1976. The above average rainfall was due to two significant rainfall events in the first half of February. The first major rainfall event was associated with ex-tropical cyclone *Olga*, which produced falls across the north western parts of the Basin in early February. Following this, on 13–14 February 2010 a major rain event produced large falls. March 2010 was also a wet month, largely due to a monsoonal low event, that resulted in high rainfall in the north of the region. February and March 2010 experienced their fourth and third highest monthly rainfall respectively in the long-term record (July 1911 to June 2010).

Monthly evapotranspiration was below normal levels between October and December 2009 as a result of the relatively dry start to the year. Following the very high rainfall events of December, February and March, higher than normal monthly totals were experienced until April 2010, as water availability no longer acted as a constraint to evapotranspiration, particularly across the wetter north of the region.

Modelled landscape water yield for the region is on average low throughout the year as a consequence of relatively high evapotranspiration losses relative to rainfall inputs, particularly during the generally wetter summer months. Landscape water yield for 2009–10 shows significant responses to the higher than normal rainfall in December 2009, February and March 2010. Modelled landscape water yield for March 2010 represents the record highest March total in the long-term record (July 1911 to June 2010).

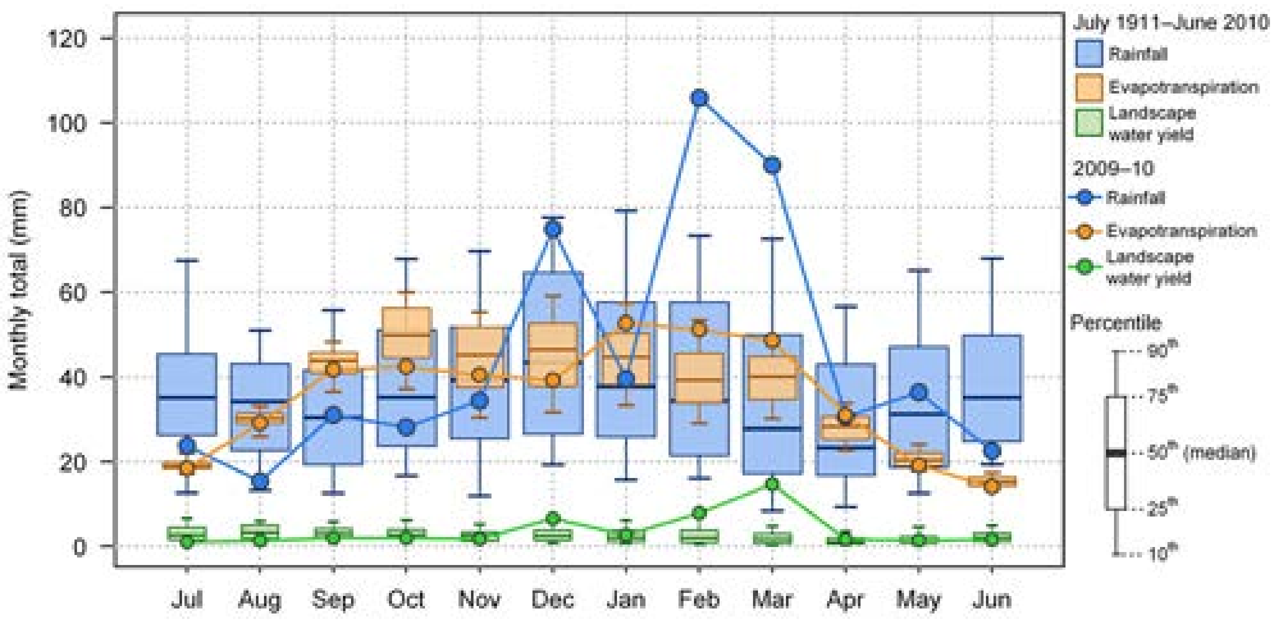


Figure 7-5. Monthly landscape water flows for the Murray–Darling Basin region in 2009–10 compared with the long-term record (July 1911 to June 2010)

7.4.1 Rainfall

Rainfall for the Murray–Darling Basin region in 2009–10 was estimated to be 533 mm, which is 16 per cent above the region's long-term (July 1911 to June 2010) average of 458 mm. Figure 7-6 (a) shows that during 2009–10, rainfall was highest in the alpine areas of the southeast of the region, but also relatively high in the central-east and northwest. Rainfall deciles for 2009–10, shown in Figure 7-6 (b), indicate annual rainfall was above average across much of the region, particularly in the north and west. Below average to very much below average rainfall was experienced in the northeast.

Figure 7-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 305 mm (2002–03) to 615 mm (1988–89). The annual average for the period was 465 mm. The data show that 2009–10 was the first year since 2000–01 to experience annual rainfall above the 30-year average.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-7 (b). This graph shows annual rainfall for the region is roughly equally distributed between winter and summer. The moving average for winter in particular reflects the prolonged period of below average winter rainfall experienced since 2000–01. Summer rainfall has increased over recent years while winter rainfall has remained low.

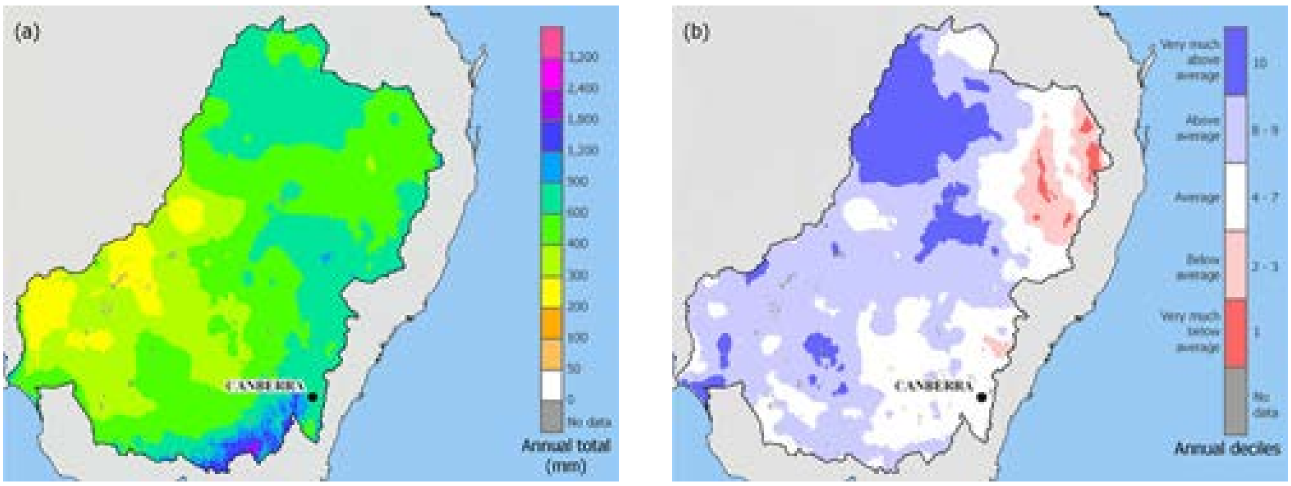
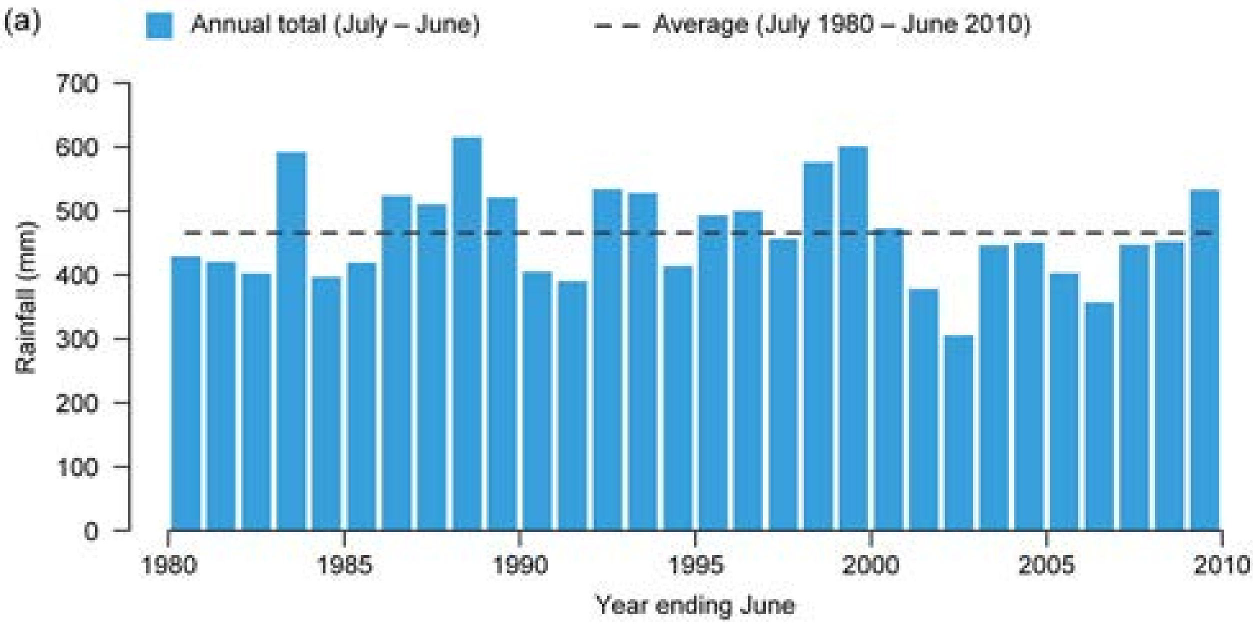


Figure 7-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Murray–Darling Basin region



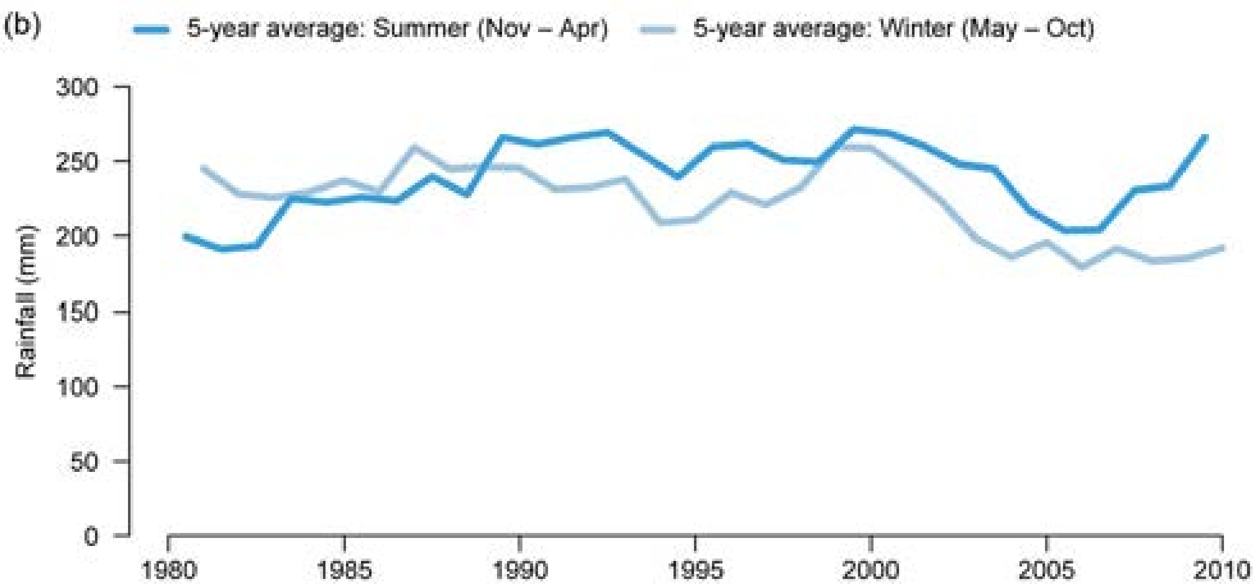


Figure 7-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Murray–Darling Basin region

7.4.1 Rainfall (continued)

Figure 7-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The summer period analysis shows generally increasing trends in rainfall across much of the region, particularly in the north. The winter period analysis highlights reductions in rainfall across almost the entire region with the strongest negative trends observed to the south and southeast.

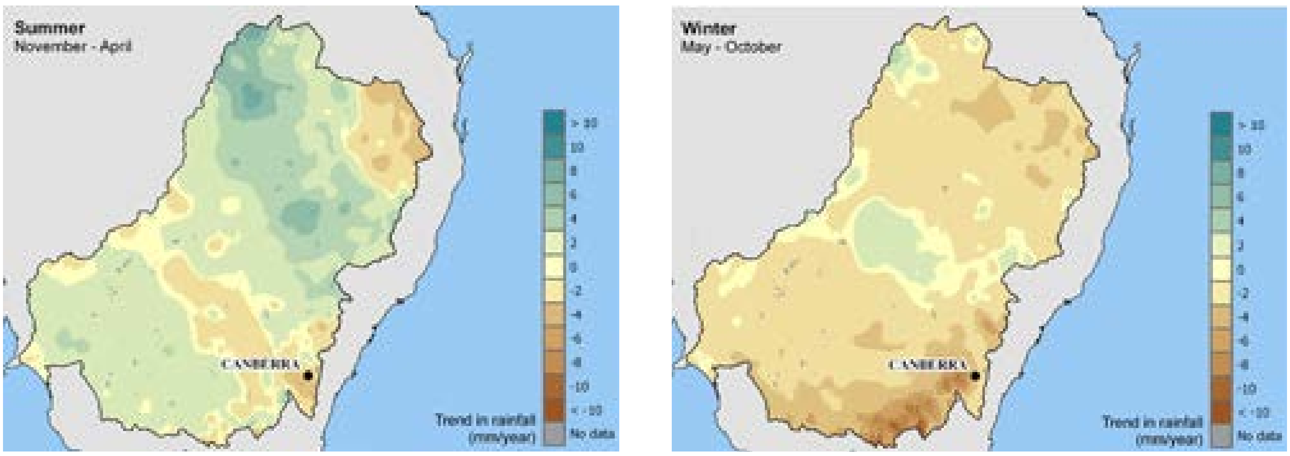


Figure 7-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low

7.4.2 Evapotranspiration

Evapotranspiration for the Murray–Darling Basin region for 2009–10 was estimated to be 428 mm, which is approximately equal to the region's long-term (July 1911 to June 2010) average of 422 mm. Figure 7-9 (a) shows that during 2009–10, evapotranspiration across the region was closely related to the distribution of rainfall (see Figure 7-6 [a]). Highest values were in the southeast and east, decreasing to the southwest of the region. Evapotranspiration deciles for 2009–10, shown in Figure 7-9 (b), indicate above average values across much of the centre, west and far southeast of the region. Lower than average values are apparent in the northeast and also to the east and south.

Figure 7-10 (a) shows annual evapotranspiration for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 315 mm (1982–83) to 517 mm (1983–84). The annual average for the period was 423 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-10 (b). Evapotranspiration over the region in summer is consistently higher than in the winter period.
The moving average for summer reflects low average evapotranspiration between 2002–03 and 2006–07, which was constrained by low rainfall during these years.

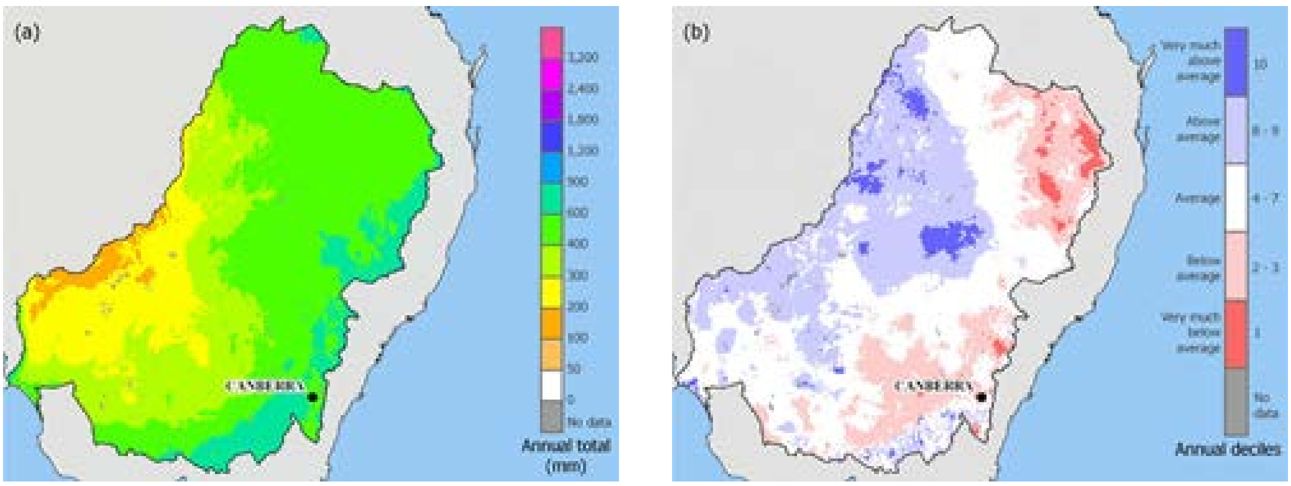
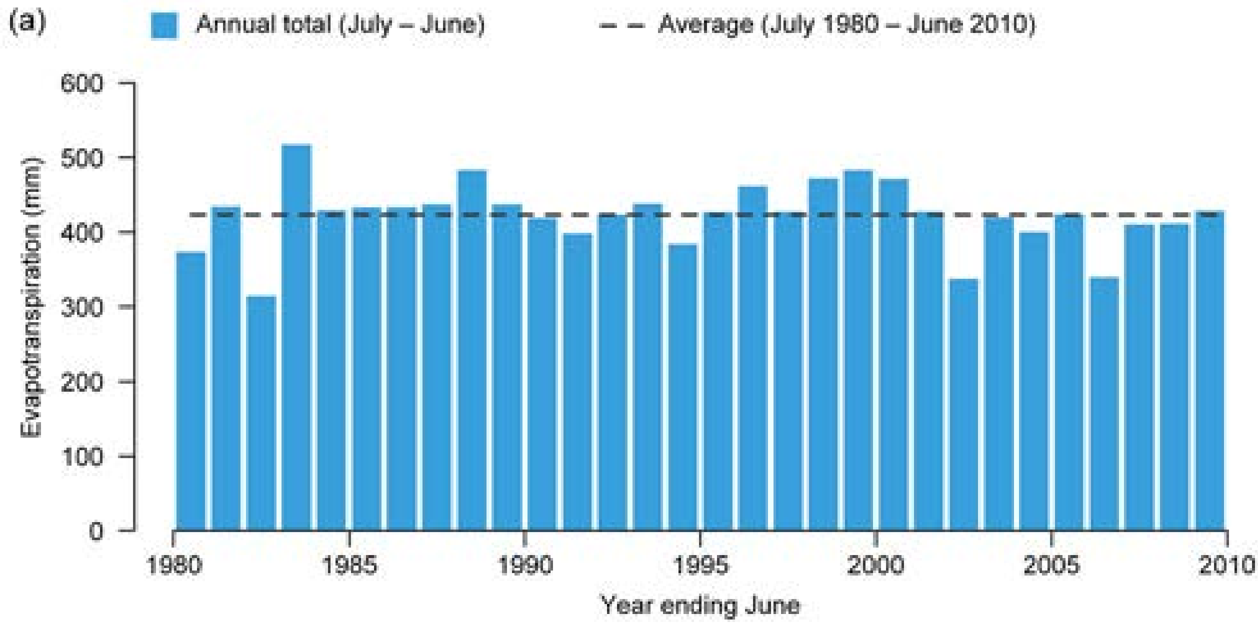


Figure 7-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Murray–Darling Basin region



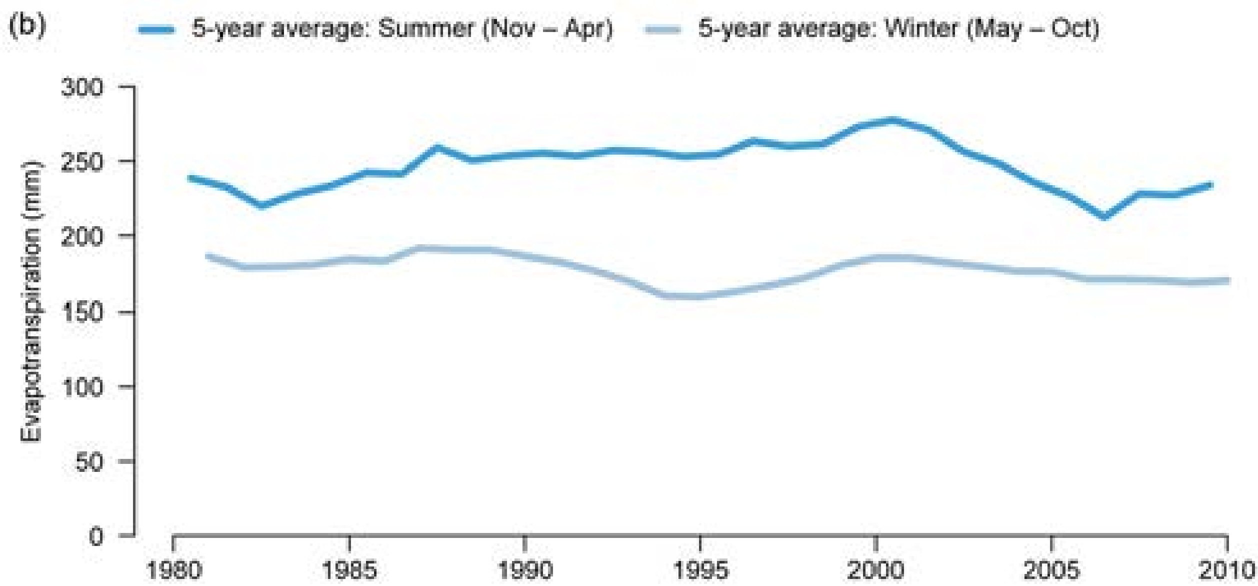


Figure 7-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Murray–Darling Basin region

7.4.2 Evapotranspiration (continued)

Figure 7-11 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis shows some areas of increasing evapotranspiration across the northwest and centre of the region, with decreasing trends in the northeast and around the foothills of the Great Dividing Range in the southeast. The winter period analysis shows no particularly strong positive or negative trends in any part of the Basin.

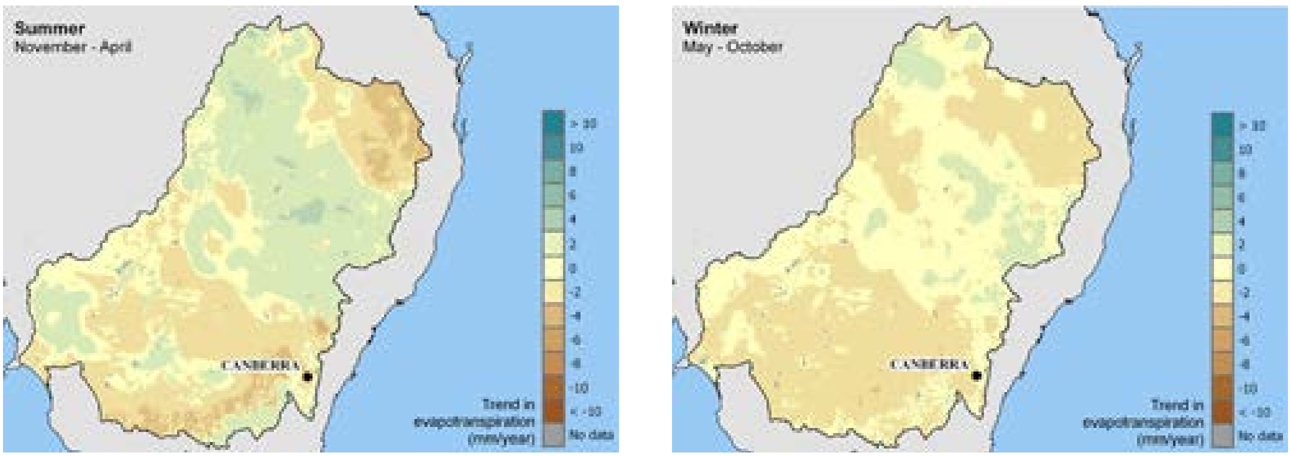


Figure 7-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low

7.4.3 Landscape water yield

Landscape water yield for the Murray–Darling Basin region for 2009–10 was estimated to be 45 mm, which was 30 per cent above the region's long–term (July 1911 to June 2010) average of 35 mm. Figure 7-12 (a) shows water yield for 2009–10 was highest in the New South Wales and Victorian alps in the far southeast of the region. Relatively high levels of landscape water yield were also estimated to have occurred in the river basins of the central-east and northwest.

Landscape water yield deciles for 2009–10, shown in Figure 7-12 (b), indicate very much above average yield values across much of the centre and north of the region. Below average values occurred in the northeast and along much of the southeastern and southern boundaries of the region.

Figure 7-13 (a) shows annual landscape water yield for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 13 mm (2006–07) to 61 mm (1993–94). The annual average for the period was 37 mm. The high level of interannual variability in annual totals relative to the average reflects the sensitivity of the region's landscape water yield to variations in both rainfall and evapotranspiration.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 7-13 (b). The graph shows that landscape water yield was estimated to be higher for winter than for summer until the early 1990s. Since 2002–03, landscape water yield has been a little higher for the summer period than in the winter. The moving average for summer also shows a clear increase at the end of the 30-year record.

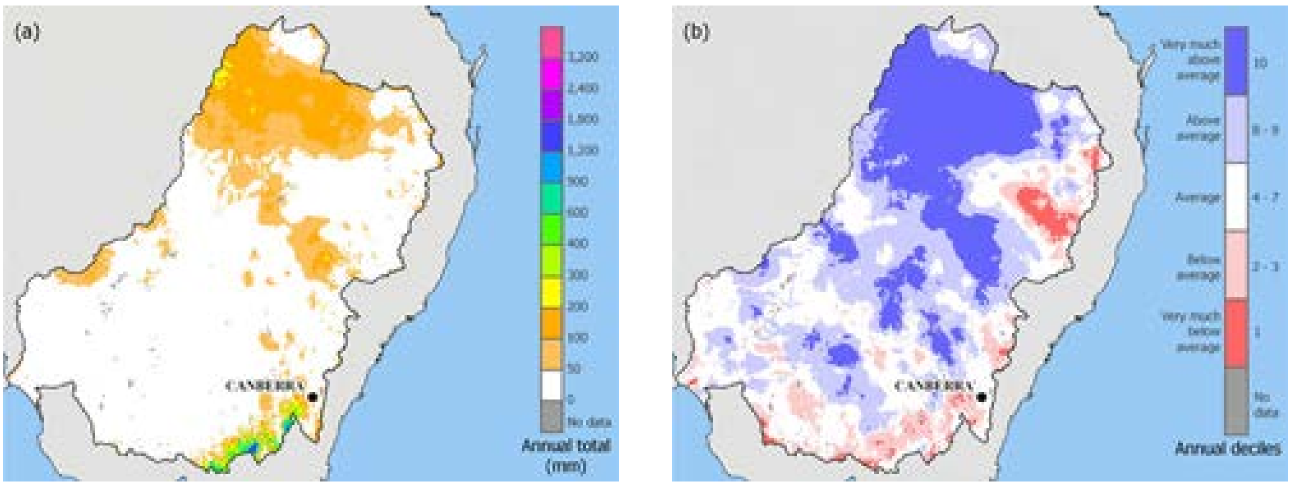
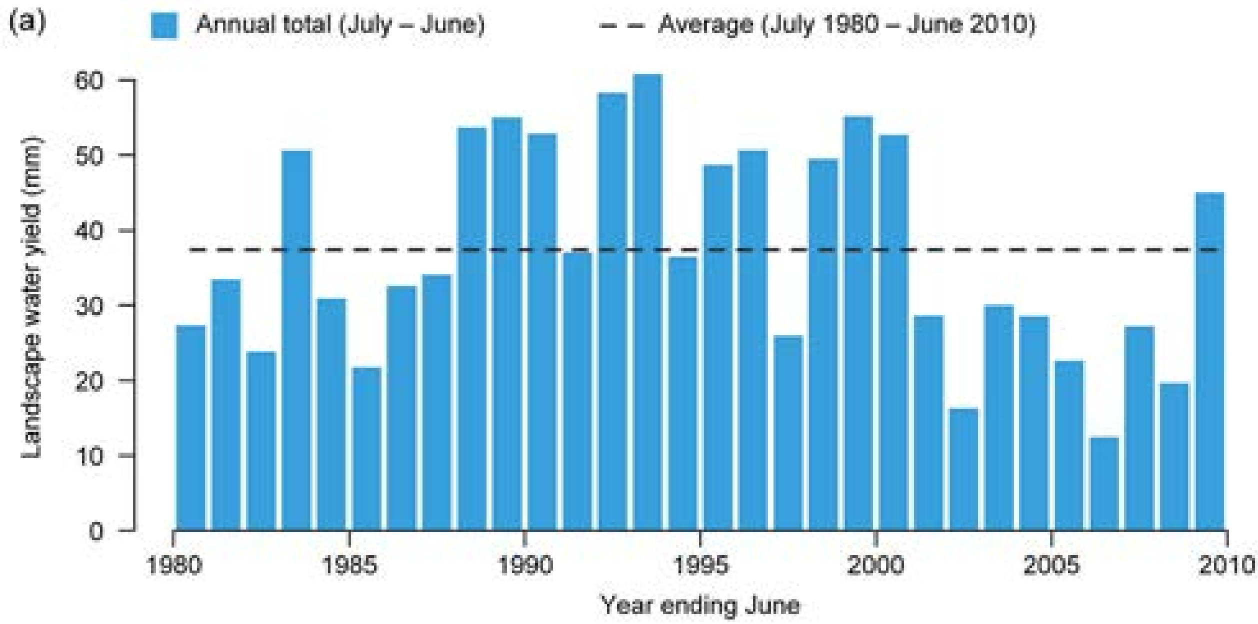


Figure 7-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Murray–Darling Basin region



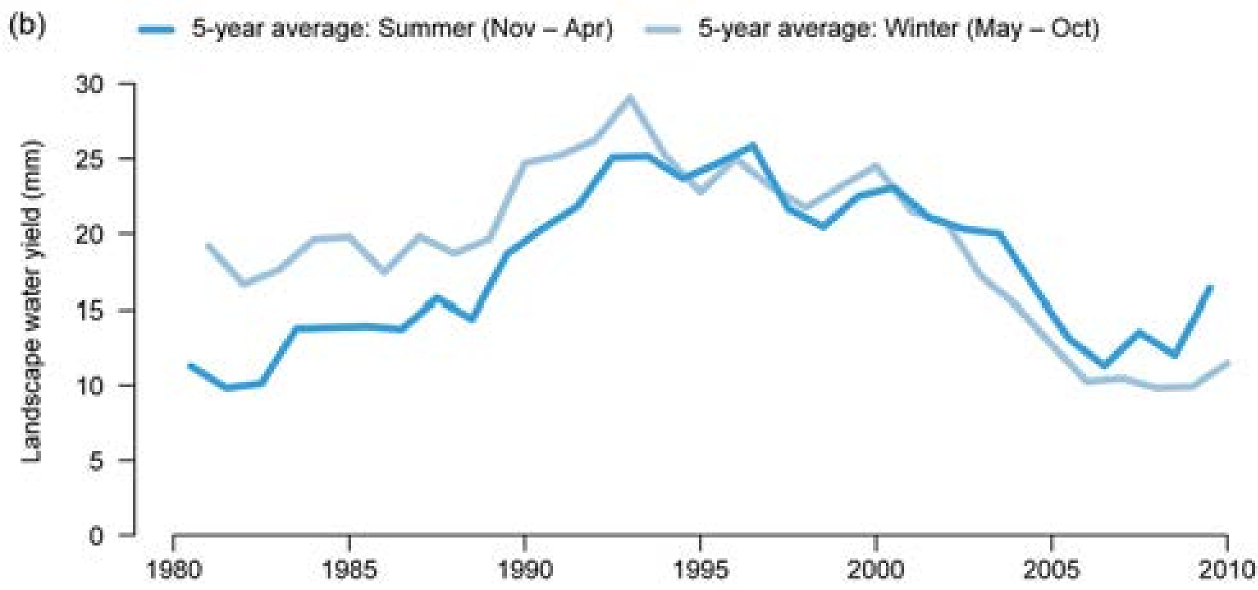


Figure 7-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Murray–Darling Basin region

7.4.3 Landscape water yield (continued)

Figure 7-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period shows only slight trends, both positive and negative, with the most apparent increasing trends in the north of the region. Decreasing trends are identified in the far southeast of the region, particularly at the top of the Murrumbidgee River basin in the New South Wales alpine areas near Canberra.

The winter period analysis shows strong negative trends in landscape water yield across the far southeast of the region. The reductions observed across the south-eastern areas are noticeably high relative to average winter landscape water yield over the 30-year period. This area represents the main streamflow generating headwater catchments of a number of important rivers in the region, including the Murray, Murrumbidgee, Kiewa, Ovens, Goulburn and Broken rivers.

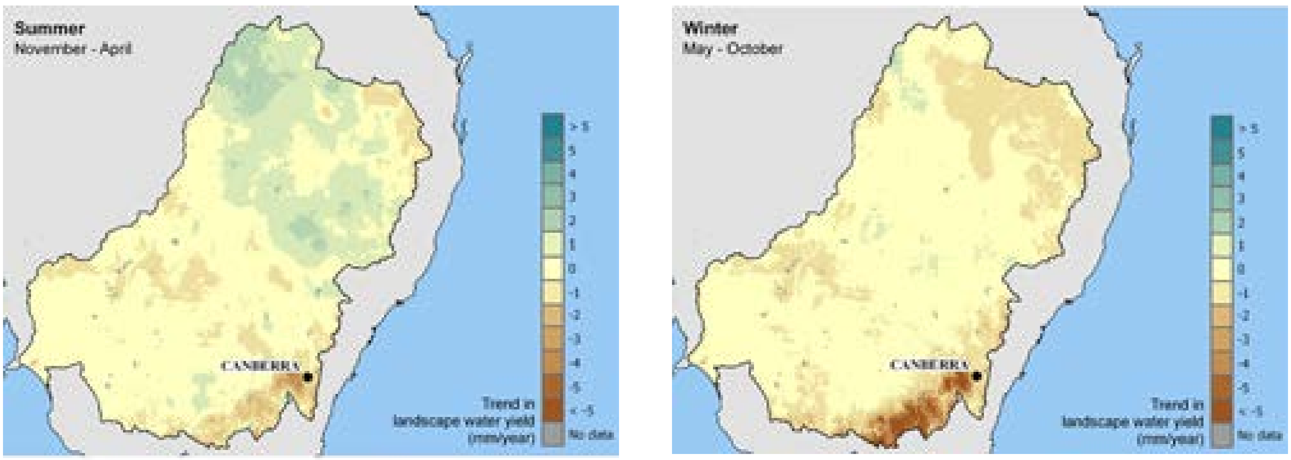


Figure 7-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Murray–Darling Basin region. The statistical significance of these trends is often very low

7.5 Rivers, wetlands and groundwater

The 80 stream gauges with at least 30 years of records across 20 geographically representative river basins were selected for examination of regional streamflow in this report (see Figure 7-15). Streamflow at these gauges in 2009–10 was analysed in relation to the flow record. Additionally, seven gauges were selected for analysis of wetland river inflow for the region.

Groundwater use in the region is extensive. Total groundwater use in 2008–09 was 1,273 GL, which was more than 30 per cent of the surface water diversion in the region (Murray–Darling Basin Authority 2010). This level of use is reflected in the large number (95) of groundwater management areas in the region. The large number of groundwater management units were created to identify areas with significant groundwater resources and to provide a boundary within which resource management can be focused. Groundwater extraction and intensity of use in many units is controlled through a range of planning mechanisms. The Bureau's Interim Groundwater Geodatabase contains information for 95 groundwater management units within the region.

Figure 7-16 shows some major groundwater management units within the region where total groundwater allocation is typically larger than 30 GL/yr. Groundwater management units in the Lower Murray–Darling Basin are also shown. The boundary and name of the Eastern Downs groundwater management unit in Queensland will be updated in the future but currently represents the groundwater management area in the Condamine valley.

The units selected for analysis represent fresh groundwater resources associated with:

- the Murray Group within the Murray Basin
- major alluvial/transitional sediments at the margin of the Murray Geological Basin or overlying the Great Artesian Basin
- alluvial-fill upland paleovalleys
- fractured rock basalt.

In other groundwater management units, except for the Great Artesian Basin, groundwater is often saline or of poor yield, and used for local stock and domestic water supply.

7.5.1 Streamflow and flood report

Figure 7-17 presents an analysis of river flows over 2009–10 relative to annual flows for the past 30 years at 80 monitoring sites throughout the Murray–Darling Basin region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for the 2009–10 are colour-coded relative to their decile rank over the 1980 to 2010 period at each site.

With regard to total annual discharge in 2009–10, Figure 7-17 shows that observations from monitoring gauges across the south and east of the region reflect the below average to very much below average modelled landscape water yield results shown in Figure 7-12 (b). Very much above average modelled yields in the river basins of the northwest of the region, and in the Bogan River basin, are also reflected in gauge results in these areas. Above average modelled yields in lower parts of river basin areas in the centre and west of the region (Figure 7-12 [b]) do not contribute enough streamflow (in total volume) to significantly raise streamflow levels in these areas. The magnitude of streamflow at these rivers is largely determined by yields in upper catchment areas to the south and east, and to some extent by releases and spills from on-river storages. Figure 7-17 shows two dominant patterns:

- below average to very much below average streamflow in the southern and eastern rivers in the region
- above average to very much above average streamflow in the northern river basins including the Paroo, Warrego and Condamine–Culgoa river basins.

With regard to lower basin streamflow in the region in 2009–10:

- the lower Darling River recorded average streamflow, suggesting high flows in the northern river basins were largely averaging out their streamflow amounts of high flows in the northwest and low flows in the east
- streamflow in the lower River Murray upstream of the Darling River junction was very much below average, consistent with the below to very much below average upstream flow totals
- streamflow downstream of the River Murray and Darling River junction was very much below average despite the average inflow from the Darling River.

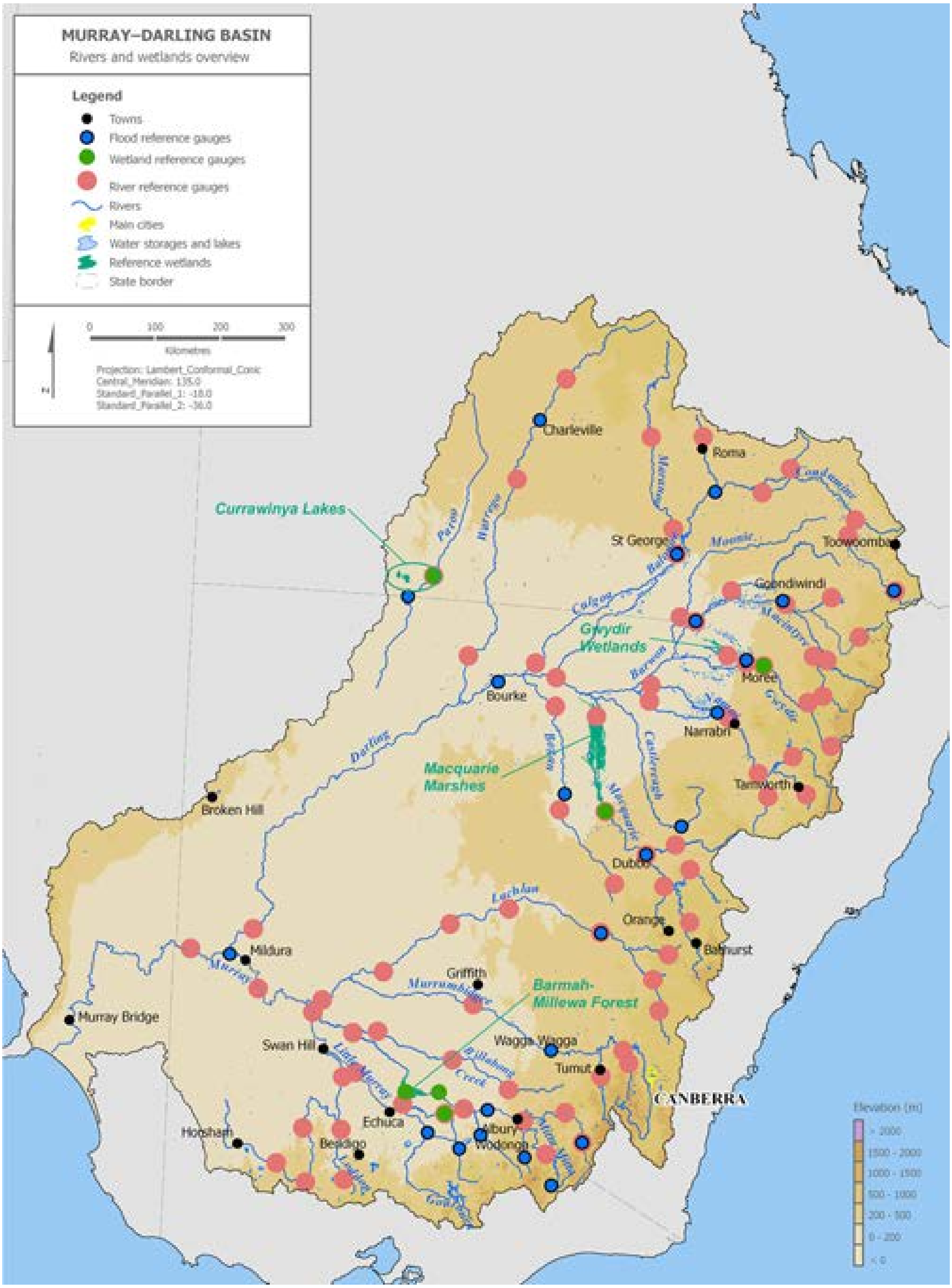


Figure 7-15. Stream gauges selected for analysis in the Murray–Darling Basin region

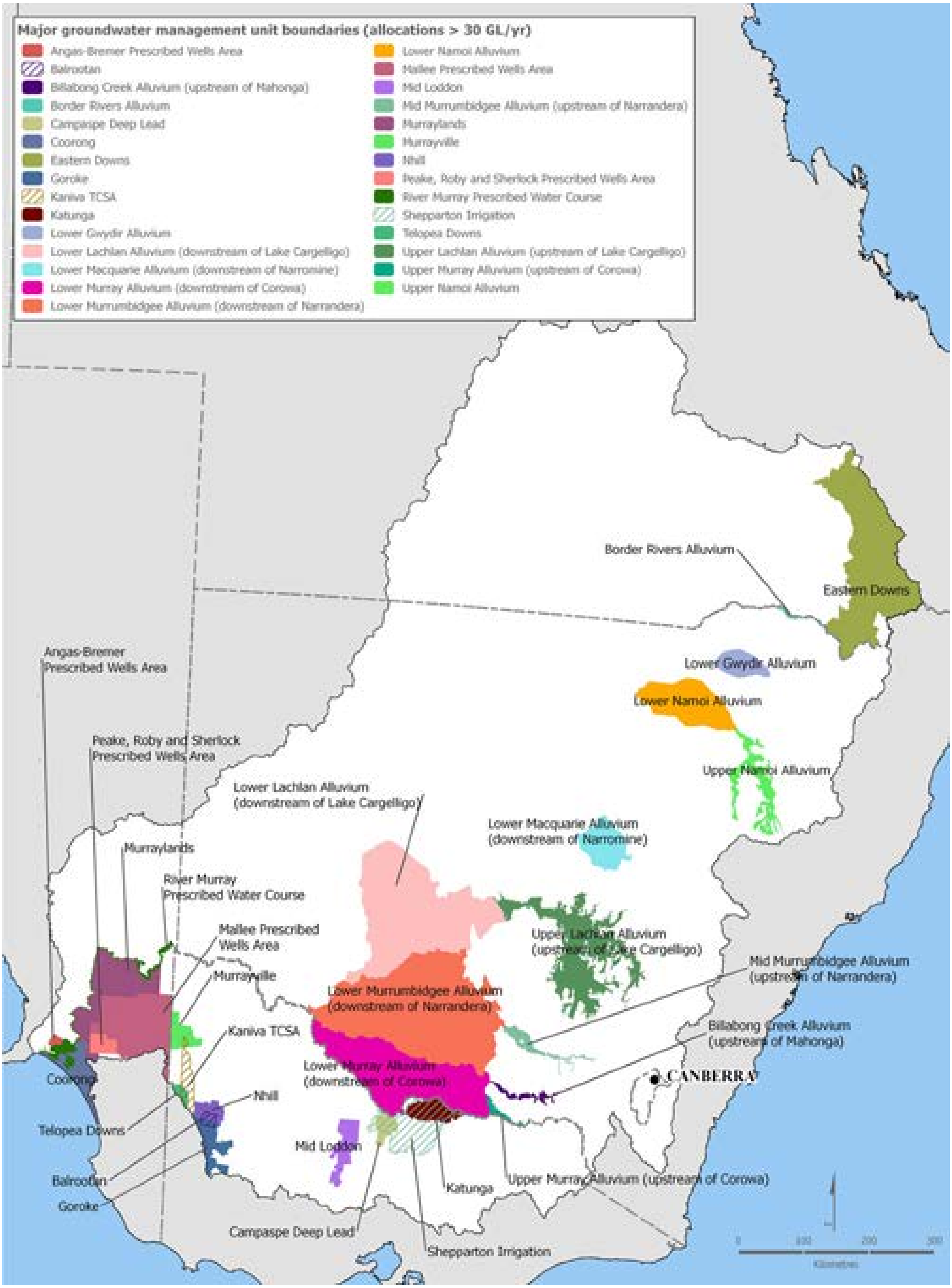


Figure 7-16. Major groundwater management units in the Murray–Darling Basin region (Bureau of Meteorology 2011e)

7.5.1 Streamflow and flood report (continued)

Through flood monitoring partnership arrangements, data were available for a number of flood gauges allowing reporting on flood occurrence and severity at those sites. The 23 gauges selected as indicative stations for the Murray–Darling Basin region are situated on rivers in the Basin from the Condamine River in the north to the River Murray in the south (Table 7-2). The stations were also selected on the basis of data quality and coverage for the 2009–10 year.

In 2009–10, there was major flooding in many of the inland river valleys of New South Wales and Queensland. The first major flood event resulted from former tropical cyclone *Laurence* that tracked across the continent from Western Australia and developed into a slow moving low, which on Christmas Day 2009 was located on the New South Wales–Queensland border. Up to 200 to 300 mm of rain was recorded at official gauges, which caused significant overland flooding between Bourke and Brewarrina and in the lower Namoi Valley, and moderate flooding along the Paroo and Warrego rivers. Record major flooding occurred along the lower Culgoa River from heavy local rainfalls, with up to 480 mm being reported from unofficial gauges in the area. As the low moved further west another 60 to 130 mm of rain fell over the Castlereagh Valley, which resulted in major flooding at Coonamble.

Rainfall associated with ex-tropical cyclone *Olga* was recorded in a wide area across Queensland during the first ten days of February 2010. Moderate to heavy rainfall produced fast stream rises over already saturated catchments. *Olga* crossed the coast north of Cairns initially on 24 January 2010 and, once re-formed in the Gulf, crossed again around Normanton on 29 January. The system then weakened into a rain depression within hours of making landfall and tracked steadily southeast. By 3 February 2010, the system was located over the far northeast corner of South Australia. It then moved eastwards along the Queensland–New South Wales border and during this time produced areas of moderate to heavy rainfall and flooding in the Paroo, Warrego, Condamine and Balonne rivers. The former tropical cyclone reached southeast Queensland on 7 February 2010 then moved westward, producing more areas of moderate to heavy rainfall and flooding on already saturated catchments before finally exiting Queensland on 9 February 2010.

In March 2010, a low, which began in the Northern Territory, tracked eastward to southwest Queensland resulting in widespread rainfall across a large area of southern Queensland. This caused record major flooding in the Condamine–Balonne rivers as well as major flooding in the Warrego and Paroo rivers. The floodwaters from Queensland caused major flooding along the Culgoa, Bokhara, Birrie and Narran rivers in New South Wales, and the flows from the Paroo River reached the Darling River upstream of Wilcannia for the third time in the past 200 years.

7.5.2 Inflows to wetlands

This section looks at water flows into a selection of wetlands important to the Murray–Darling Basin region. Four internationally recognised Ramsar wetland sites across the region (Currawinya Lakes, Gwydir Wetlands, Macquarie Marshes and the Barmah Forest) were selected for examination.

Seven reference gauges were selected for analysis of the pattern of wetland inflows for the four wetlands (Figure 7-15.). Figure 7-18 presents a comparison of 2009–10 monthly flows with flow deciles over the 30-year period 1980–81 to 2009–10 for each of these gauges.

While streamflow observations from the seven selected reference gauges do not represent the total volume of freshwater inflows to the wetlands under study, the reference gauge discharges are assumed to be representative of the variation of actual freshwater inflows to the wetlands.

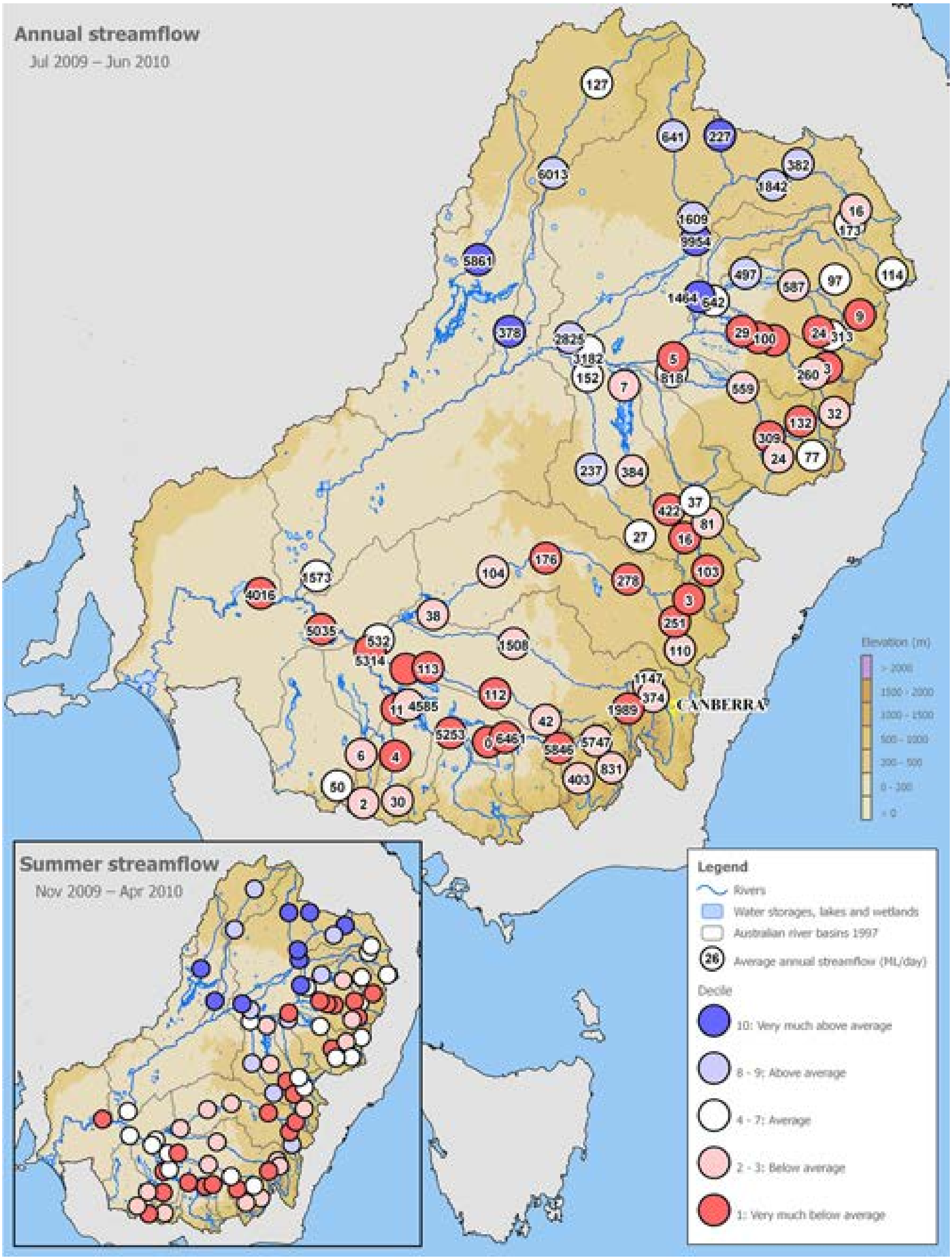
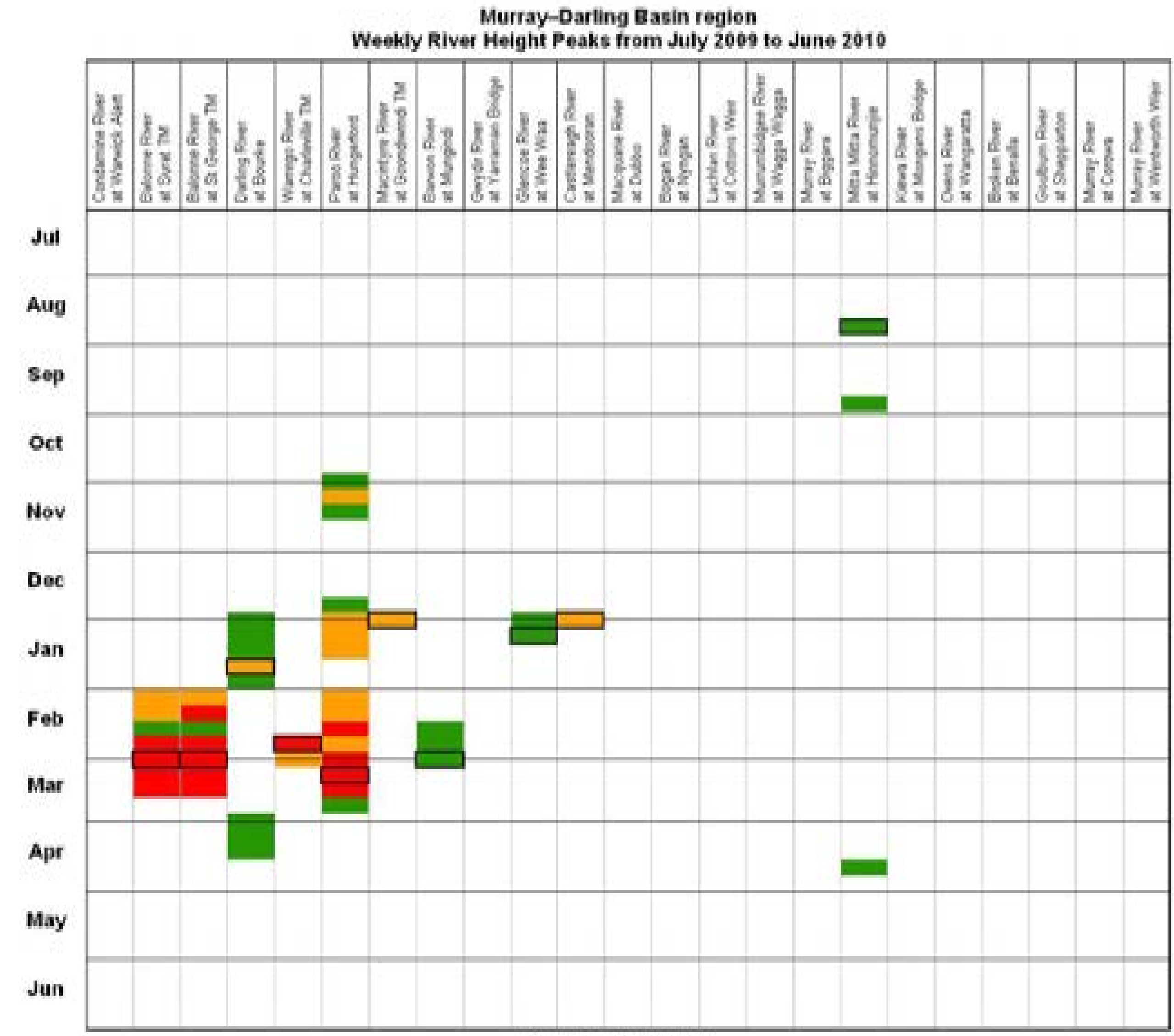


Figure 7-17 Annual and summer streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the Murray–Darling Basin region

Table 7-2. Weekly flood classifications for key flood gauging sites within the region (flood classes are derived in consultation with emergency services and local agencies, the peak height for the year is also included)



Peak flood level (m) and River height classes (m)

Site	Peak flood level (m): date	Peak flood level (m)	Major	Moderate	Minor
Condamine River at Warwick Alert	-	-	7.0	6.0	5.0
Balonne River at Surat TM	on 04/03/2010	12.0	8.5	6.5	4.5
Balonne River at St George TM	on 07/03/2010	12.9	6.0	5.0	4.0
Darling River at Bourke	on 23/01/2010	10.8	12.2	10.7	9.0
Warrego River at Charleville TM	on 02/03/2010	6.6	6.0	5.0	4.0
Paroo River at Hungerford	on 15/03/2010	2.9	2.0	1.5	1.0
Macintyre River at Goondiwindi TM	on 31/12/2009	6.3	8.5	6.0	4.0
Barwon River at Mungindi	on 08/03/2010	6.4	7.2	6.7	6.1
Gwydir River at Yarraman Bridge	-	-	7.0	6.5	4.0
Glencoe River at Wee Waa	on 06/01/2010	6.3	6.7	6.4	6.3
Castlereagh River at Mendooran	on 03/01/2010	7.3	9.0	5.0	3.3
Macquarie River at Dubbo	-	-	11.0	7.9	5.5
Bogan River at Nyngan	-	-	4.2	3.5	NA
Lachlan River at Cottons Weir	-	-	6.6	6.3	3.5
Murrumbidgee River at Wagga Wagga	-	-	9.6	9.0	7.3
Murray River at Biggara	-	-	3.0	2.6	2.0
Mitta Mitta River at Hinnomunjie	on 21/08/2009	1.9	3.0	2.5	1.8
Kiewa River at Mongans Bridge	-	-	4.5	3.5	2.4
Ovens River at Wangaratta	-	-	12.7	12.4	11.9
Broken River at Benalla	-	-	4.5	3.7	2.5
Goulburn River at Shepparton	-	-	11.0	10.7	9.5
Murray River at Corowa	-	-	6.6	5.9	3.8
Murray River at Wentworth Weir	-	-	33.8	32.7	32.1

Colour codes:

- Below flood level
- Annual flood peak
- Major flooding
- Moderate flooding
- Minor flooding

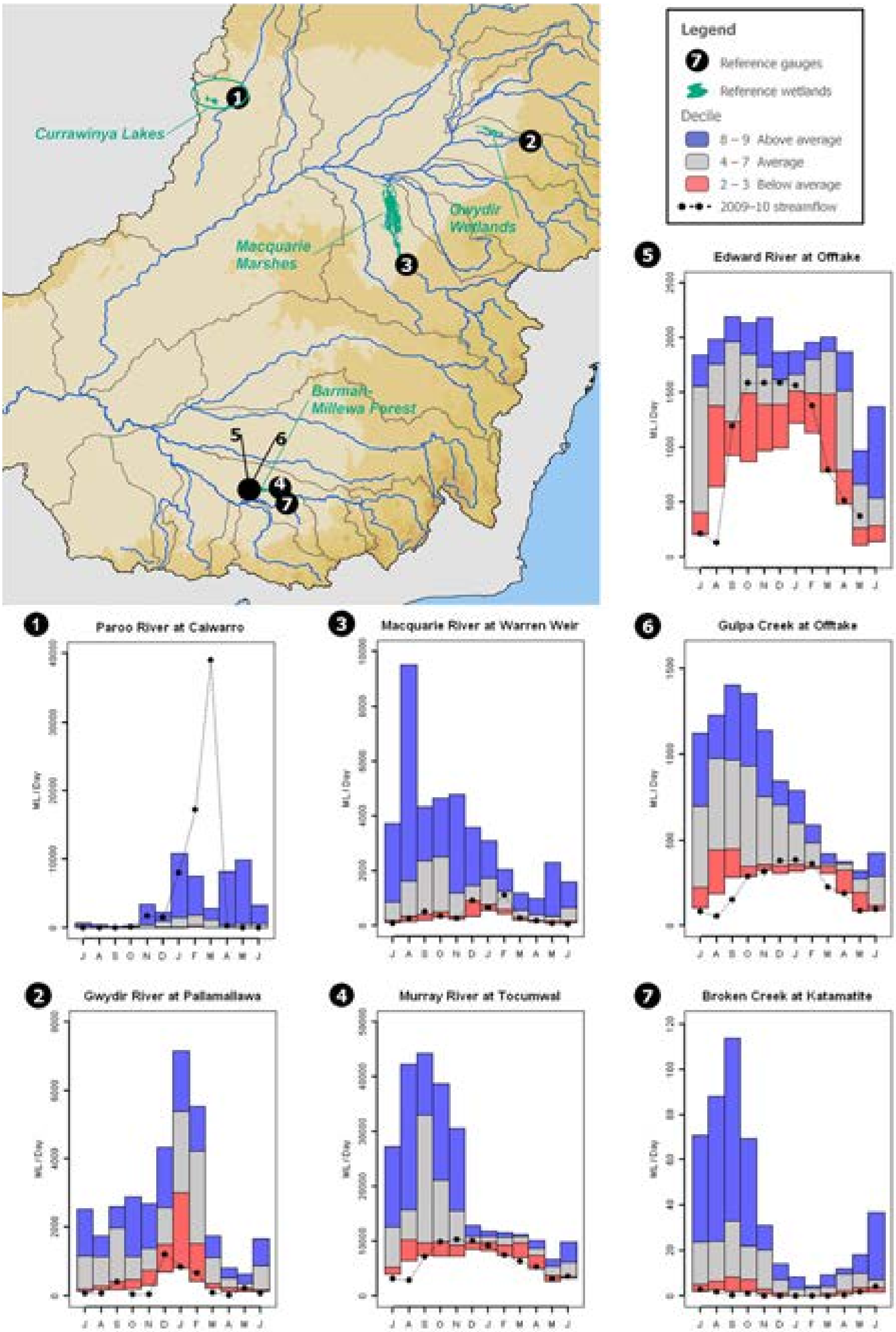


Figure 7-18. Monthly discharge hydrographs for 2009–10 compared with the period of 1980 to 2010 for reference gauges on rivers flowing into selected wetland sites of the Murray–Darling Basin region

7.5.2 Inflows to wetlands (continued)

With this in mind, the following may be observed with respect to water supply to these wetlands in 2009–10 relative to the 30-year record:

- in the arid northern part of the region, the Paroo River inflow to the Currawinya Lakes (gauge 1) experienced a very much above average late summer flow peak. In contrast, the 2009–10 winter flows were very low and closer to the 30-year average
- for the Gwydir Wetlands on the Gwydir River in the northeast of the region (gauge 2), the normally high inflows during summer were below average to very much below average in 2009–10
- inflows to the Macquarie Marshes on the Macquarie River in the central north of the region (gauge 3) were below average in all months of 2009–10 except for February, when inflows were average
- inflows to the southern Barmah Forest wetlands from the River Murray (gauge 4) were generally below average or very much below average in most months of 2009–10 including the normally high inflow months during winter and spring
- in the Edward River (gauge 5), feeding the Barmah Forest wetlands in the north, flows were mostly average over early summer but generally below average at other times
- the Gulpa Creek (gauge 6) streamflow into the Barmah Forest wetlands was very much below average for most months of 2009–10 with only the three summer months of December 2009 to February 2010 experiencing average flows
- the Broken Creek, a smaller inflow to the southern part of the Barmah Forest (gauge 7), showed below average to very much below average flows throughout 2009–10.

Figure 7-19 explores the pattern of changing wetland river inflows through the 30 years between 1980 and 2010. A five-year moving window was applied over daily streamflow data to produce the 10th, 50th and 90th flow percentiles for each of the seven reference gauges.

The 10th, 50th and 90th flow percentiles were selected to approximate patterns of low, median and high flows, respectively. Low flows are associated with a base level environmental inflow needed to ensure a minimum level of ecological function over the long-term. Median river flows sustain basic wetland hydrology and ecological function whereas high flows and extreme events are associated with wetland flooding and floodplain inundation, and are necessary for reproduction and recruitment of flora and fauna.

Note that any variability in the flow percentiles of Figure 7-19 can be a result of changing climatic conditions as well as human activity. However, the purpose of the graphs is not to analyse the cause of the variability and, in addition, the 10th percentiles (low flow) are sometimes estimated to be 0 ML/day and therefore are shown as the minimum plotted value for a gauge in Figure 7-19.

With respect to the 30-year period, Figure 7-19 indicates:

- the ephemeral Paroo River had variable median and high inflows to the Currawinya Lakes, with substantial periods of negligible flow over the 30-year record (gauge 1)
- low, median and high inflows into the Gwydir Wetlands and Macquarie Marshes (gauges 2 and 3) show a cyclic pattern with a decline over the 30-year period
- the especially high flows of the River Murray upstream of the Barmah Forest wetland (gauge 4) show a slight decline in volume over the 30-year record, suggesting that less frequent flooding occurs and flood volumes decrease
- high, median and low flows in the Edward River (gauge 5) were steady for most of the 30-year period, with low flows dropping substantially in volume in the mid-1990s and remaining at relatively low levels thereafter
- Gulpa Creek (gauge 6) displayed little variation in the pattern of low, median and high flows into the Barmah Forest wetland over the 30-year record, with only a slight, but steady decline in flow volumes after 1993
- low, median and high flows into the Barmah Forest wetlands from the Broken Creek (gauge 7) all increased in the late 1980s and early 1990s but then progressively declined to historically low levels by the end of the 30 year period.

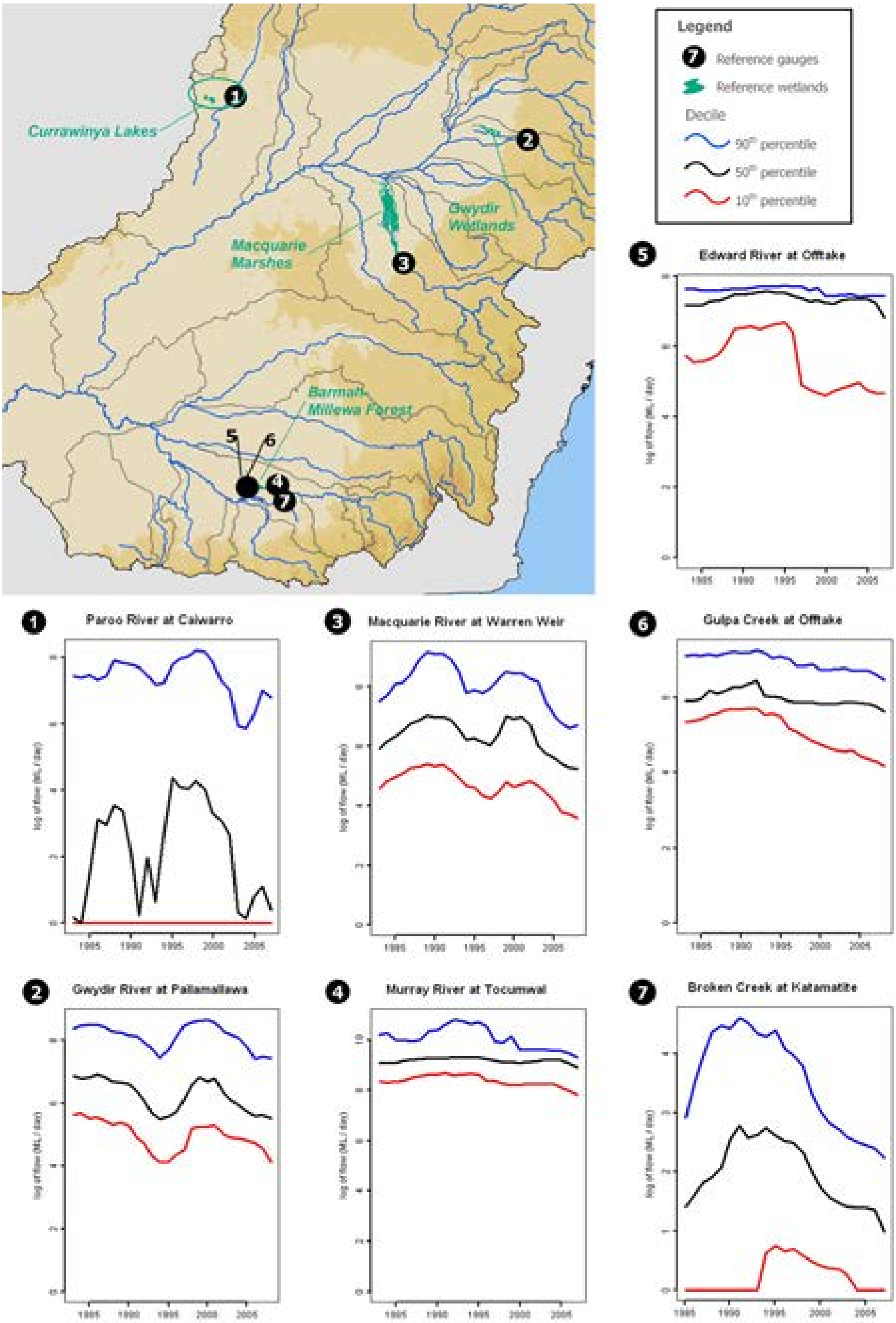


Figure 7-19. Daily flow percentiles extracted from a five-year moving window at reference gauges on rivers flowing into selected wetland sites of the Murray–Darling Basin region

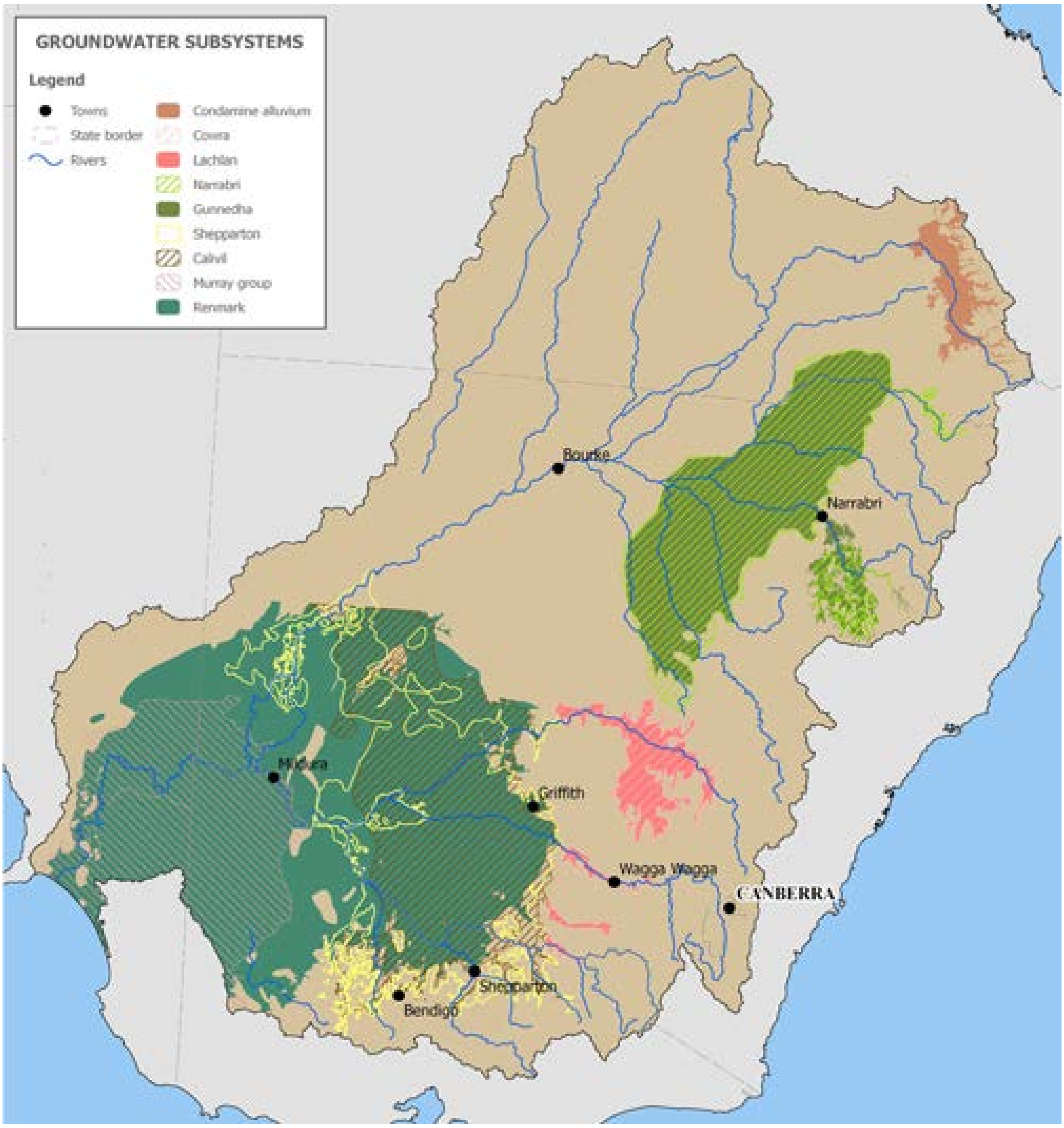


Figure 7-20. Groundwater aquifer subsystems in the Murray–Darling Basin region

7.5.3 Groundwater status

The status of groundwater levels in the Murray–Darling Basin region is evaluated for the most productive aquifers associated with major groundwater management units (Figure 7-20). Status is assessed by estimating trends in groundwater levels from 2005 to 2010. This period follows the Murray–Darling Basin Commission Groundwater Status Report for the period of 2000–05 (Murray–Darling Basin Commission 2008).

The trends in groundwater levels from 2005–10 are evaluated in the following way using a 20 km grid across an aquifer:

- a linear trend in groundwater levels is evaluated for each bore with at least 20 level measurements since 2005
- the linear trend in groundwater levels for a 20 km grid cell is assessed as:
  - decreasing (where more than 60 per cent of the bores have a negative trend in levels lower than -0.1 m/year)
  - stable (where the trend is lower than 0.1 m/year and higher than -0.1 m/year for more than 60 per cent of the bores)
  - increasing (where more than 60 per cent of the bores have a positive trend in levels higher than 0.1 m/year)
  - variable (where there is no dominant trend in groundwater levels amongst the bores within a 20 km grid cell).

Bore data used in this assessment are derived from New South Wales, Queensland and South Australia; Victorian data were not ready for inclusion in this report. Example bore hydrographs are presented for each aquifer over the 1990–2010 period and trends are discussed with a focus on the 2005–10 period. Where possible, the bore hydrographs presented are for the same bores used in the Groundwater Status Report 2000–05 (Murray–Darling Basin Commission 2006).

Condamine Alluvium Subsystem

The map in Figure 7-21 illustrates the spatial and temporal trends in groundwater levels in the Condamine Alluvium Subsystem from 2005–10. Many of the 20 km grid cells are shown as 'variable' indicating that, within a grid cell, no clear majority of bores has a specific trend. In other cells, groundwater levels are declining or stable.

Selected bores 1, 2 and 4 show a linear decline in groundwater levels over the 2005–10 period. Groundwater salinity data are not available for many bores in the Condamine, but for bore 2 electric conductivity values are less than 1,000 µS/cm (approximately 600 mg/L) and are relatively constant. The fluctuations in water level observed in bore 3 are likely to be caused by groundwater extraction in nearby bores. Bore 6 shows an upward trend in water level observed in areas near the upper tributaries of the Condamine River.

Narrabri and Gunnedah Subsystems

Figure 7-22 illustrates the spatial and temporal trends in the Narrabri Subsystem and the associated underlying Gunnedah Subsystem. The water levels in bores within Narrabri Subsystem are generally falling, with some areas showing variable or stable levels within the 20 km grid cells from 2005–10.

Bore 1 is located in the upper reaches of the Border Rivers groundwater management unit in Queensland. The hydrograph indicates a drop in groundwater level of about 30m since 1990 and high annual fluctuations in the groundwater level that may be caused by nearby groundwater extractions. Bore 2 is located in the Lower Namoi groundwater management unit. The hydrograph shows that water levels in 2005–10 continued their gradual long-term decline. Bore 3 is located in the Cox's Creek region of the Upper Namoi groundwater management unit. The groundwater levels show a very gradual rate of decline with little annual fluctuation indicating that the bore is remote from the influence of groundwater extraction. Bore 4 is located in the Gwydir catchment and shows a very stable water level over the measurement period.

The groundwater levels in the more permeable Gunnedah Subsystem, like the Narrabri, indicate a declining trend overall. There are a small number of cells that show stable or increasing trends in water levels.

Bore 1 is located in the Lower Namoi groundwater management unit and shows a slight increase in the water level, but is generally stable. Bore 2 is located at the western margin of the Lower Namoi groundwater management unit and is stable. Bores 3 and 4 are at the eastern (upstream) end of the Lower Namoi groundwater management unit and are located in an area of groundwater extraction. Both show a decline in the groundwater level and possible interference from local groundwater extraction.

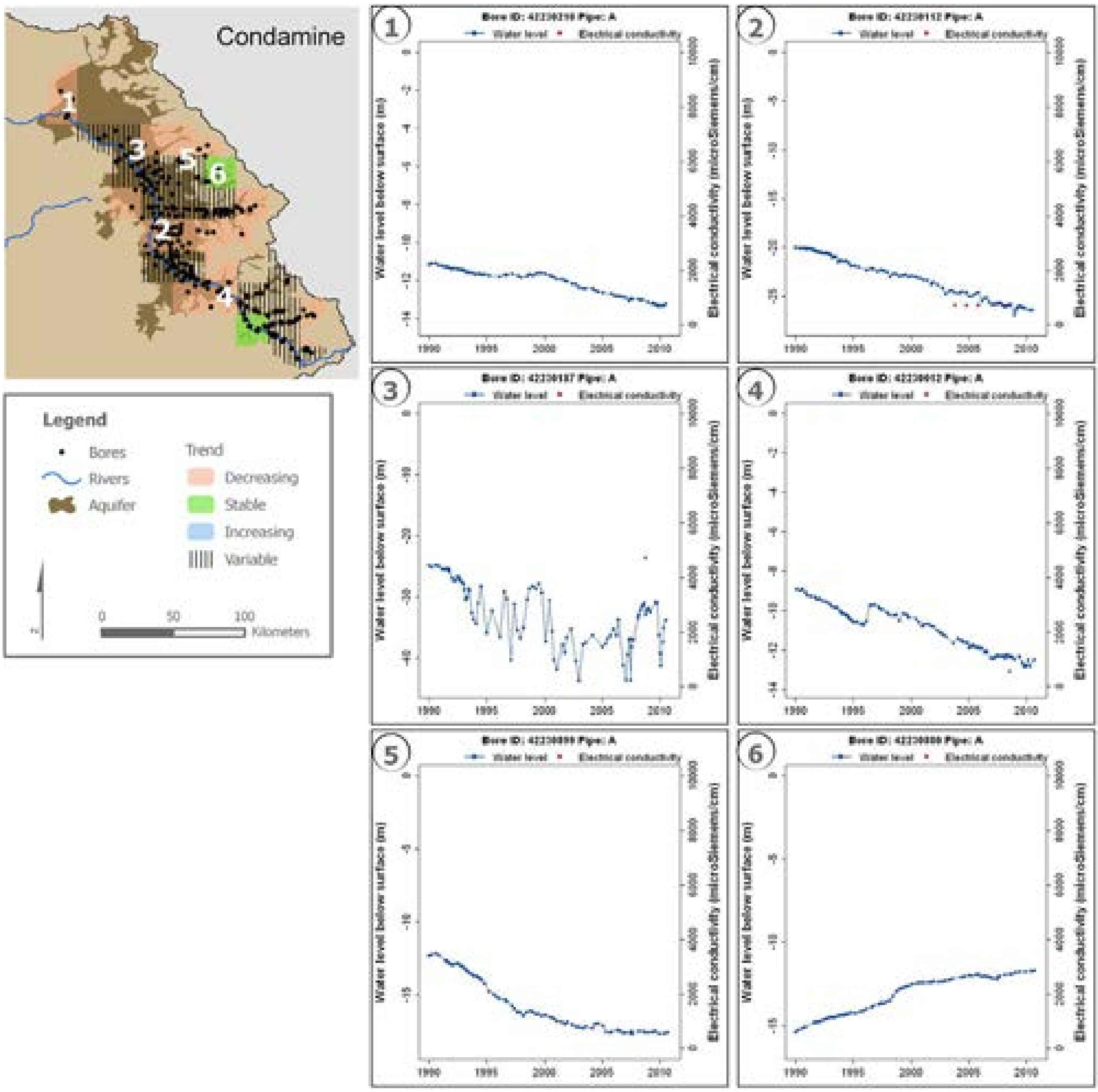


Figure 7-21. Spatial distribution of trends in groundwater levels for the Condamine Alluvium Subsystem for 2005–10, with selected hydrographs showing groundwater levels (blue line) and salinity (red dots)

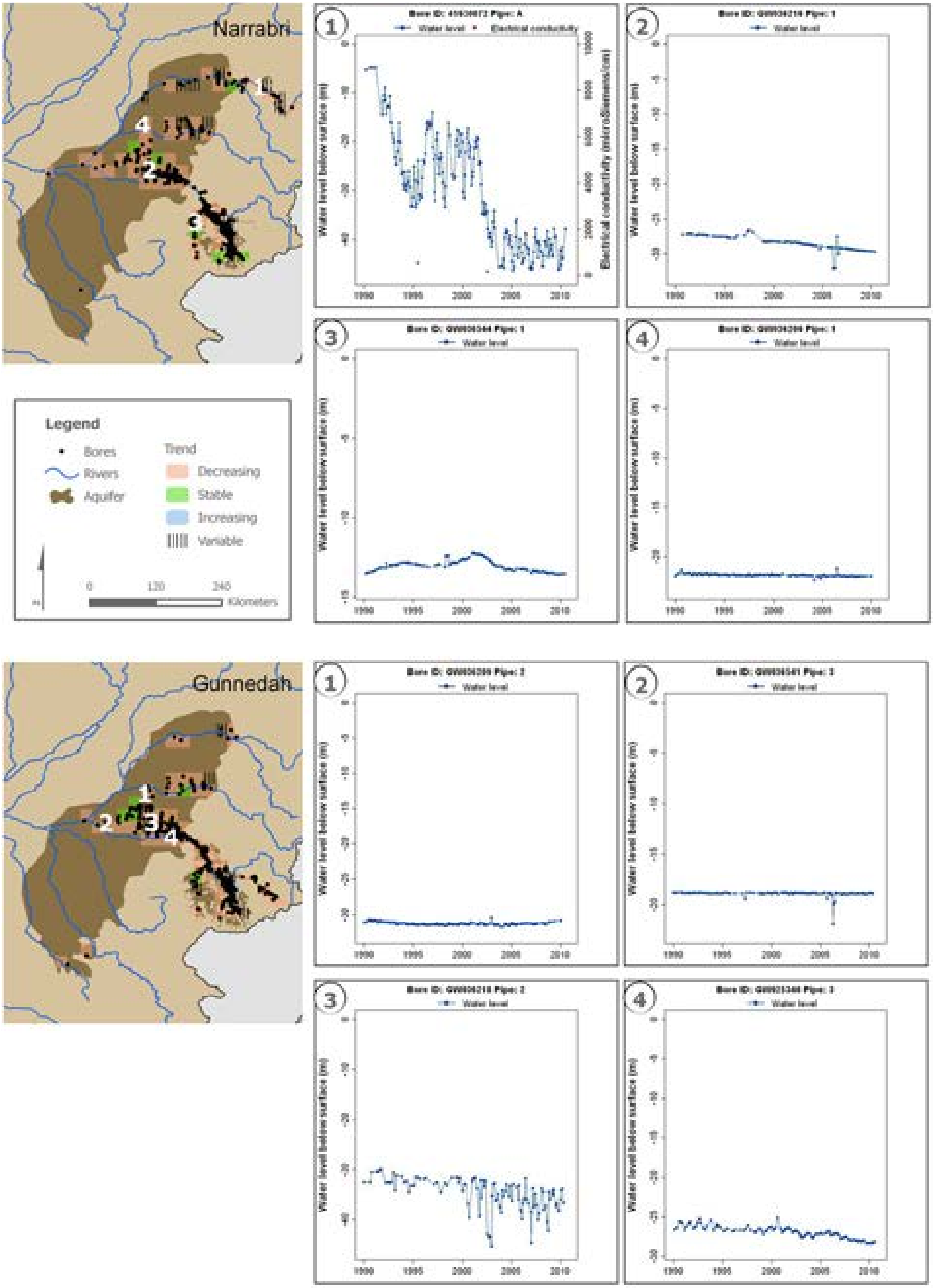


Figure 7-22. Spatial distribution of trends in groundwater levels for the Narrabri and Gunnedah Subsystems for 2005–10, with selected hydrographs showing groundwater levels (blue line) and salinity (red dots)

Cowra and Lachlan Subsystems

Figure 7-23 illustrates the spatial and temporal trends in the Cowra and the underlying Lachlan Subsystems. Generally the Cowra and Lachlan Subsystems show declining levels, with a few cells in the Cowra Subsystem indicating variable trends in water levels for 2005–10.

Bores 1a, 2a and 3a represent groundwater levels in the Cowra Subsystem while bores 1b, 2b and 3b represent groundwater levels in the Lachlan Subsystem. These bores are nested and the hydrographs indicate hydraulic connection between the Lachlan and overlying Cowra Subsystem. Annual variations in groundwater level in the deeper Lachlan Subsystem are most likely due to the effects of groundwater extraction from this aquifer. In the mid-Murrumbidgee (bores 1 and 2), a steady decline in groundwater levels is noticeable from 1994 onwards. The single bore hydrograph in the Lachlan valley (bore 3) suggests that a decline in levels begins around the year 2000.

Shepparton Subsystem

Generally the water level fluctuation for the Shepparton Subsystem over the past five years shows declining levels. Bore levels most likely respond to groundwater extraction in the main groundwater management units as well as to comparatively low rainfall.

Hydrographs of two bores located within the Shepparton Subsystem are presented in Figure 7-24. Bore 1 is located southwest of Deniliquin in the Lower Murray groundwater management unit of New South Wales. The hydrograph indicates an increasing water level overall, with a slight decline in levels since 2007. Bore 2 is located west of Griffith in the Lower Murrumbidgee groundwater management unit of New South Wales. The hydrograph shows an annual fluctuation of water level of up to 10 m. The high amplitude of water level fluctuation is due to the effects of seasonal groundwater extraction. There is also a long-term decline in levels.

Calivil Subsystem

The trend analysis indicates that groundwater levels within the Calivil Subsystem are predominantly decreasing. This decline is likely to be the result of groundwater extraction in groundwater management units and comparatively low rainfall (and associated low groundwater recharge) over the period.

Hydrographs of groundwater levels in three bores located near the southern and western margins of the Calivil Subsystem are presented in Figure 7-24. Bore 1 is located at the western (downstream) end of the Lower Murrumbidgee groundwater management unit. The hydrograph shows relatively stable groundwater levels since 1990. Bore 2 is located on the River Murray, north of Barham in New South Wales. The water level trends over 2005–10 indicate a decline, which appears to be increasing over the period. This decline is consistent with a response to pumping in the Lower Murray groundwater management unit further to the east. Bore 3 is located near Deniliquin in the Lower Murray groundwater management unit of New South Wales. The hydrograph shows considerable fluctuation in groundwater levels due to drawdown associated with groundwater extraction during the irrigation season and subsequent recovery when the extraction ceases in winter. There is a falling trend in groundwater level from the mid-1990s.

Murray Group Subsystem

The groundwater levels mostly decreased within the Murray Group from 2005–10 (using monitoring bore data in South Australia only and including data from bores outside the Murray–Darling Basin region). This is clearly illustrated in Figure 7-25.

Bore 1 shows a high annual fluctuation in the water levels due to pumping at nearby wells and has a declining water level overall. Bores 2 and 4 are outside the region and the groundwater level is shallow and declining with fluctuations due to the effects of pumping. Bore 3 located east of Murray Bridge indicates a stable water level for 1990–2010.

Renmark Subsystem

The spatial and temporal trends in the Renmark Subsystem are also shown in Figure 7-25, which indicate that the water levels in the Renmark Subsystem over the past five years are mainly declining. The groundwater bores that are used in this analysis are relatively evenly distributed in the east with usually only one bore per reference cell.

The hydrograph of bore 1 shows slightly decreasing groundwater levels from 1990 onwards. Bore 2 is located in the centre of groundwater pumping influences of the Lower Murrumbidgee groundwater management unit. The groundwater water level data is available up to 2007. During the period of 2005–07, the levels responded dramatically to the seasonal groundwater extraction cycle. There is also a declining trend in groundwater levels since the mid-1990s.

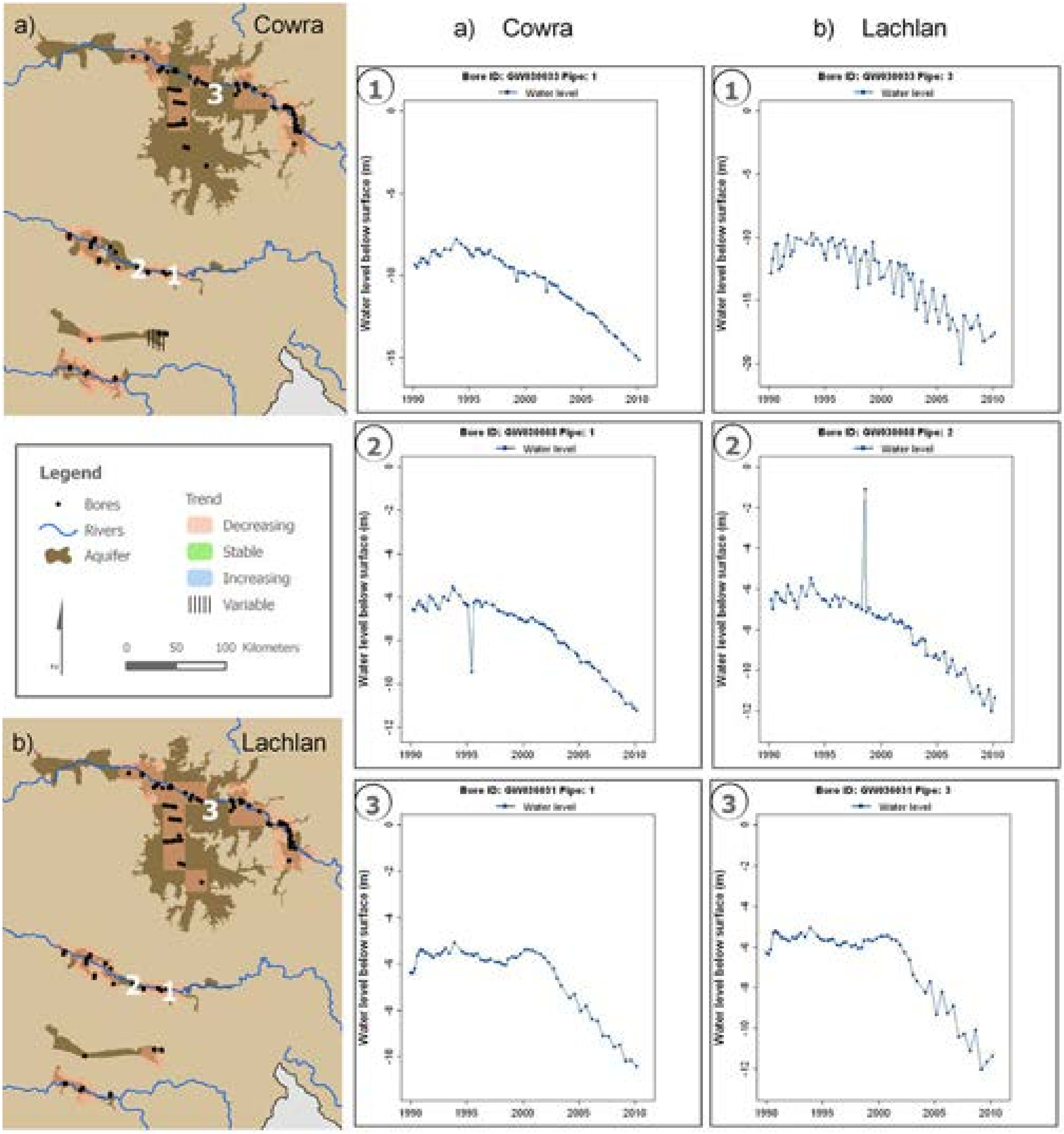


Figure 7-23. Spatial distribution of trends in groundwater levels for the Cowra and Lachlan Subsystems for 2005–10, with selected hydrographs showing groundwater levels

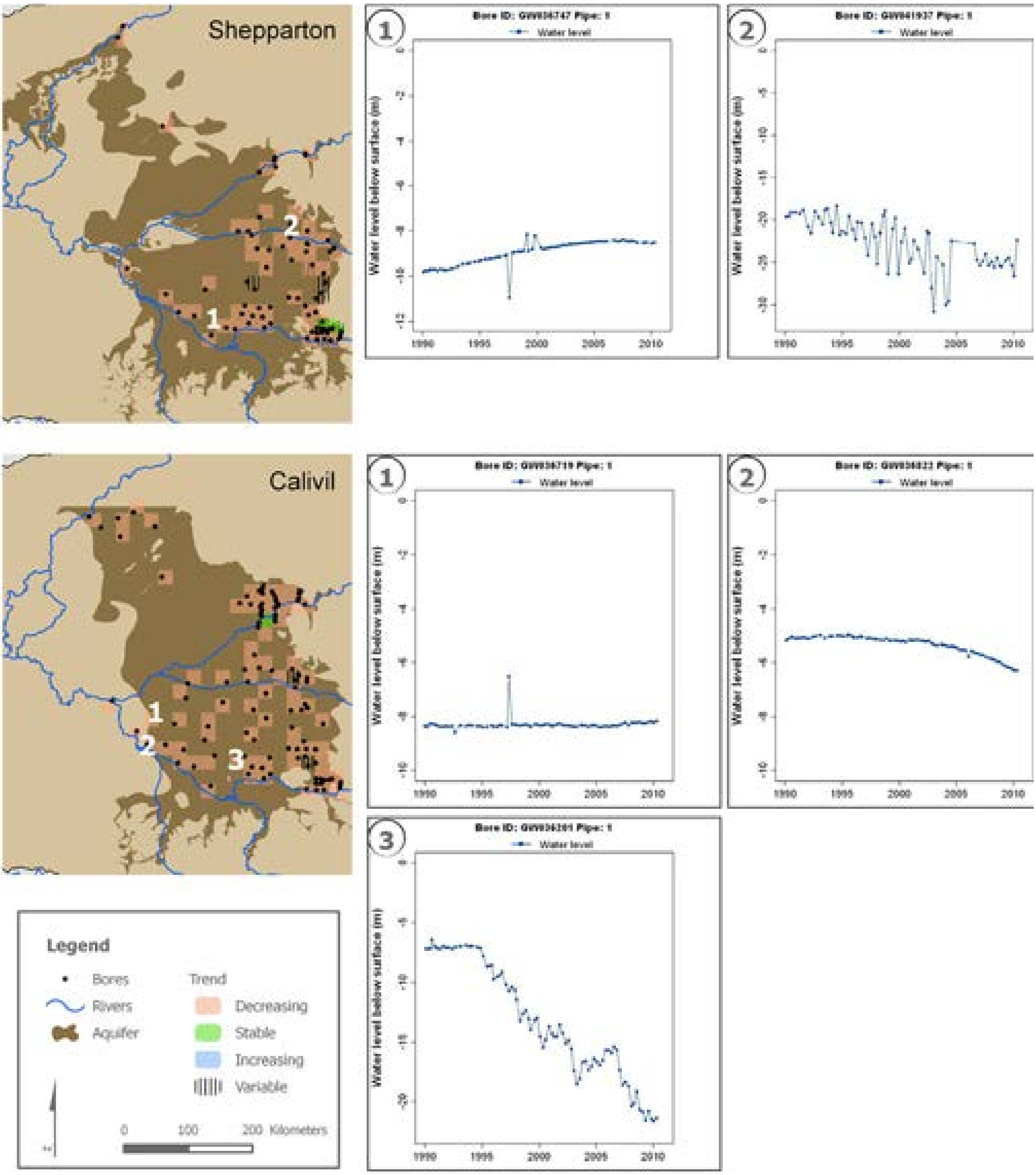


Figure 7-24. Spatial distribution of trends in groundwater levels for the Shepparton and Calivil Subsystems for 2005–10, with selected hydrographs showing groundwater levels

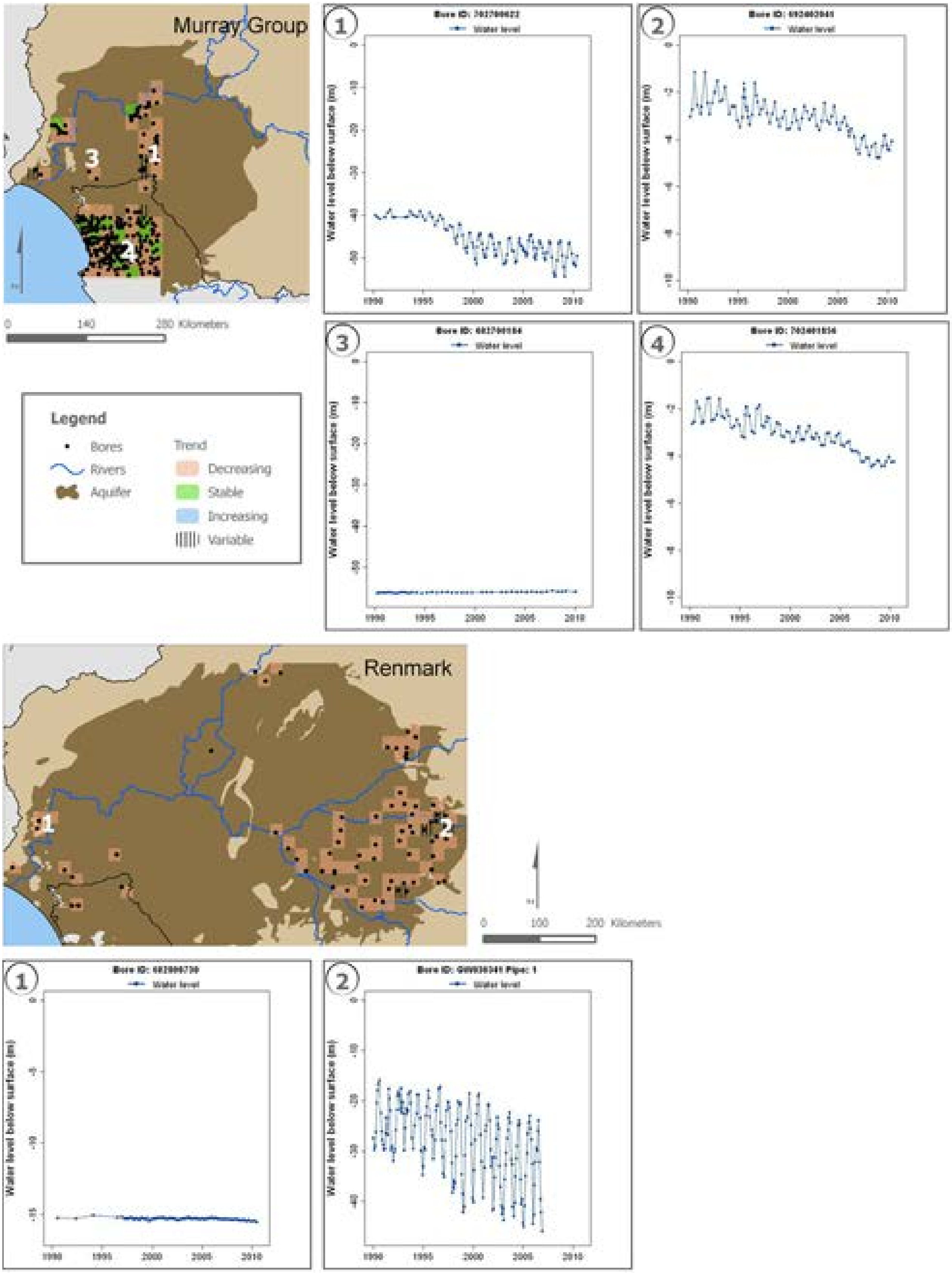


Figure 7-25. Spatial distribution of trends in groundwater levels for the Murray Group Subsystem and for the Renmark Subsystem for the 2005–10 period, with selected hydrographs showing groundwater levels

7.6 Water for cities and towns

The main urban centres of the Murray–Darling Basin region are sparsely distributed throughout the region, with most centres located on the western slopes of the Great Dividing Range and along the River Murray as shown in Figure 7-26. The major cities and towns of the region (those with a population greater than 25,000) are shown in Table 7-3 together with the river basin in which they are located and their main urban water supply sources.

The Canberra and Queanbeyan conurbation is the largest urban centre in the region. The Corin and Googong reservoirs represent 93 per cent of the total storage capacity for this centre. Figure 7-26 shows the accessible storage in the Corin and Googong reservoirs from 1980 to 2010 and during 2009–10.

Table 7-3. Cities and their water supply sources in the Murray–Darling Basin region

City/town	Population*	River basin	Major supply sources
Canberra	350,000	Murrumbidgee	Cotter, Bendora and Googong reservoirs and Murrumbidgee River
Toowoomba	128,000	Condamine–Culgoa	Cooby Creek, Cressbrook and Perseverance reservoirs
Albury–Wodonga	100,000	Murray–Riverina and Kiewa	River Murray
Bendigo	89,000	Loddon	Lake Eppalock and Malmsbury and Upper Coliban reservoirs
Wagga Wagga	58,000	Murrumbidgee	Murrumbidgee River and groundwater
Queanbeyan	51,000	Murrumbidgee	Cotter, Bendora and Googong reservoirs and Murrumbidgee River
Mildura	50,000	Mallee	Mildura Weir
Shepparton–Mooroopna	48,000	Goulburn–Broken	Goulburn and Broken rivers
Tamworth	46,000	Namoi	Chaffey Reservoir
Orange	38,000	Macquarie–Bogan	Suma Park and Spring Creek reservoirs
Dubbo	37,000	Macquarie–Bogan	Macquarie River and groundwater
Bathurst	33,000	Macquarie–Bogan	Chifley and Winburndale reservoirs
Griffith	25,700	Murrumbidgee River	Murrumbidgee River via irrigation canals

* Australian Bureau of Statistics (2010b)

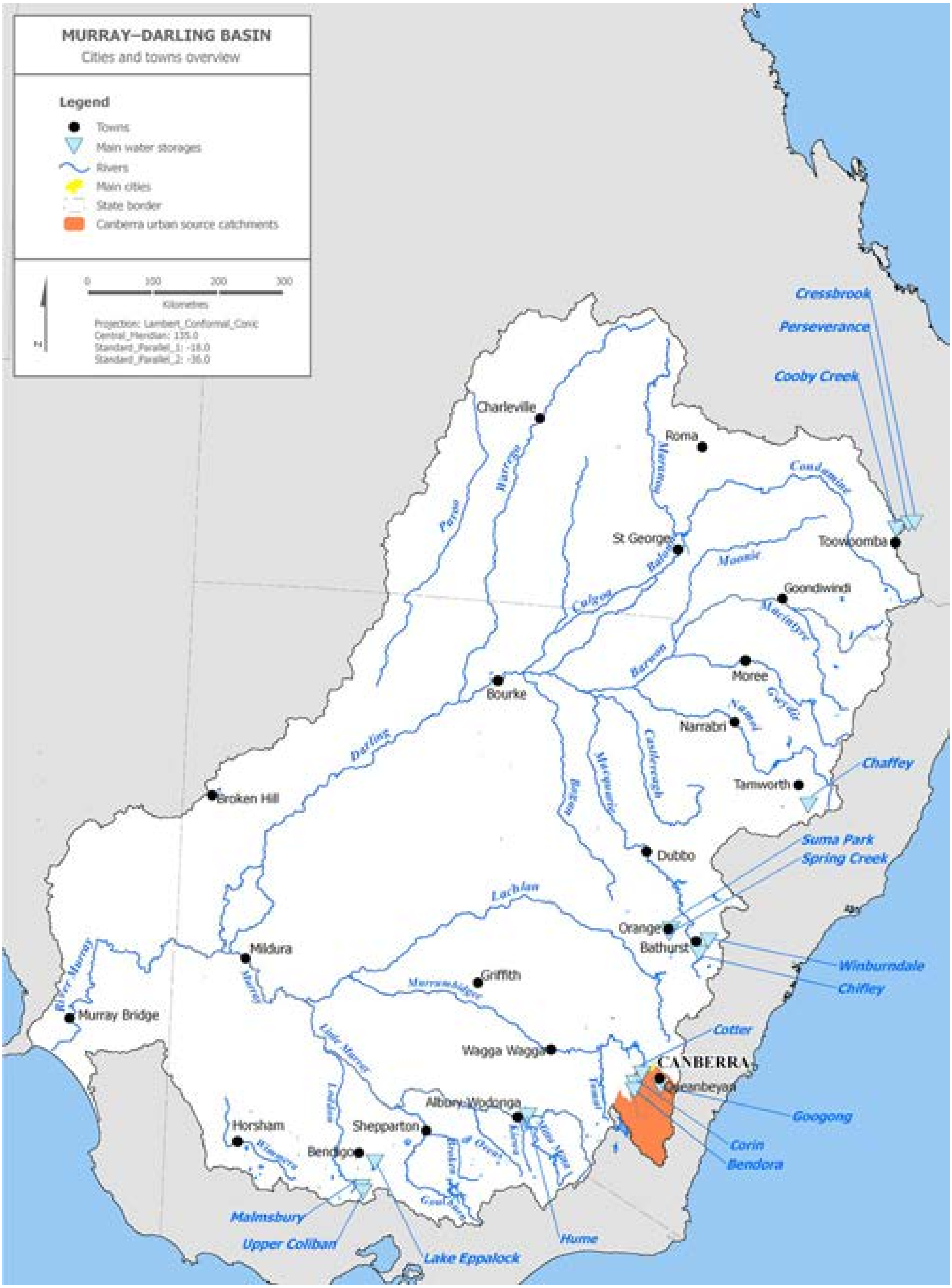


Figure 7-26. Urban areas and supply storages in the Murray–Darling Basin region

7.6.1 Canberra and Queanbeyan

The Canberra and Queanbeyan water supply area is located 150 km inland to the east of the nearby Brindabella Ranges. The area has a population of over 400,000 (Australian Bureau of Statistics 2010b).

Urban water infrastructure and management in Canberra and Queanbeyan

ACTEW Corporation is the ACT Government-owned statutory body that owns and manages the Canberra water supply system. ACTEW controls surface water diversions, operates water treatment plants, maintains Canberra's reticulation system and delivers water to Queanbeyan where the infrastructure is managed and maintained by Queanbeyan City Council.

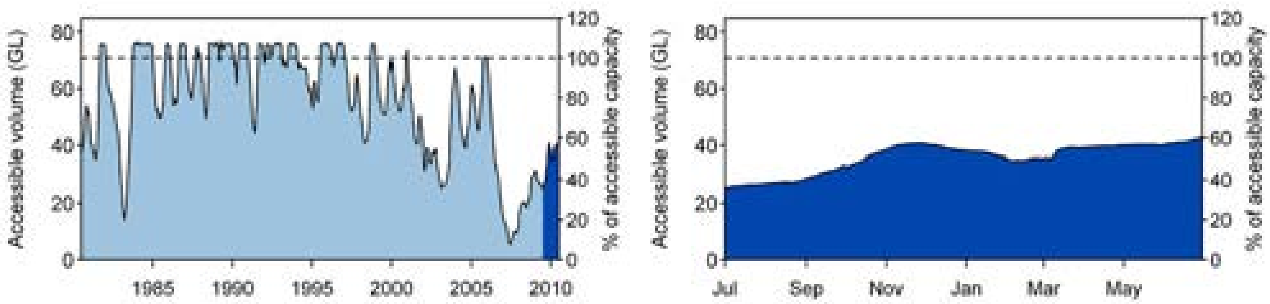
Figure 7-28 illustrates the major components of the Canberra and Queanbeyan urban water supply system. The key components of the system are four water storages, two water treatment plants and four wastewater treatment plants. Water is sourced from three catchments: the Cotter River catchment, the Murrumbidgee River catchment and the Queanbeyan River catchment.

The Mount Stromlo water treatment plant receives water from the Corin, Bendora and Cotter reservoirs, all located on the Cotter River, as well as water from the Murrumbidgee River at the Cotter pump station. Water taken from Googong Reservoir receives treatment at the Googong water treatment plant. Excess treated water can be released into the Googong Reservoir for storage (ACTEW 2007).

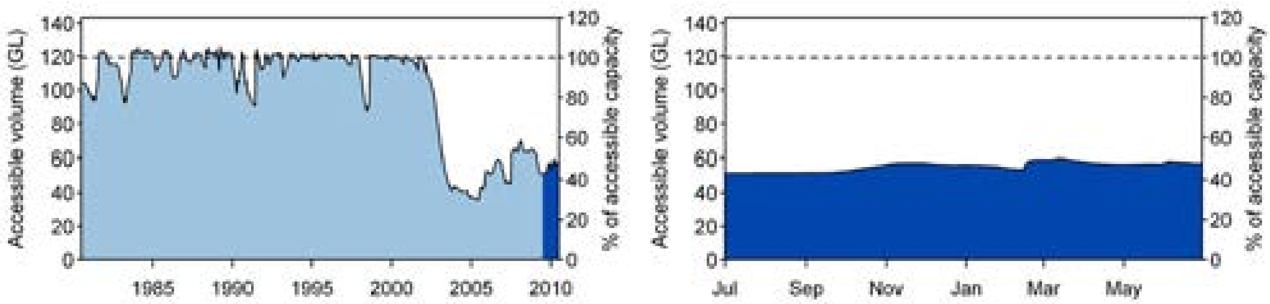
Intense bushfires in the Cotter River catchment in January 2003 resulted in poor water quality in the Cotter River system, requiring the Mount Stromlo water treatment plant to be upgraded to ensure adequate treatment whilst the Cotter catchment recovered. The upgraded plant was commissioned in 2004.

In 2005 and 2006, bathymetric surveys were conducted on the four water storages. As a result, the total accessible storage capacity of the system was down-rated from 215 GL to 212 GL (ACTEW 2007).

Canberra and Queanbeyan (Corin) *



Canberra and Queanbeyan (Googong) *



* Note that the percentage of accessible capacity was calculated using the 2010 total accessible capacity. It ignores the transitional change of accessible volume, which reduced the capacity of both storages. The capacity of Googong Reservoir had a phased change from 1975 to 2006, while the Corin Reservoir capacity had a phased change from 2003 to 2006. These changes cause the percentage of capacity shown to exceed 100 per cent prior to 2006. The total volume can also exceed 100 per cent capacity during periods of high inflow.

Figure 7-27. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for Canberra and Queanbeyan

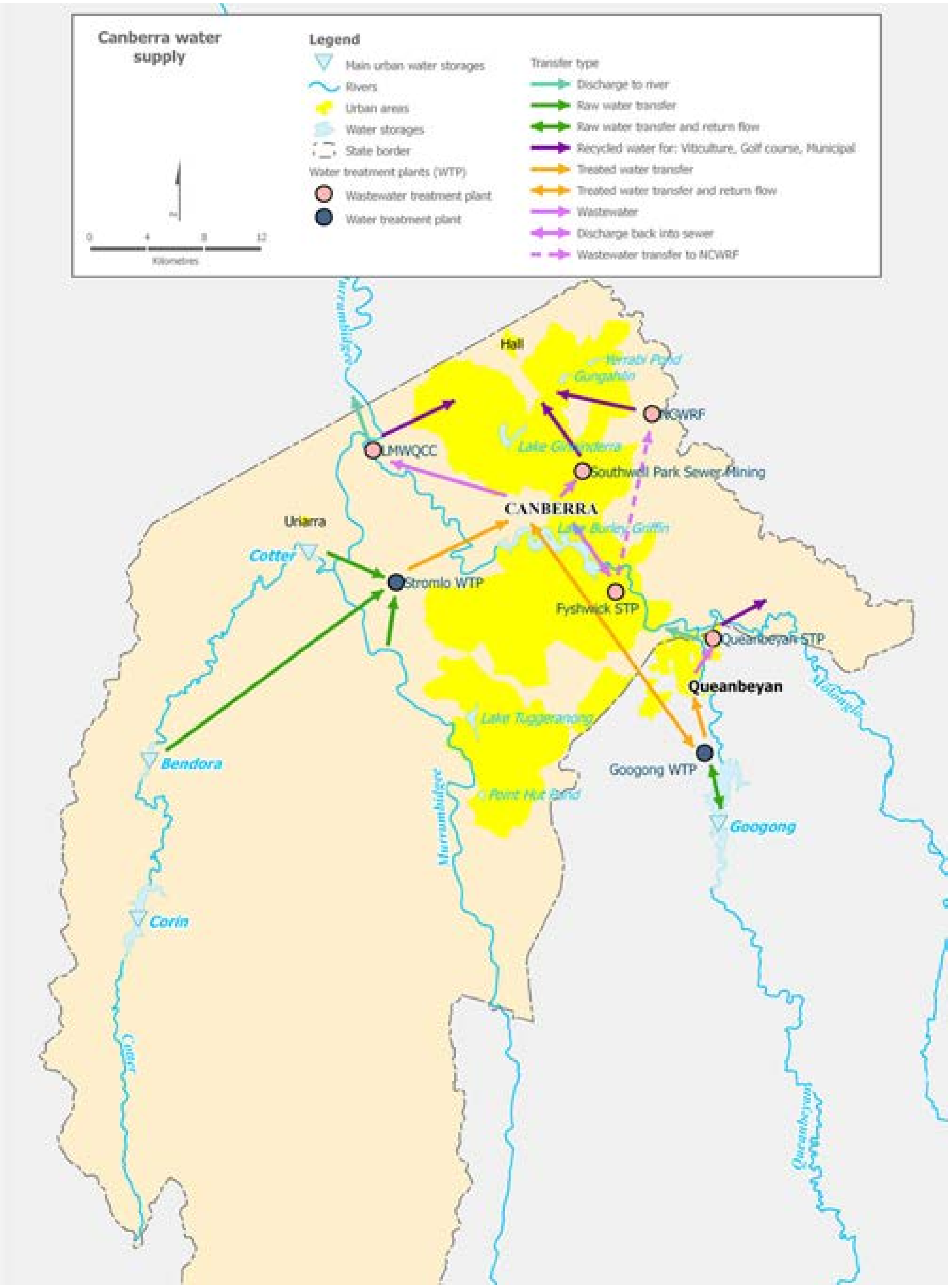


Figure 7-28. Water supply schematic for Canberra and Queanbeyan

7.6.1 Canberra and Queanbeyan (continued)

In order to secure water resources for Canberra and Queanbeyan's future, two main projects are in progress. The most significant is the enlargement of the Cotter Reservoir from 3.9 GL to 78 GL total accessible storage capacity. Construction of the new dam wall commenced in late 2009 (ACTEW 2011). The second project is a 13 km underground pipeline that will transfer water from the Murrumbidgee River at Angle Crossing to Burra Creek, where it will flow into the Googong Reservoir. Construction on the pipeline commenced in January 2011 (ACTEW 2011).

The Lower Molonglo Water Quality Control Centre is the largest wastewater treatment plant in Canberra. The plant treats more than 90 ML/day of wastewater before discharging it to the Molonglo River or providing it for irrigation purposes at nearby vineyards and golf courses. The Fyshwick wastewater treatment plant collects and treats industrial and domestic sewage from Fyshwick and surrounding suburbs. Treated wastewater from this plant is then discharged back into the sewer or delivered to the North Canberra Water Reuse Facility where it undergoes secondary treatment before it is used for irrigation purposes. A sewer mining facility at Southwell Park also supplies recycled wastewater for irrigation purposes. Wastewater treated at the Queanbeyan sewage treatment plant is discharged to the Molonglo River with only a small fraction used for on-site irrigation purposes.

Surface storage levels and volumes in recent years

Figure 7-29 shows the combined accessible storage volume of the Corin and Googong reservoirs between 1980 and 2010 and for 2009–10. The Corin and Googong reservoirs have a combined accessible storage of 190 GL, which constitutes 93 per cent of Canberra and Queanbeyan's total system accessible storage. The accessible storage volumes of individual reservoirs are given in Figure 7-27.

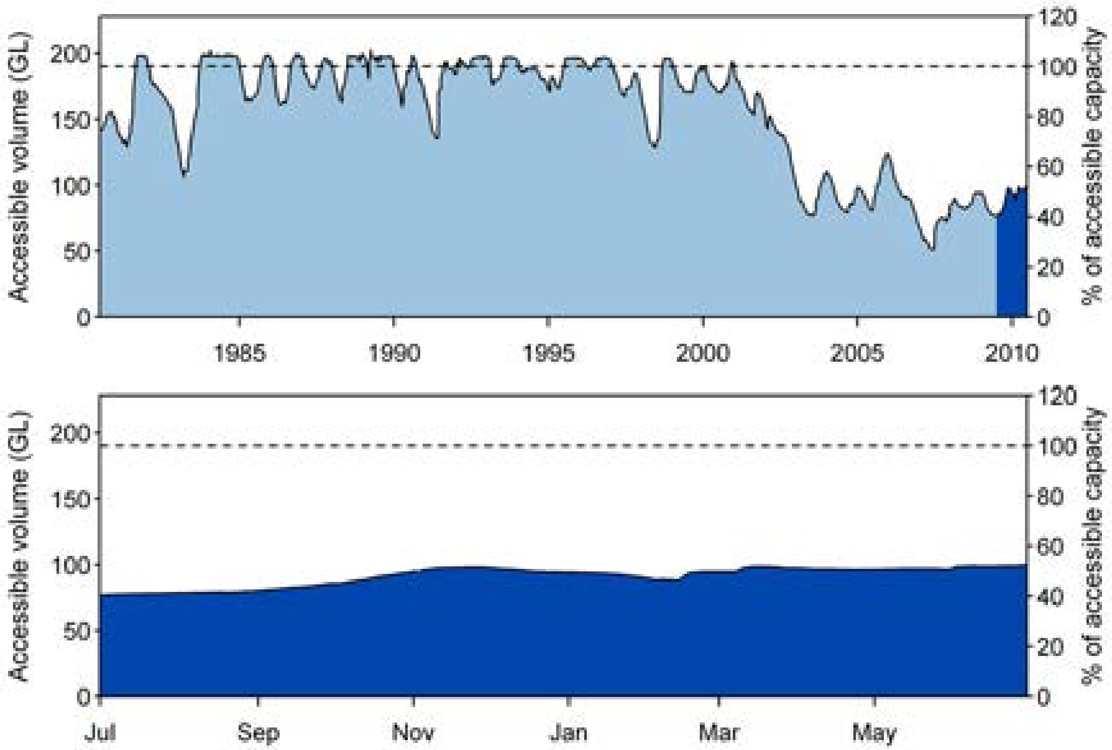


Figure 7-29. Combined surface water storage volumes for Googong and Corin reservoirs since July 1980 (top) and during 2009–10 (bottom), with the percentages based on the 2010 accessible storage capacity

7.6.1 Canberra and Queanbeyan (continued)

Throughout much of the 1980s and 1990s the combined storage of the Corin and Googong reservoirs remained above 80 per cent of capacity, with only a few significant draw-downs due to low rainfall in isolated years. In contrast, the combined storage volume was greatly reduced in the 2000s due to prevailing drought conditions. As a result, the combined storage volume of the Corin and Googong reservoirs has been below 80 per cent since January 2002, rarely exceeding 60 per cent of the combined accessible storage capacity.

Two significant draw-downs in the 2000s can be observed in Figure 7-29 (top). The first occurred during the 2001–03 period and the second from the start of 2006 to mid-2007. Both were a result of El Niño events causing exceptionally warm and dry weather during a period of prolonged low rainfall conditions from 2002–09. As a result of the draw-down in 2006, the combined water storage volume dropped to just above 25 per cent in early 2007.

Figure 7-29 (bottom) shows that the combined storage volume of the Corin and Googong reservoirs increased by 12 per cent over 2009–10. This increase was assisted by significant snow melt in spring 2009 and two major rainfall events in the summer of 2009–10.

Water restrictions in recent years

ACTEW manages decisions about water restrictions for the ACT, with Queanbeyan City Council applying the same decisions for Queanbeyan residents. Restrictions imposed in Canberra and Queanbeyan from 1999–2010 are shown against combined storage volumes in Figure 7-30. The different stages of the restrictions are defined in the Utilities (Water Conservation) Regulation 2006 under the ACT's *Utilities Act 2000*.

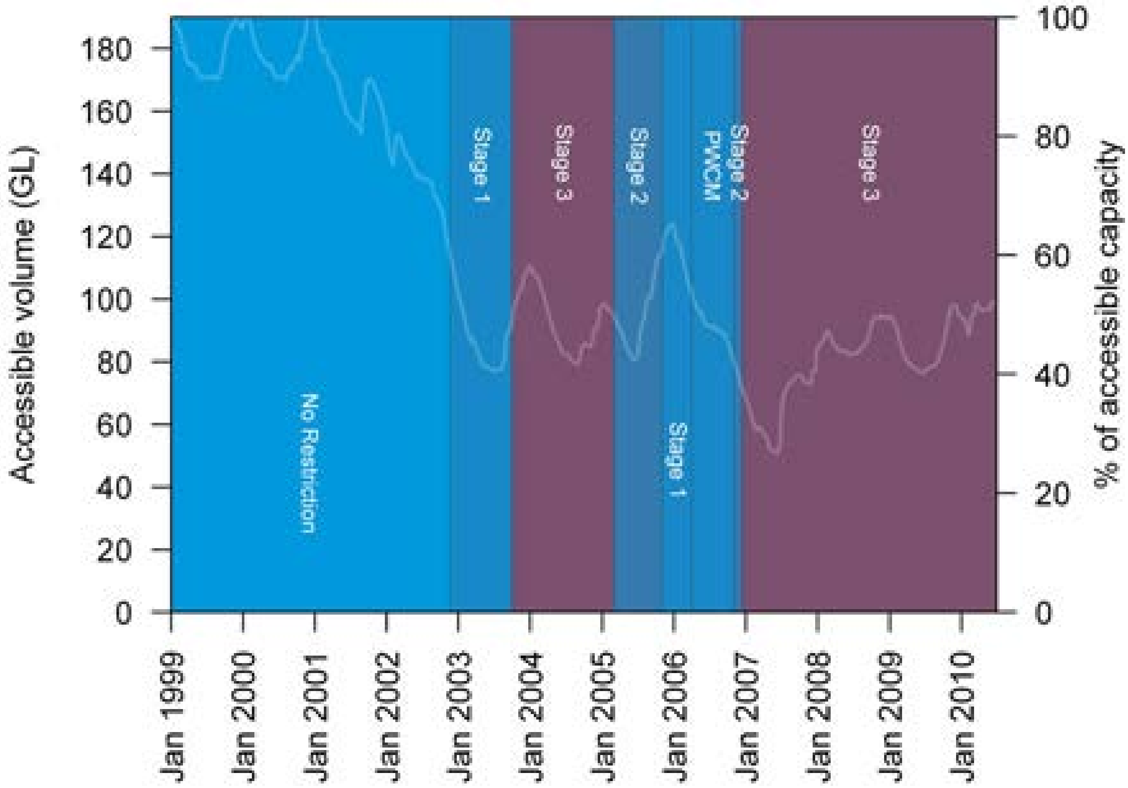


Figure 7-30. Urban water restriction levels for the ACT since 1999 shown against the combined accessible water volume of Googong and Corin reservoirs

7.6.1 Canberra and Queanbeyan (continued)

Until November 2002, Canberra had not experienced water restrictions since 1969 when the population of the ACT was approximately 120,000 (Commonwealth Bureau of Census and Statistics 1969). The ACT's population grew to an estimated 321,800 (Australian Bureau of Statistics 2002) by November 2002 and the onset of drought caused water storage volumes to diminish significantly. Voluntary Stage 1 water restrictions were introduced in November 2002 but were quickly replaced by mandatory Stage 1 water restrictions when storage volumes dropped below 55 per cent capacity. In October 2003, several factors including climatic conditions, consumption patterns, low storage volumes and bushfires resulted in the introduction of Stage 3 water restrictions, surpassing Stage 2 (ACTEW 2003). Restrictions were relaxed to Stage 2 in March 2005 and in November that year a four-month trial of Stage 1 water conservation measures was introduced.

Permanent Water Conservation Measures were introduced in March 2006 and approximately 18 per cent savings were achieved during the four-month trial (ACTEW 2006). The Permanent Water Conservation Measures include basic water saving practices that are designed to remain in place when water restrictions are not required.

Stage 2 water restrictions were introduced in November 2006 due to extremely low storage inflows. They were quickly moved to Stage 3 restrictions in December 2006 as warm and dry weather conditions persisted. Stage 4 restrictions were nearly implemented in May 2007. Stage 3 water restrictions continued for the rest of 2009–10.

Source and supply of urban water in recent years

Water supplied to Canberra and Queanbeyan comes from surface water and recycled water. Figure 7-31 (National Water Commission 2011a) shows the total water supplied from both sources for 2005–06 to 2009–10. During the past five years, the greatest volume sourced for Canberra and Queanbeyan's water supply was in 2005–06. During that year, Stage 2 water restrictions were replaced with Permanent Water Conservation Measures.

During 2006–07 and 2007–08, the volume of water supplied decreased as a result of Stage 2 and Stage 3 water restrictions being introduced. Stage 3 water restrictions remained in place until the end of 2009–10, which resulted in a relatively constant volume of water being sourced.

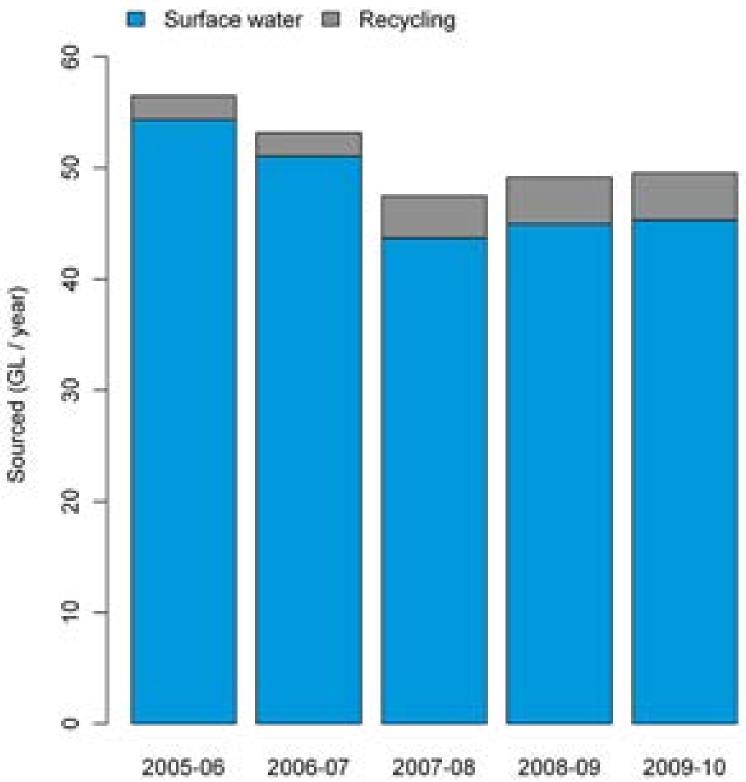


Figure 7-31. Total urban water sourced for Canberra and Queanbeyan from 2005–06 to 2009–10

7.6.1 Canberra and Queanbeyan (continued)

The use of recycled water increased over the period shown in Figure 7-31, being supplied primarily for commercial, municipal and industrial uses. Recycled water use doubled from 2.1 GL in 2005–06 to 4.2 GL in 2009–10.

Figure 7-32 (National Water Commission 2011a) shows the total volume of water delivered between 2002–03 and 2009–10 to residential, commercial, municipal and industrial customers in Canberra only. Queanbeyan consumption data were not available at the time of publication of this report. The figure shows that water consumption dropped in the eight-year period, although the population grew steadily.

The consumption pattern is a response to the water restrictions outlined above. In 2002–03, when Stage 1 water restrictions were in place, the Canberra consumption was 60 GL. During 2003–04, Stage 3 water restrictions were introduced and consumption dropped approximately 20 per cent to 48 GL. When restrictions were eased and replaced by Permanent Water Conservation Measures in 2005–06, the consumption increased approximately nine per cent, but returned to 48 GL during 2006–07, when Stage 2 followed by Stage 3 water restrictions were introduced. Stage 3 water restrictions continued through to 2009–10 and Canberra's water consumption remained steady at approximately 41 GL.

The proportion of water use per sector remained steady during 2002–03 to 2009–10. Residential water consumption was approximately 65 per cent; commercial, municipal and industrial sector use approximately 25 per cent and the remaining water supplied for other uses.

Canberra and Queanbeyan's per capita water use decreased significantly between 2002–03 and 2009–10. In 2002–03, the unrestricted water consumption was 461 litres/person/day (L/p/d), which decreased to 360 L/p/d by 2004–05 due to the introduction of water restrictions. The easing of water restrictions meant consumption increased to 386 L/p/d in 2005–06. From 2005–06 to 2009–10, water restrictions and increasing awareness of water conservation caused consumption to reduce from 349 to 288 L/p/d.

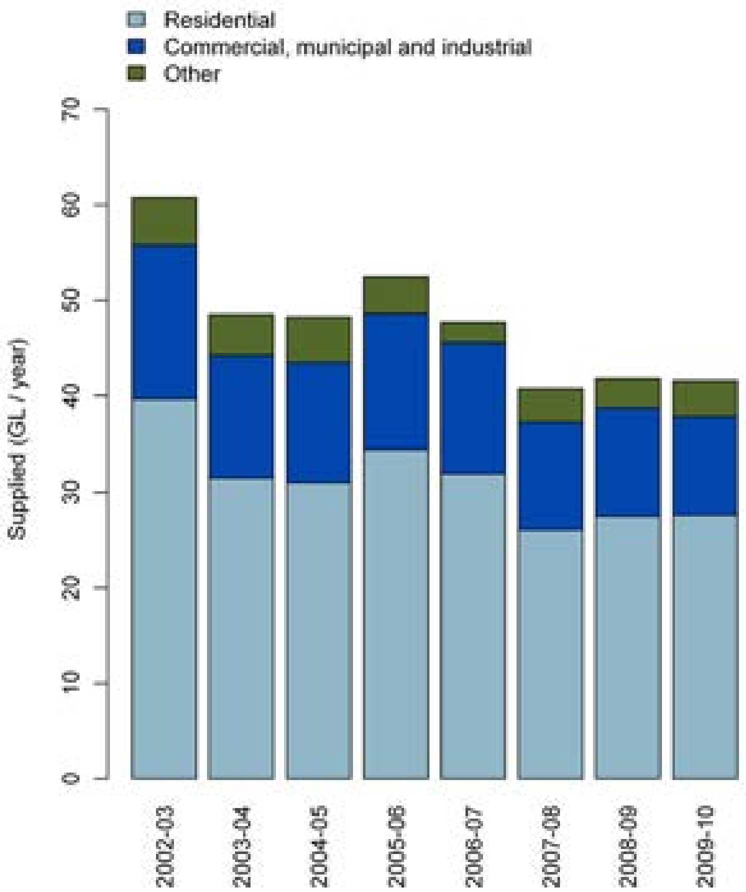


Figure 7-32. Total urban water supplied to Canberra from 2002–03 to 2009–10

7.7 Water for agriculture

Agriculture is the dominant economic activity in the Murray–Darling Basin region. Land uses related to agriculture comprise nearly 80 per cent of the area of the region. Cropping is mostly rain-fed and includes cereals, oilseed, cotton, horticulture and vegetables. Although irrigated agriculture covers less than two per cent of the basin, it uses a considerable amount of water. Increasing groundwater use in the region is primarily due to the expansion of irrigated agriculture combined with prolonged periods of drought.

7.7.1 Soil moisture

Upper soil moisture content during the summer (November–April) of 2009–10 was above average to very much above average in most dryland agricultural areas in the region in response to average or above average rainfall from December 2009 to April 2010. Below average upper soil moisture conditions were modelled in parts in the east of the region, however, particularly in the Gwydir River basin (Figure 7-33).

Upper soil moisture content for winter (May–October) of 2010 was above average to very much above average for most dryland agricultural areas of the region, particularly in central and northern river basins (Figure 7-33). Dryland agricultural areas in the far south of the region were estimated to have average upper soil moisture conditions.

7.7.2 Irrigation areas

The largest irrigation areas in the Murray–Darling Basin region are located in the Murrumbidgee, Murray, Lachlan, Goulburn, Broken, Loddon and Lower Murray basins in the south of the region, and the Condamine, Border, Gwydir, Namoi and Macquarie river basins to the north of the region (Figure 7-34).

A comparison of annual irrigation water use (from surface and groundwater) across the Murray–Darling Basin from 2005–06 to 2009–10 is shown in Figure 7-35 and Figure 7-36 by natural resource management region. Data were sourced from the *Water Use of Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011).

The figures also indicate that the average water use for 2005–10 was highest in the Murrumbidgee River basin, which contains the Murrumbidgee and Coleambally irrigation areas. Water resource conditions and use in the Coleambally and Murrumbidgee irrigation areas in the Murrumbidgee River basin are considered in more detail in Sections 7.7.3 and 7.7.4.

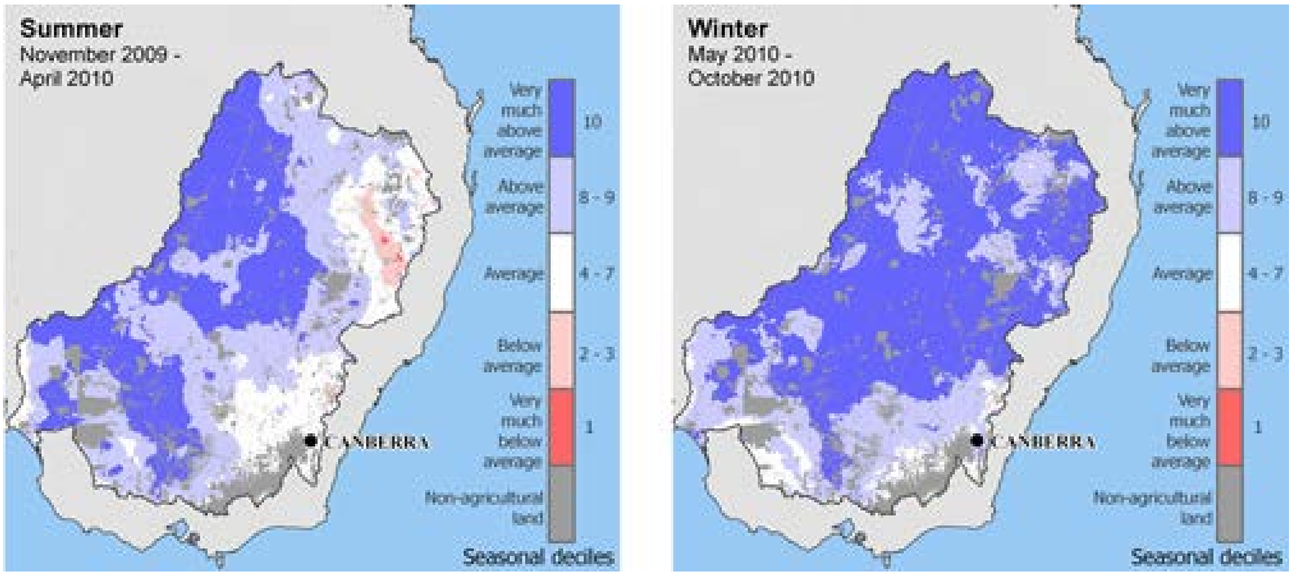


Figure 7-33. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the Murray–Darling Basin region

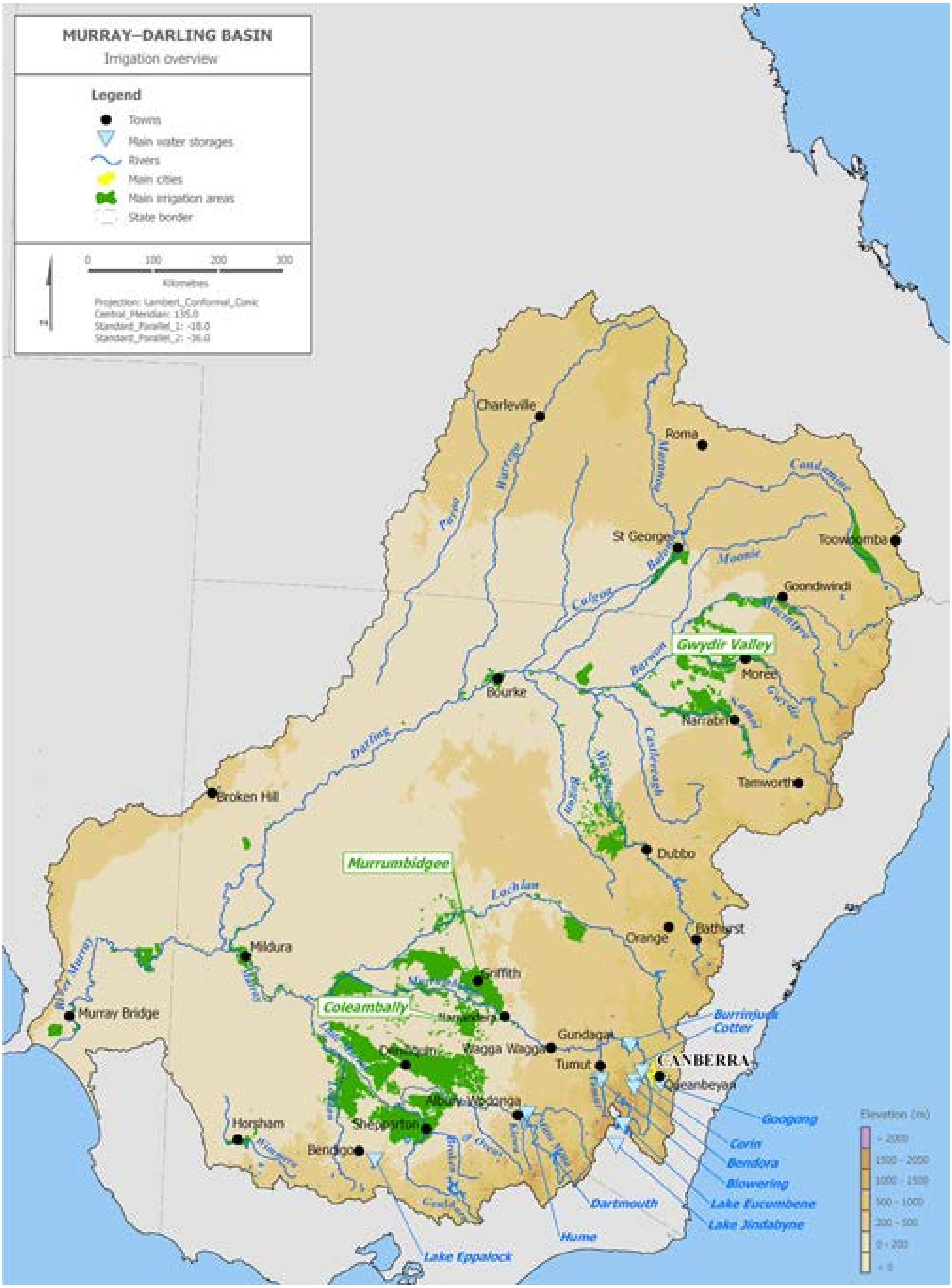


Figure 7-34. Context map of irrigation areas and infrastructure in the Murray–Darling Basin region

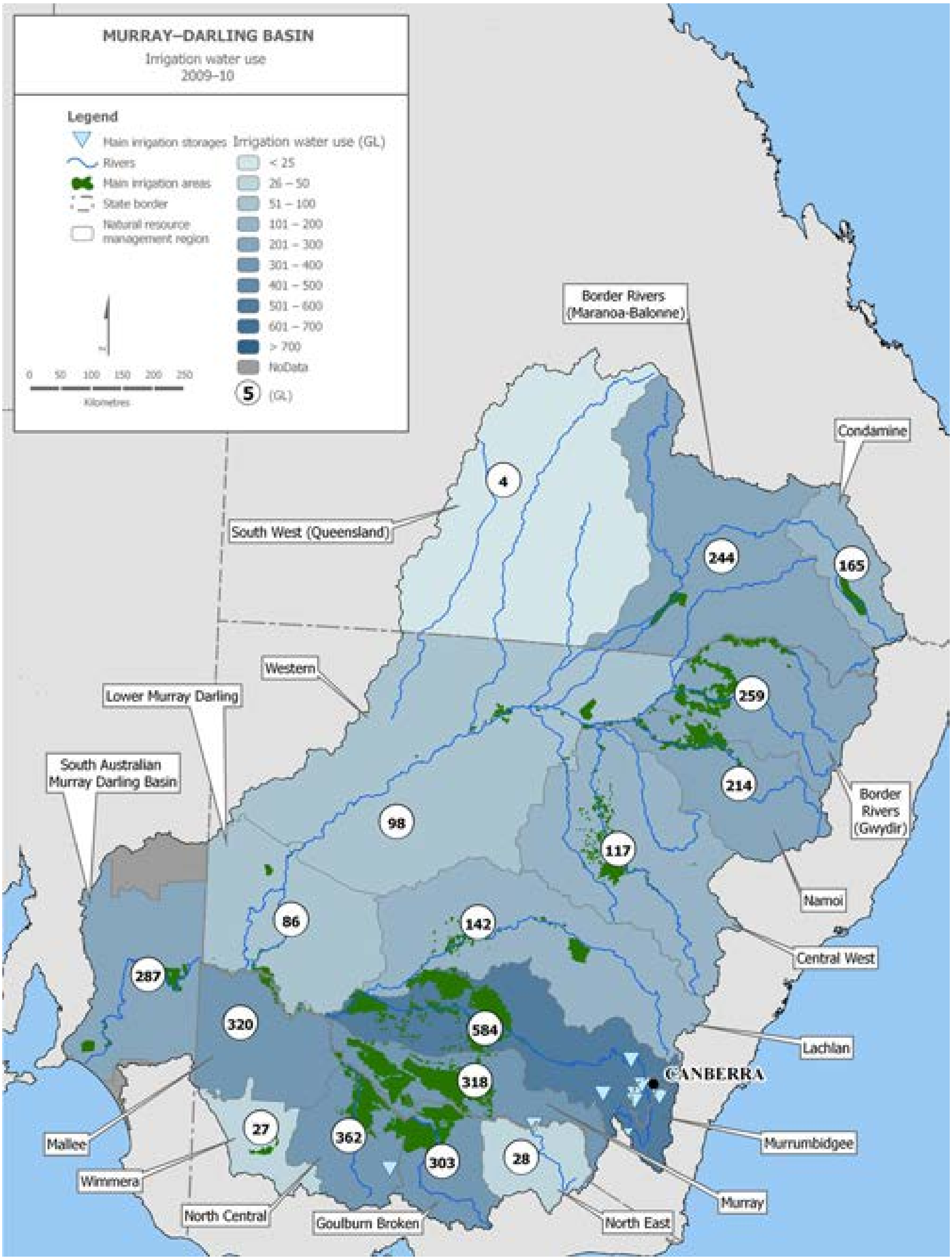


Figure 7-35. Average annual irrigation water use per natural resource management region for 2005–06 to 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

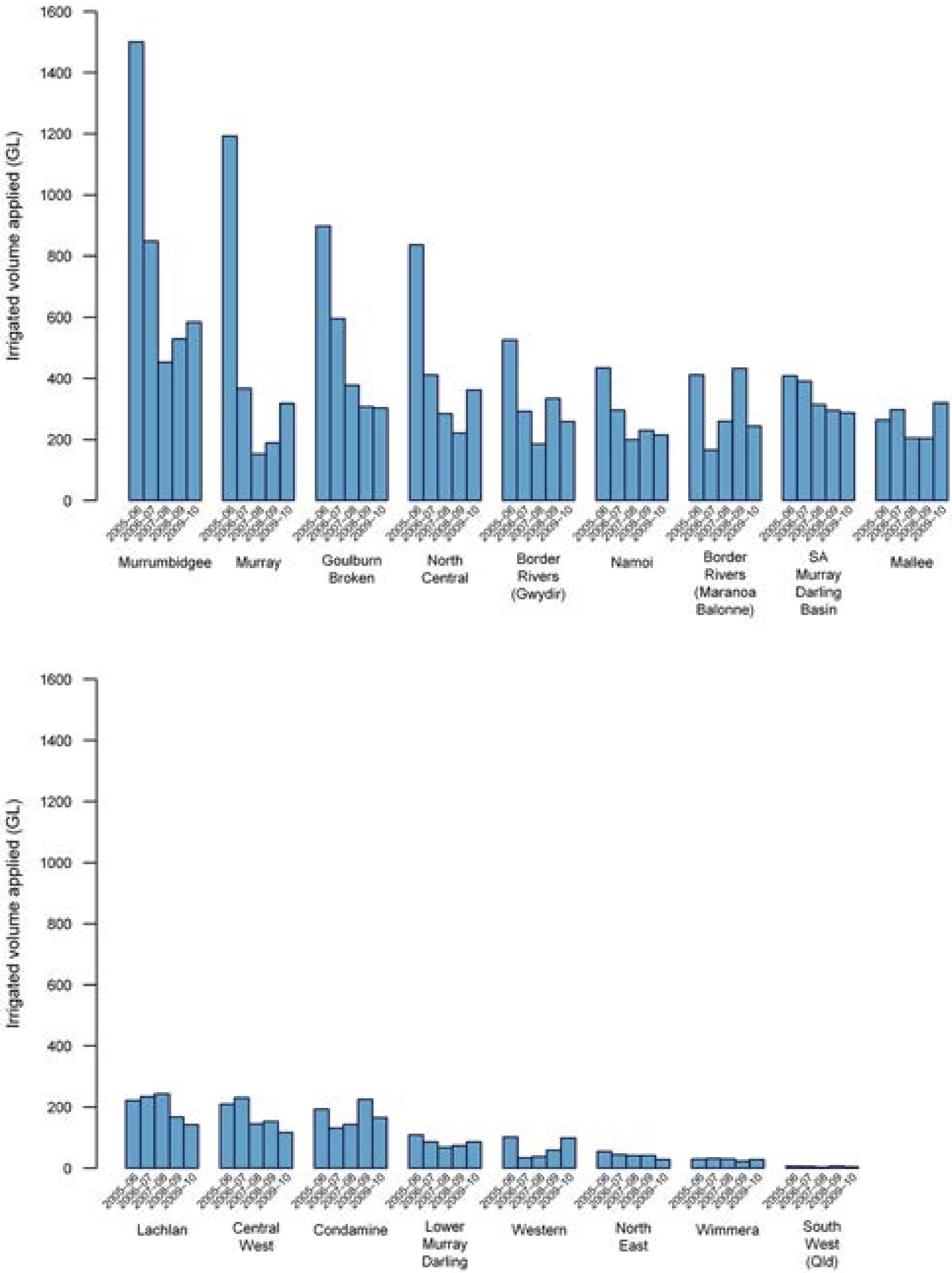


Figure 7-36. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the Murray–Darling Basin region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

7.7.3 Murrumbidgee River basin

Overview of the region

The Murrumbidgee River basin has a diverse climate and distinct physical characteristics. The basin is an 84,000 km^2 area, about 17 per cent of which is covered by native vegetation. Land use varies from sheep and cattle grazing, conservation reserves and residential areas in the upper catchment to irrigated agriculture, horticulture, dryland cropping, grazing and forestry in mid to lower areas of the catchment. Some important sites of international ecological significance are located in the Murrumbidgee River basin, including the Fivebough and Tuckerbil swamps and the Lowbidgee wetlands.

The Murrumbidgee River basin is one of the most densely populated regions in rural Australia – over 520,000 people with a growth rate of 1.5 per cent per annum (CRC for Catchment Hydrology 2004).

The region uses over 22 per cent of the total surface water diverted for irrigation and urban use in the Murray–Darling Basin region. Over 24 per cent of the groundwater use in the region occurs in the Murrumbidgee River basin. The irrigation industry provides 25 per cent of fruit and vegetable production in New South Wales, 42 per cent of the State's grape production, and half of Australia's rice production (Murrumbidgee Catchment Management Authority 2010).

Water supply

The region's rivers are regulated by multiple storages including those of the Snowy Mountains Hydro-electric Scheme, the ACT Water Supply System and the major New South Wales irrigation storages of Blowering (on the Tumut River) and Burrinjuck (on the Murrumbidgee River). Most of the groundwater is extracted from alluvial aquifers in the central Murrumbidgee and lower Murrumbidgee groundwater management units (Commonwealth Scientific and Industrial Research Organisation 2008).

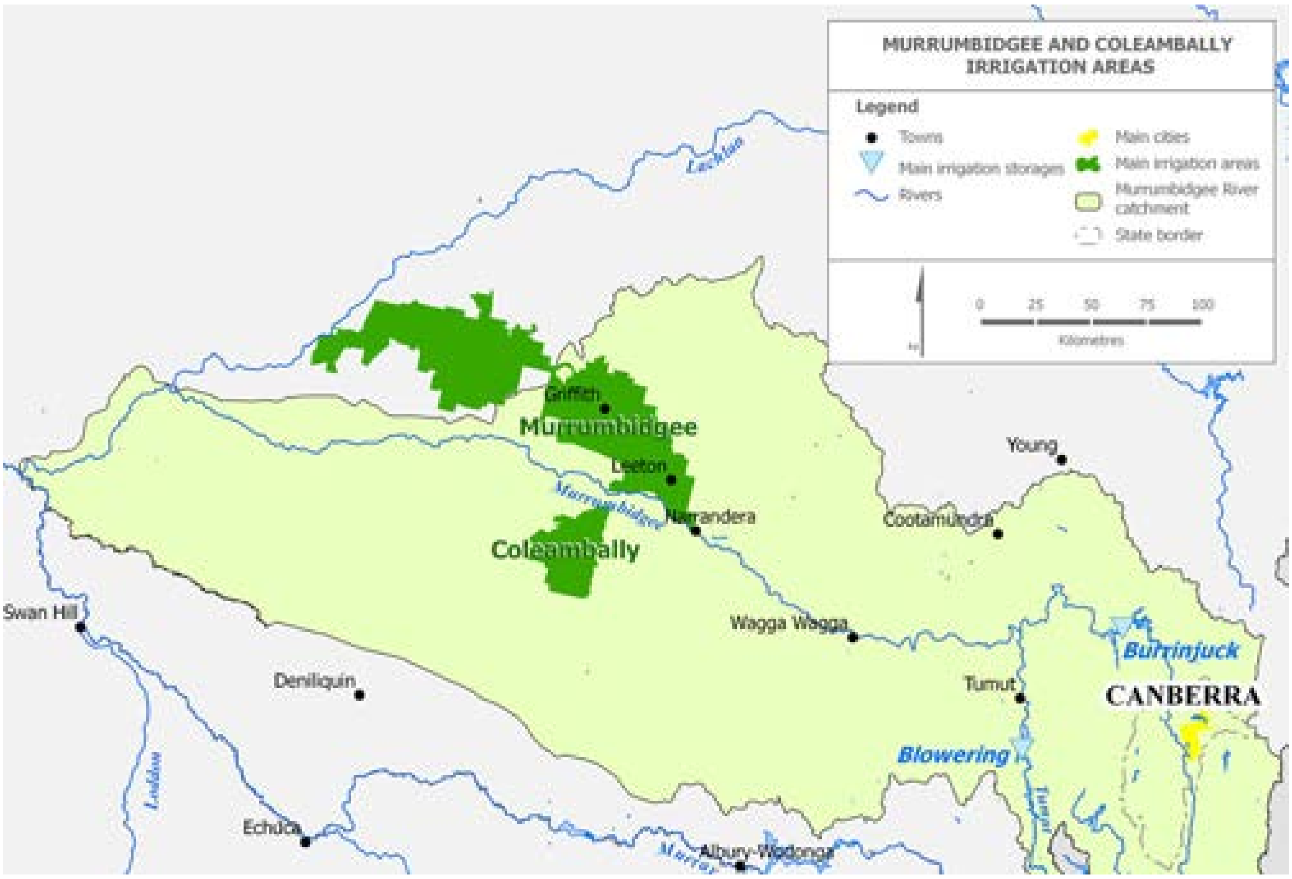


Figure 7-37. Coleambally and Murrumbidgee irrigation areas in the Murrumbidgee catchment

7.7.3 Murrumbidgee River basin (continued)

The Murrumbidgee and Coleambally irrigation areas in the lower Murrumbidgee catchment are the two most important irrigation areas in the region (Figure 7-37). The management of water in the two districts was privatised in the late 1990s. They are supplied with water from Burrinjuck and Blowering reservoirs through more than 10,000 km of irrigation channels. Burrinjuck Reservoir has a catchment area of about 13,000 km^2 with a total accessible capacity of 1,023 GL. Blowering Reservoir has an accessible storage capacity of 1,600 GL and catchment area of 1,600 km^2.

As a result of persistent drought, surface water diversions within the Murrumbidgee River basin declined substantially from a peak of around 2,600 GL in 1996–97 to 450 GL in 2007–08 (Figure 7-38). In 2009–10, the inflows to the Burrinjuck and Blowering reservoirs were the lowest on record and the storages were at less than half of their full capacity (Figure 7-39, Figure 7-40 and Figure 7-41). Diversions over the whole of the river basin in 2009–10, however, were higher than in the previous two years and close to 2006–07 levels (Figure 7-38).

Irrigation water management

Water Sharing Plans define water sharing arrangements between the environment and water users in the regulated Murrumbidgee River basin. There are a number of categories of water licences, which are assigned different priorities based on the intended use of water (New South Wales Office of Water 2011). An Available Water Determination (AWD) is set at the start of each financial year in terms of megalitres per share. The total number of shares held by a licence holder multiplied by the ML/share announced gives the volume of water credited to that licensee's account, in addition to carry over provisions.

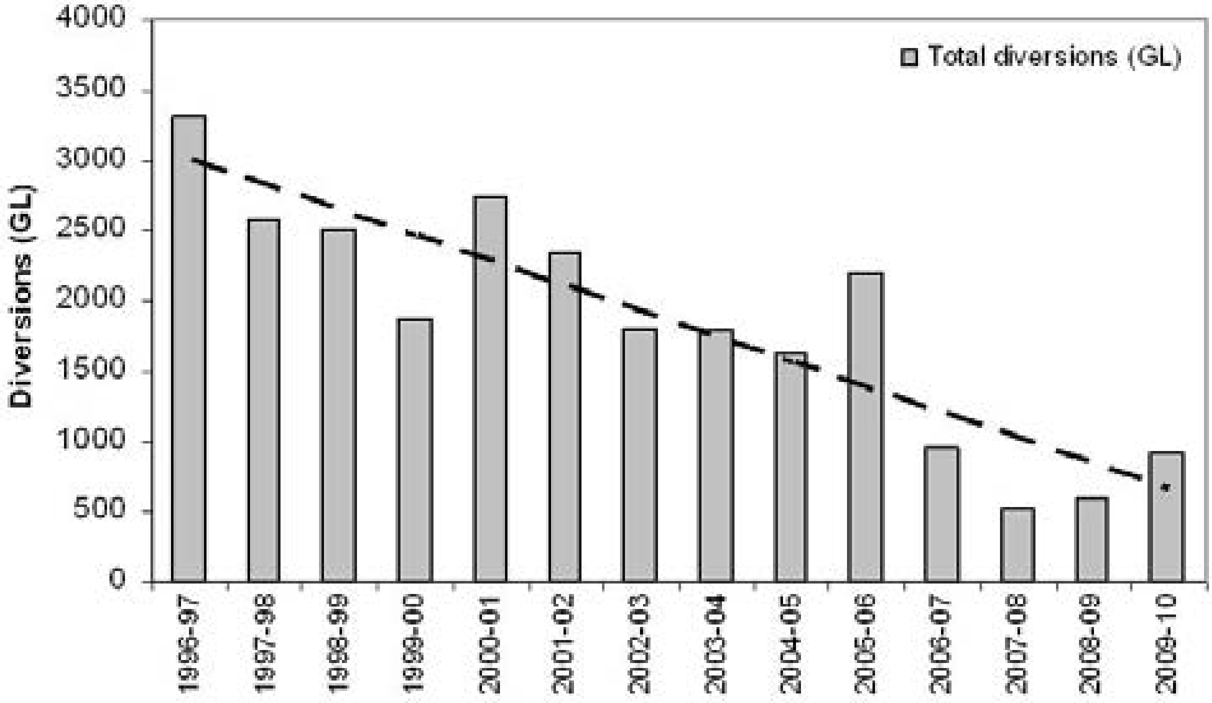


Figure 7-38. Surface water use in Murrumbidgee (from Murray–Darling Basin Commission Water Audit Reports 1996 to 2009), with the dashed line showing the overall trend in total diversions

7.7.3 Murrumbidgee River basin (continued)

The majority of the water entitlements held within the Murrumbidgee River basin are general security entitlements. Priority is given to high security entitlements primarily used for horticultural and grape production. Annual water availability has a significant influence on the volume of water used for summer and winter crop production.

Table 7-4 lists licence category priorities and share components in the regulated Murrumbidgee River determined on 30 June 2010 (NSW Office of Water 2011). Water was actively traded both within the river basin and with the neighbouring River Murray region.

Table 7-4. Murrumbidgee Regulated River share components determined on 30 June 2010

Access licence category	AWD priority	Total share component (ML)
General Security	Low	1,888,070
High Security	High	377,435
Murrumbidgee Irrigation Conveyance	Low	243,000
Coleambally Irrigation Conveyance	Low	130,000
Regulated River Conveyance	Low	2,968
Supplementary	Lowest	198,779
Domestic and Stock	Very high	35,939
Local Water Utility	Very high	23,586

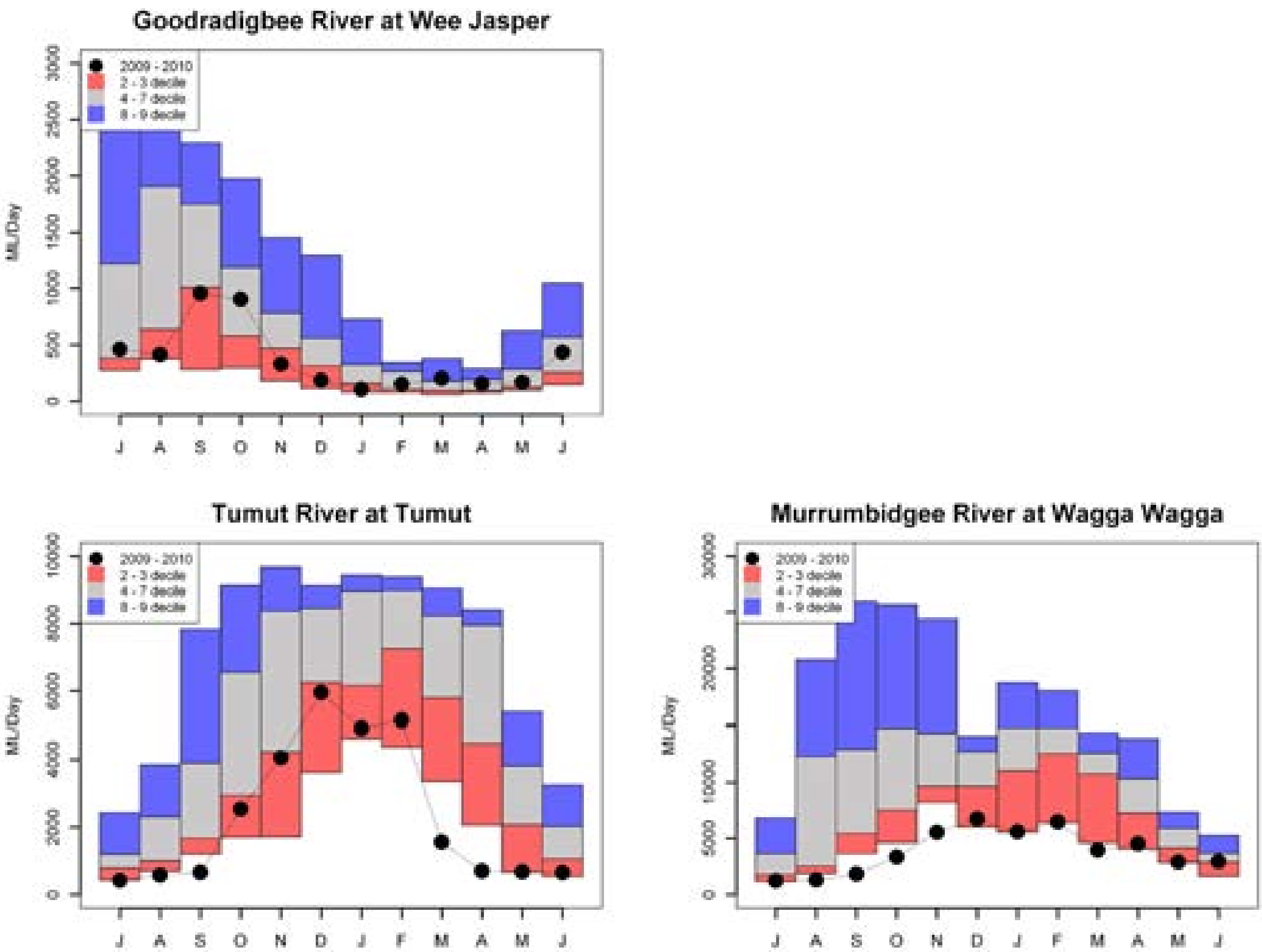


Figure 7-39. Monthly discharge hydrographs compared to discharge deciles at reference gauges for inflows to the Burrinjuck and Blowering reservoirs

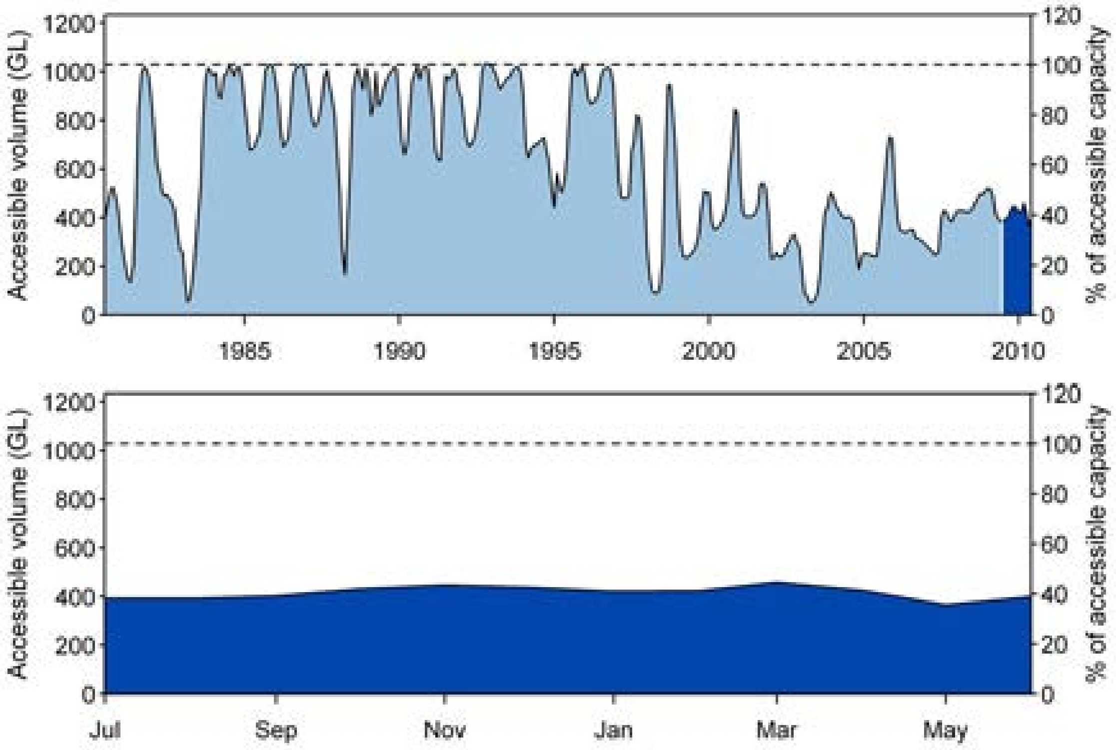


Figure 7-40. Water storage volumes available for irrigation at the Burrinjuck Reservoir since 1980 (top) and during 2009–10 (bottom)

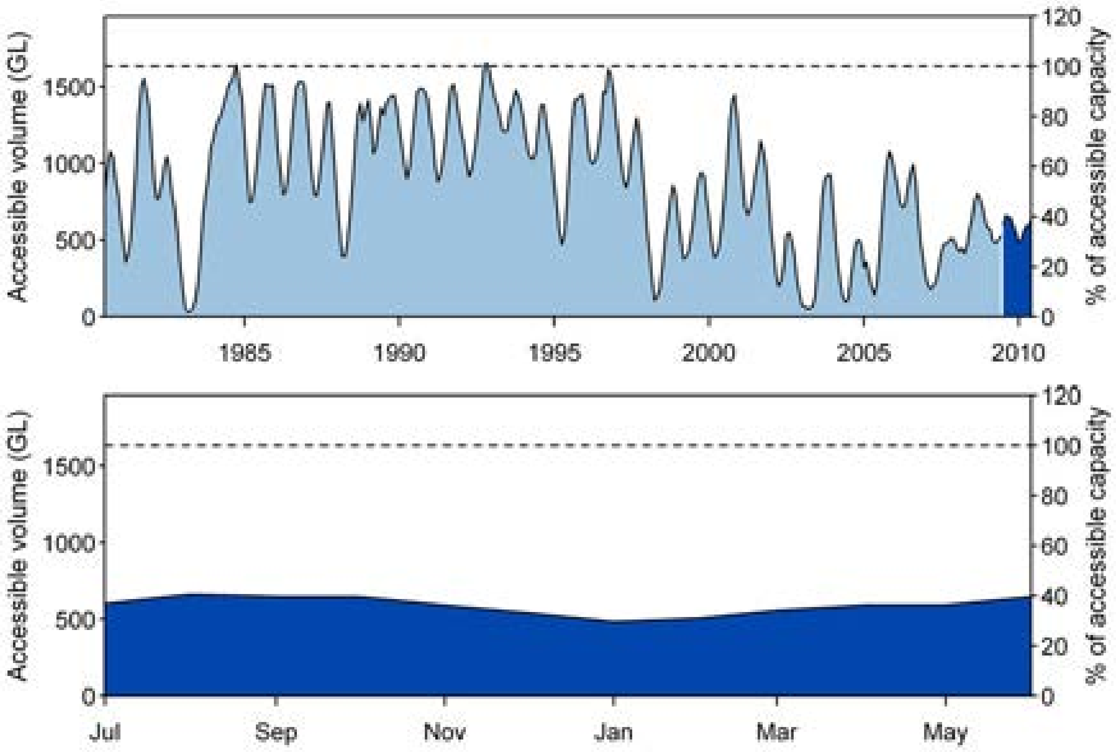


Figure 7-41. Water storage volumes available for irrigation at the Blowering Reservoir since 1980 (top) and during 2009–10 (bottom)

7.7.4 Murrumbidgee and Coleambally Irrigation Areas

The Murrumbidgee Irrigation Area occupies an area of approximately 3,620 km^2. It covers around 160,000 ha of intensive irrigation and 3,320 ha of landholdings. The area is located on the northern side of the Murrumbidgee River, between Leeton and Griffith and is fed by two canals receiving diverted water from the Murrumbidgee River: the Main Canal and the Sturt Canal.

The Main Canal receives water diverted at Berembed Weir to serve the Yanco, Leeton and Griffith areas and can accommodate flows of up to 6,500 ML/day. The Sturt Canal receives water diverted at Gogeldrie Weir to supply the Whitton and Benerembah areas and can accommodate flows of up to 1,700 ML/day.

River diversions for the 2009–10 irrigation season were 505,000 ML of which 368,000 ML was delivered to irrigators (Murrumbidgee Irrigation Ltd 2010). Total irrigated area in 2009–10 was 79,000 ha of which 28,000 ha was allocated to winter crops, 29,000 ha to horticultural crops and 8,000 ha to rice.

The Coleambally Irrigation District is located between Darlington Point and Jerilderie. The Coleambally Irrigation Co-operative Limited is the provider of water to the area, which contains 79,000 ha of irrigated land. Water is sourced from the Murrumbidgee River which is diverted into the Coleambally Main Canal upstream of Gogeldrie Weir, near Darlington Point. Water supplies are regulated from two major Snowy River Scheme storages: Burrinjuck and Blowering. The supply system is gravity fed and consists of 41 km of canal from the Murrumbidgee River, 477 km of supply channels and a further 734 km of drainage channels.

In 2009–10, total water diversion into the area was 157,700 ML out of which 39,800 ML was channel losses and 117,900 ML was delivered to irrigators. The general security allocation was 27 per cent. Groundwater usage was 96,700 ML. The total irrigated crop area was 46,400 ha, including 19,800 ha of summer crops, 26,600 ha of winter crops and 3,700 ha of rice.

Groundwater in the Coleambally Irrigation Area

For the purpose of this report, the Coleambally Irrigation Area was selected as an example for the discussion of groundwater use in an irrigation area in the Murray–Darling Basin region. More than 40 per cent of the total water used for irrigation in the Coleambally Irrigation Area is groundwater. During 2009–10 the total metered groundwater use in the area was 96,733 ML while surface water delivered to customers during the year was 117,937 ML. Prolonged dry conditions between 2002 and 2010 and subsequent reductions in surface water availability are generally responsible for the increased contribution of groundwater to irrigation in the area (Coleambally Irrigation Co-operative Limited 2010).

The Coleambally Irrigation Area is located in the eastern part of the Murray Geological Basin and overlies the Lower Murrumbidgee alluvial aquifer system which starts downstream of Narrandera and consists of unconsolidated alluvial deposits of sands, silts, clays and peat. The alluvial system is comprised of three main units: the unconfined shallow Shepparton subsystem, and the confined intermediate Calivil and deep Renmark subsystems. These last two subsystems are often in hydraulic continuity.

The lowermost Renmark Subsystem consists of Palaeocene to late Miocene fluvial clays, silts and gravels overlying the basaltic bedrock. In the eastern part of the Murrumbidgee catchment, the Renmark Subsystem has an average thickness of about 280 m (Lawson & Webb 1998).

Overlying the Renmark Subsystem are the late Miocene to Pliocene sands of the Calivil Subsystem. They were deposited by, and are thickest in, the ancestral drainage channels of modern-day rivers. It typically consists of 50 to 70 per cent coarse quartz sand with lenses of pale grey to white kaolinitic clay. The Calivil Subsystem varies in thickness from about 50 to 70 m and can extend to depths greater than 150 m. Of the three regional aquifer systems, the Calivil is the most productive.

The uppermost unit is the Shepparton Subsystem, which is typically 20 to 60 m thick. The Shepparton Subsystem comprises a series of fluvio–lacustrine clays, sands and silts that were deposited during the late Tertiary to Quaternary period. These sediments are laterally discontinuous and form a highly heterogeneous unconfined aquifer system. In the Coleambally Irrigation Area, the Shepparton Subsystem can be clearly divided into two parts, the upper (0–12 m deep) and lower Shepparton (12–60 m deep).

7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

Recharge to and discharge from the shallow Shepparton Subsystem occurs across the area and its heterogeneity and low overall hydraulic conductivity can inhibit lateral flow. Water movement through the deep aquifers is generally from east to west; however groundwater flow directions near the production bores around Darlington Point are complex. Movement occurs under gentle gradients and is therefore very slow with estimated flow rates of around 7–10 m/yr (Lawson and Webb 1998). Recharge to deep aquifers occurs mainly from the Murrumbidgee River downstream of Narrandera and from vertical leakage from the Shepparton Subsystem.

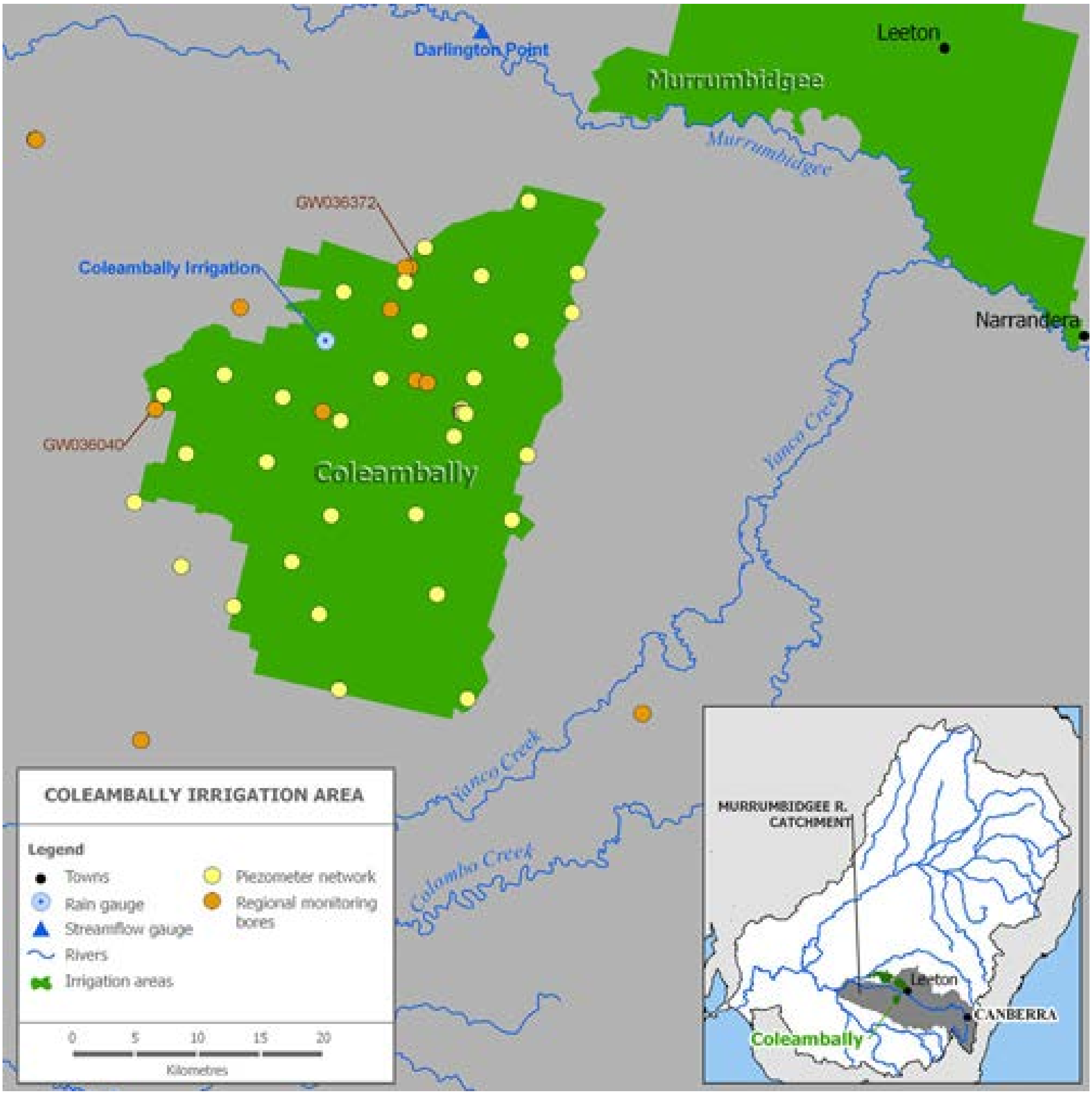


Figure 7-42. The Coleambally Irrigation Area with groundwater bore sites, including a location map of the Murrumbidgee River catchment.

7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

During the 1960s, irrigation began in the Coleambally Irrigation Area with water diverted from the Murrumbidgee River upstream of Gogeldrie Weir near Darlington Point (Figure 7-42). Irrigated agriculture often leads to recharge of regional groundwater systems at rates greater than those the systems can absorb, resulting in the development of shallow watertables and causing salinity and waterlogging. Prior to irrigation, watertable levels were at depths of 15–20 m. However, due to recharge to the groundwater from inefficient irrigation practices, leaky channels and recharge from rainfall, a significant proportion of the area had watertables within two meters of the soil surface by the late 1990s (Coleambally Irrigation Co-operative Limited 2004). These have since subsided due to recent below average rainfall and reduced water allocations. A return to normal seasonal conditions will most likely bring back the high watertables.

Fluctuations in shallow groundwater levels in the upper Shepparton are shown in Figure 7-43. A declining trend in groundwater levels is visible from 2002 onwards. Water levels are relatively stable between 1996 and 2002. To investigate the drivers of the groundwater level trends, fluctuation in shallow groundwater levels are compared to the rainfall residual mass at the Coleambally Irrigation station and to the monthly discharge of the Murrumbidgee River at Darlington Point (see Figure 7-42).

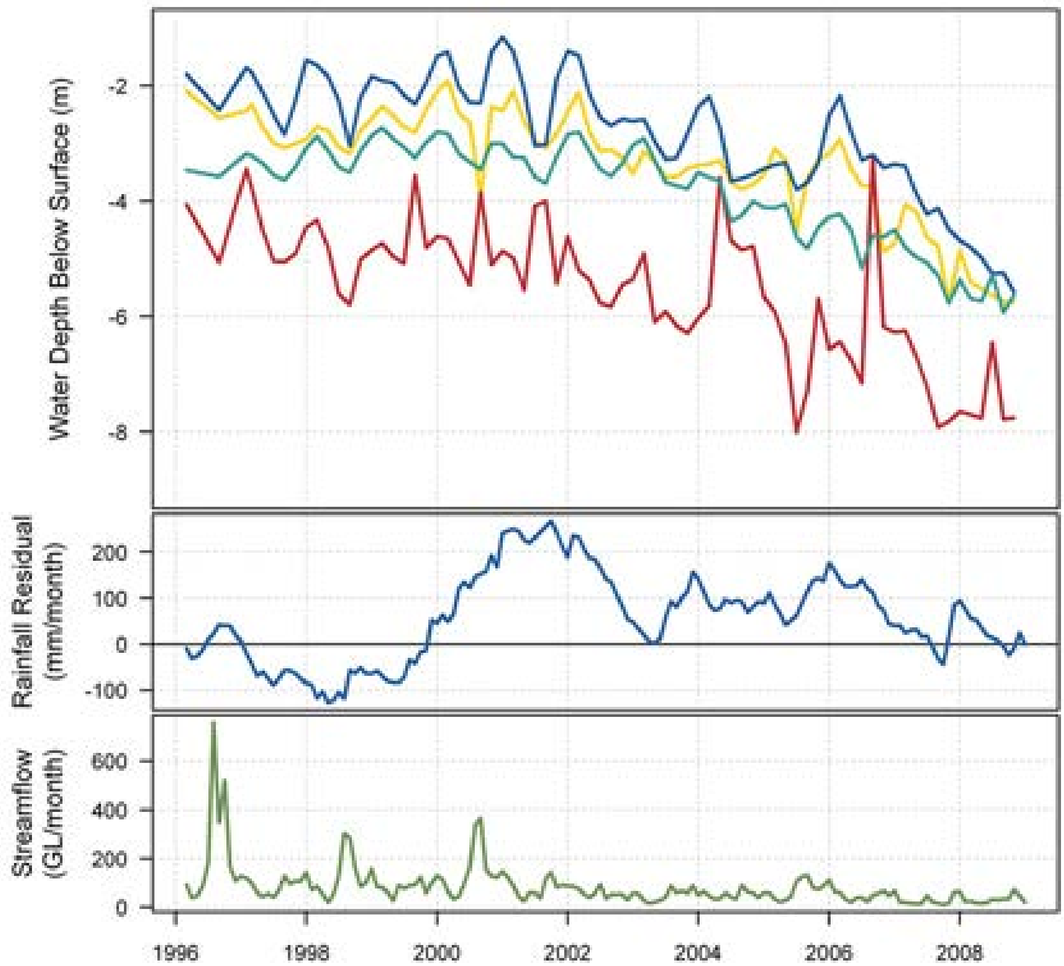


Figure 7-43. Shallow groundwater levels between 1996 and 2009 averaged by sub-areas (Coleambally Irrigation Co-operative Limited 2004, top panel) compared to cumulative rainfall residual mass at Coleambally Irrigation station 74249 (middle panel) and Murrumbidgee River discharge at Darlington Point station 410021 (lower panel)

7.7.4 Murrumbidgee and Coleambally Irrigation Areas (continued)

The rainfall residual mass curve is given as the cumulative sum of the actual rainfall for each month minus the average rainfall for that month. Periods in which the cumulative rainfall residual mass curve rises indicate wetter than average conditions. Periods with a falling trend indicate drier than average conditions. As shown, river discharge near the off-take for irrigation, and in minor part rainfall, is correlated with the observed trends in groundwater levels. Some peaks in surface water discharge and in the rainfall residual mass curve correspond to peaks in groundwater. The most striking feature is the decline in groundwater levels driven by reduced irrigation and low rainfall (and hence less recharge) and low surface water diversions.

Groundwater level status

Groundwater level measurements are an important source of information about hydrological and anthropological influences on groundwater in an area, including recharge. Figure 7-44 shows groundwater levels recorded at two regional nested sites within the Coleambally Irrigation Area reaching all three subsystems. Groundwater level fluctuations at bore 36040 are similar in the Calivil and Renmark subsystems, indicating that the two are hydraulically connected. Fluctuation in groundwater levels show the effect of pumping during the irrigation season and the subsequent recovery during the winter months when pumping ceased. Since 1996, a clear downward trend is visible, indicating the groundwater resource is under stress.

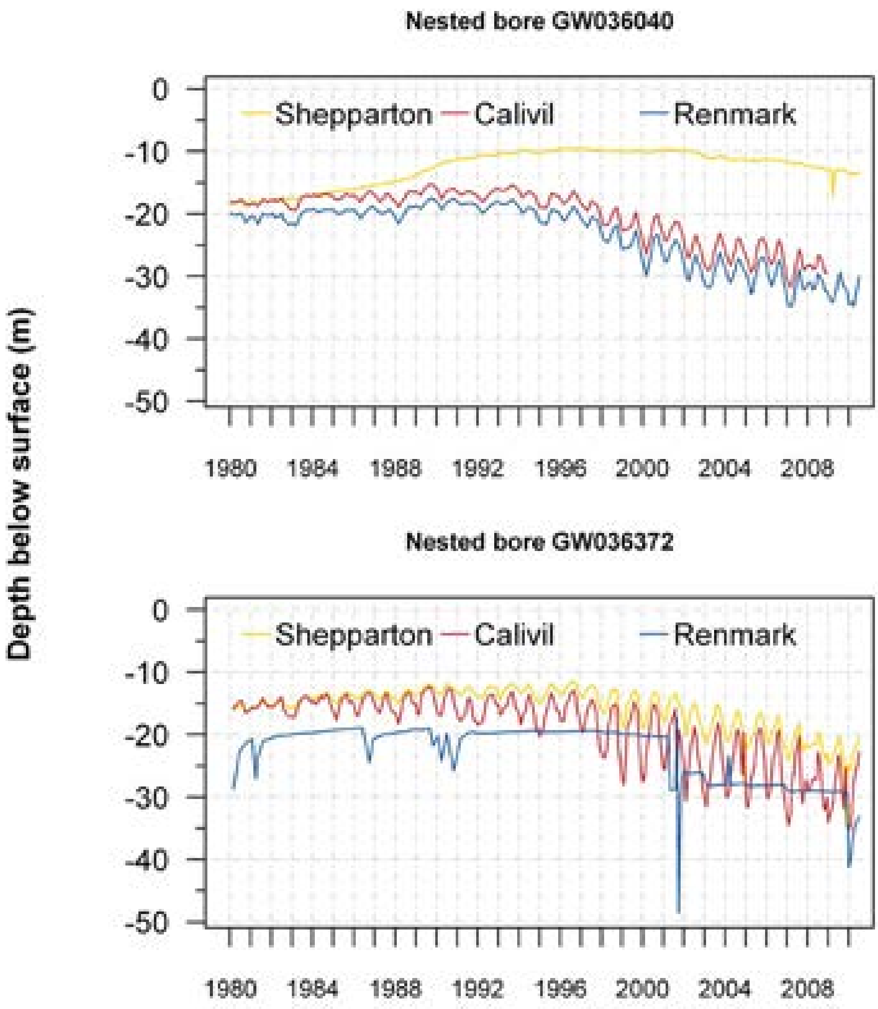


Figure 7-44. Groundwater levels between 1980 and 2010 recorded at two nested bore sites (bore 36040, top and bore 36372, bottom), reaching all three subsystems: Shepparton, Calivil and Renmark

The Shepparton Subsystem at this location (bore 36040) seems disconnected from the deeper subsystems. The groundwater levels in the Shepparton Subsystem also show an increasing trend since 1990 due to irrigation accession and a minor decline since 2002 linked to the decline in surface water allocation and, therefore, water available for irrigation. At this location, the hydraulic gradient, and therefore groundwater flow, is downward and increased in recent years. This may pose a greater risk to fresh groundwater at depth if the shallow groundwater is saline.

Groundwater levels at bore 36372 show that the lower Shepparton Subsystem is hydraulically connected to the Calivil Subsystem and both are influenced by pumping. In particular, there is a clear declining trend since the mid-1990s illustrating that these two aquifers are under stress. Similarly, the underlying Renmark Subsystem shows some effects of pumping, with the groundwater levels not recovering to previous levels of 2002. It appears that there is a weak hydraulic connection between the Remark and Calivil subsystems. The hydraulic gradient between the Shepparton and Calivil Subsystems is downward at this location and increased in recent years.

Figure 7-45 shows ranges of groundwater depth in upper Shepparton, lower Shepparton, Calivil and Renmark groundwater bores in the Coleambally Irrigation Area, and the ranking of 2008–09 median groundwater levels compared to annual median groundwater levels in since 1996. The bores used are part of a network of bores that are monitored approximately monthly and regional bores monitored by the NSW Office of Water less frequently. The analysis was carried out for 2008–09 rather than for 2009–10 due to the paucity of data in the latter period.

Groundwater levels in the Calivil and Renmark subsystems are all deeper than 10 m. Importantly, groundwater levels in the upper Shepparton and lower Shepparton subsystems are all deeper than 2.5 m. This indicates that the risk of groundwater salinisation from shallow watertables is low.

Median groundwater depths in 2008–09 are mostly in the lowest decile range of recorded levels since 1996 (Figure 7-46), indicating that groundwater levels are on average the deepest of the past 13 years in all aquifers. This is consistent with the trend in groundwater levels shown in the above sections and with the climatic conditions experienced and the reduction of surface water allocations.

Groundwater salinity status

Salinity in the Calivil and Renmark subsystems is relatively low and generally increases from east to west from Narrandera to Hay along the Murrumbidgee River. In contrast, the shallow Shepparton Subsystem is often very saline especially under irrigation areas.

Irrigation-induced salinity is a well known problem in many mature irrigation areas across Australia and internationally. The consequences of salinity in irrigation areas include production losses, increased production costs and damage to environmental and infrastructure assets in the region. The Coleambally Irrigation Area is experiencing such salinity problems. Unfortunately, no time-series data on groundwater salinity are currently available for further analysis.

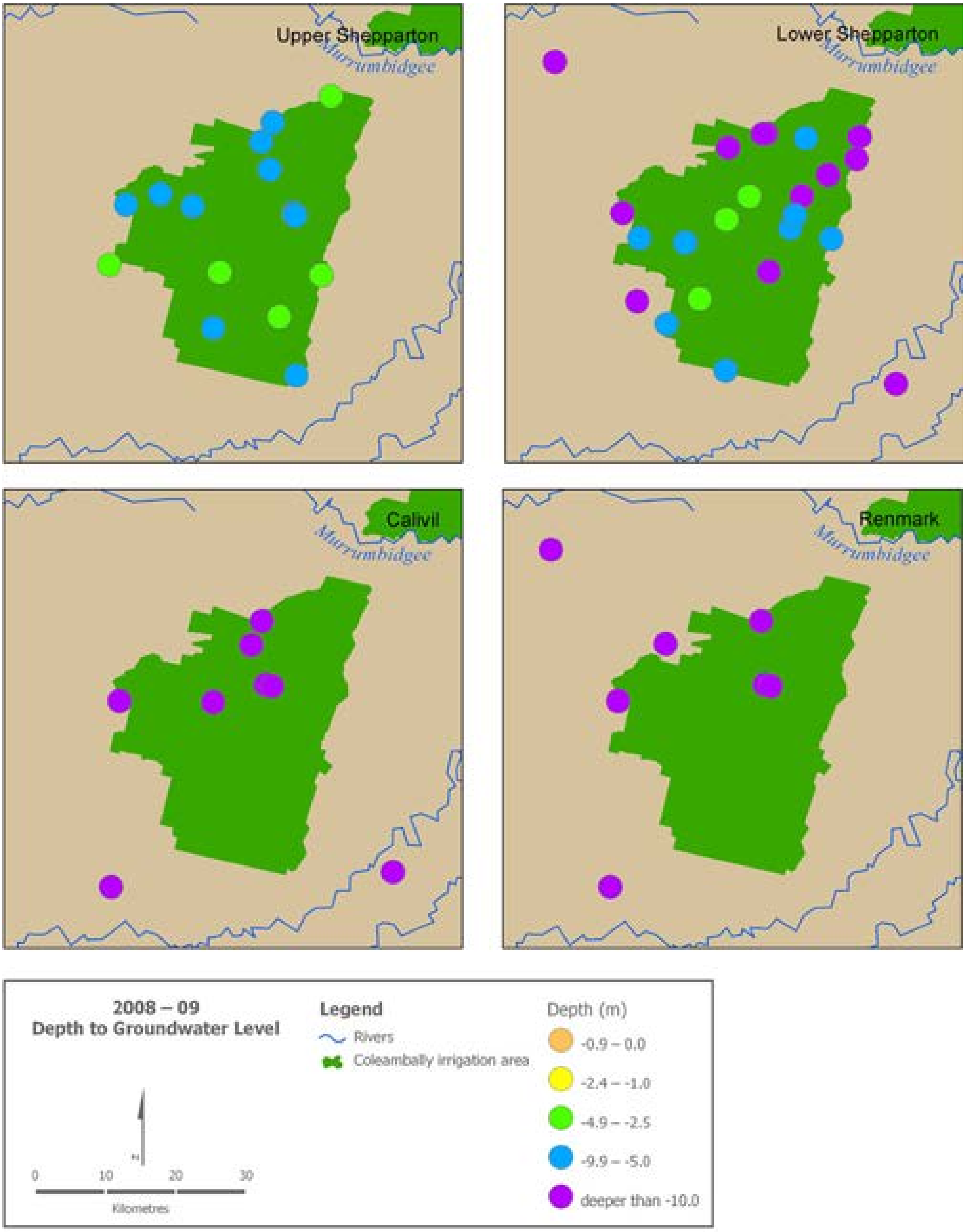


Figure 7-45. Median groundwater depth for the Coleambally area in 2008–09 compared to the upper and lower Shepparton, Calivil and Renmark subsystems

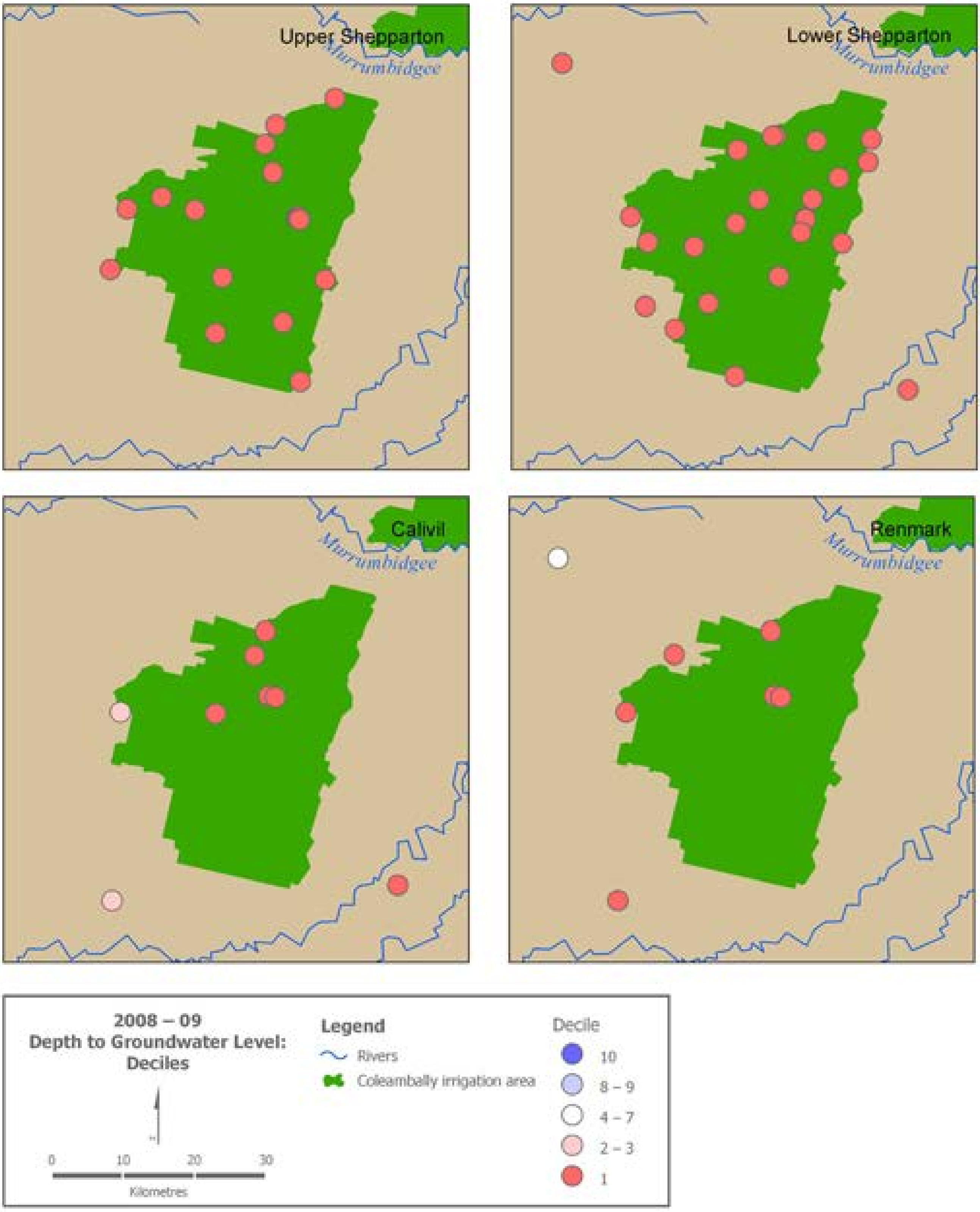


Figure 7-46. Decile rank of median groundwater depth for the 2008–09 period compared to the reference period 1996–2009 for the upper and lower Shepparton, Calivil and Renmark subsystems

8. South Australian Gulf

8. South Australian Gulf

8.1 Introduction

This chapter examines water resources in the South Australian Gulf region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers and groundwater units. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Surface water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

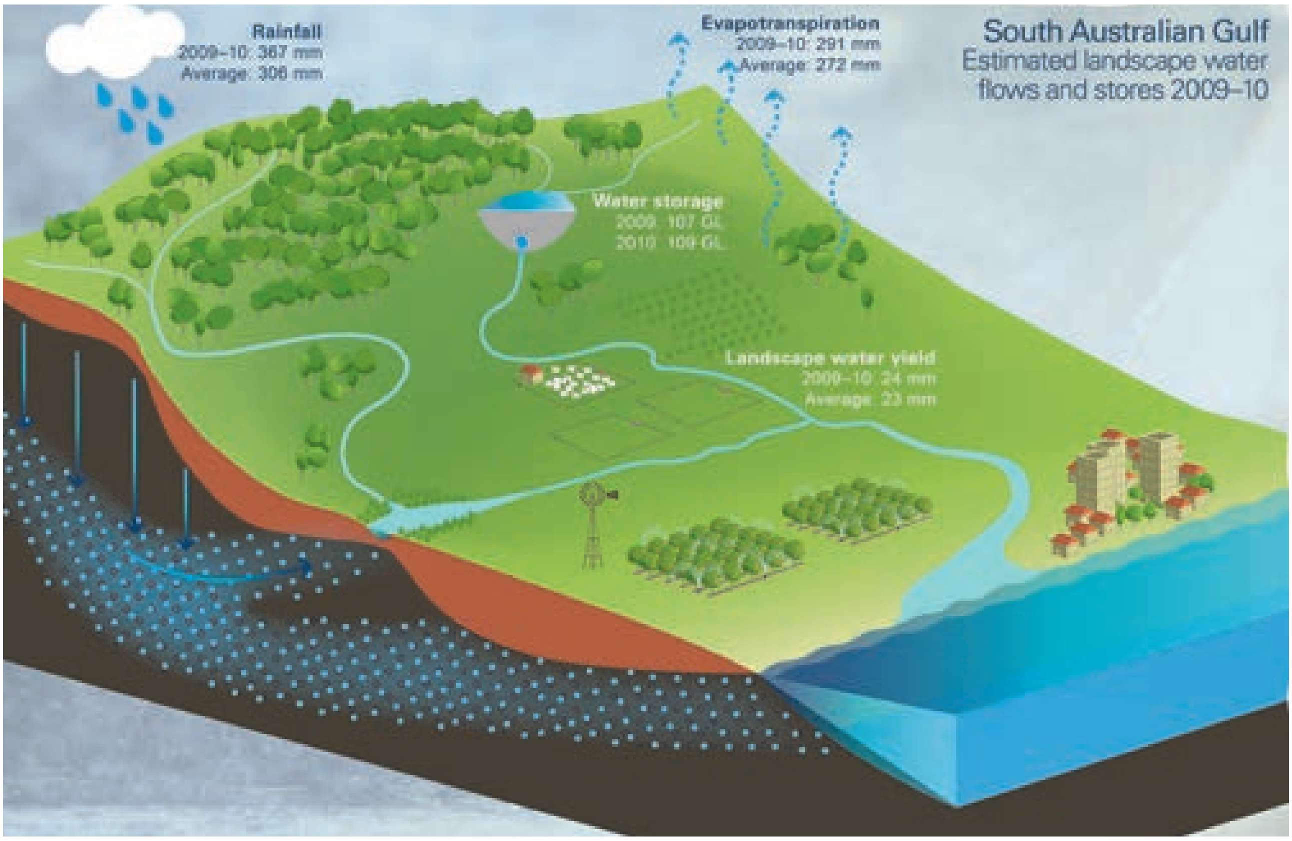


Figure 8-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the South Australian Gulf region

8.2 Key data and information

Figure 8-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the South Australian Gulf region. The major landscape water balance flows of rainfall and evapotranspiration were higher than average for the year (see Table 7-2). Landscape water yield[1] for 2009–10 was only slightly above average with much of the effective rainfall being retained in the landscape to increased soil moisture storage. Regional surface water storage increased by approximately 1.0 per cent of total accessible capacity over the year.

Table 8-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

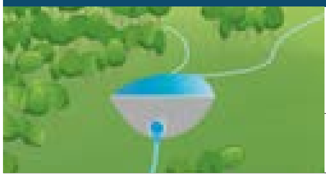
1. See Section 1.4.3 of Chapter 1– Introduction for the definition of this term.

Table 8-1. Key information on water flows, stores and use in the South Australian Gulf region[2]

Landscape water balance

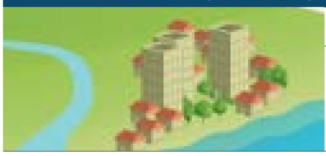
	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	367 mm	+20%	85	491 mm (1992–93)	192 mm (1982–83)
Evapotranspiration	291 mm	+7%	78	308 mm (1986–87)	223 mm (1982–83)
Landscape water yield	24 mm	+4%	66	84 mm (1992–93)	9 mm (1982–83)

Surface water storage (comprising approximately 76% of the region's total surface water storage)



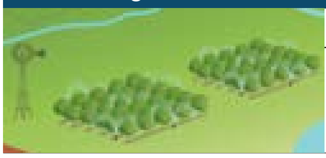
Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	% of accessible capacity	Accessible volume	% of accessible capacity	
197 GL	107 GL	54.3%	109 GL	55.3%	+1.0%

Urban water use (Adelaide)



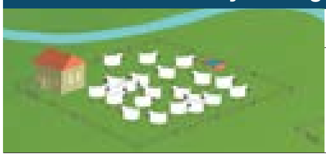
Water supplied 2009–10	Trend in recent years	Restrictions
126 GL	Decreasing	Steady at level 3 restrictions

Annual irrigation water use in 2009–10 for natural resource management regions



Adelaide and Mt Lofty Ranges	Northern and Yorke
66 GL	12 GL

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Above average in the north and west, very much above average in the northwest and average in the southeast	Predominantly above average over almost the entire region. Very much above average in the north

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

8.3 Description of region

The South Australian Gulf region comprises a 117,700 km^2 area in South Australia surrounding the Gulf of St Vincent and Spencer Gulf. It stretches inland to 300 km north of the Spencer Gulf. The Murray–Darling Basin region is to the east, the Lake Eyre Basin region to the north and the South Western Plateau region to the west. The Mount Lofty Ranges, with a highest peak of 932 m, interrupt an otherwise moderately flat terrain.

The region has a Mediterranean climate in the southeast to semi-arid climate inland and to the north. Rainfall mainly occurs in winter.

The South Australian Gulf region has no permanent freshwater lakes. A number of large endorheic salt lakes lie to the north, including Lake Torrens, Island Lagoon, Pernatty Lagoon, Lake Hart, Lake Gilles and Lake MacFarlane. To the south of the region, short rivers drain into the ocean.

The region is composed of a number of river basins including the Onkaparinga, Torrens, Gawler and Broughton River basins and the Eyre Peninsula basin. The region has some productive agricultural land, extensive native grasslands and important South Australian coastal and marine ecosystems.

The South Australian Gulf region has a population of more than 1.25 million (Australian Bureau of Statistics 2006). Approximately 95 per cent of the population is concentrated in Adelaide with the rest sparsely distributed throughout the remainder of the region. Water supply to the significant urban areas is addressed in Section 8.6.

All town centres are supplied with water from systems operated by South Australian Water Corporation, a South Australian Government-owned statutory body. South Australia is heavily dependent on supplies pumped from the River Murray in the Murray–Darling Basin region. The annual diversion from the River Murray is about 40 per cent of consumption in the South Australian Gulf region in average years and much higher when winter yields from catchments around Adelaide are low. These catchments include the Mount Lofty Ranges and the Adelaide Hills. Four pipelines are used to supply River Murray water into the region, the longest being the 356 km Morgan–Whyalla pipeline (South Australian Water Corporation 2010a). Construction of a desalination plant and numerous recycled water projects are underway to reduce the dependency on the River Murray.

There are approximately 40 major storages in the region with a total accessible storage capacity of 237 GL. Ten of these storages, totalling 197 GL, are used for supply to Adelaide. The largest storages are Mount Bold Reservoir in the Onkaparinga River basin and South Para Reservoir in the Gawler River basin.

The mix of land use in the South Australian Gulf region is illustrated in Figure 8-2. Dryland pasture and cropping are major land uses in the region. Grazing is concentrated in the northern, arid river basins such as Lake Torrens, Willochra Creek and Mambray Coast (south of Lake Torrens), and northern parts of the Broughton River basin. Several river basins (Wakefield, Gawler and Broughton) have 50 per cent or more of their area occupied by dryland agriculture. More than half of the land area devoted to nature conservation is a single reserve covering the Lake Torrens salt lake. Other significant areas of nature conservation occur in the Eyre Peninsula, Broughton River and Kangaroo Island basins. Irrigated agriculture is mostly for viticulture and wine production, the most important of which is concentrated in the Onkaparinga catchment. Water supply to the McLaren Vale Irrigation Area is described in Section 8.7.3.

The hydrogeology of the South Australian Gulf region can be partitioned into areas of surficial and underlying sediments, and areas of outcropping fractured rock. Significant groundwater resources are found in surficial sediments and the Quaternary and Tertiary aquifers that underlie them. Typically fractured rock systems offer restricted low volume groundwater resources; however, there are some parts of this region with a greater density of fractures and more substantial groundwater resource availability. A more detailed description of groundwater occurrence in the region is given in Section 8.5. Typically, groundwater use is high in groundwater management units such as McLaren Vale, the Northern Adelaide Plains and the Barossa Valley.

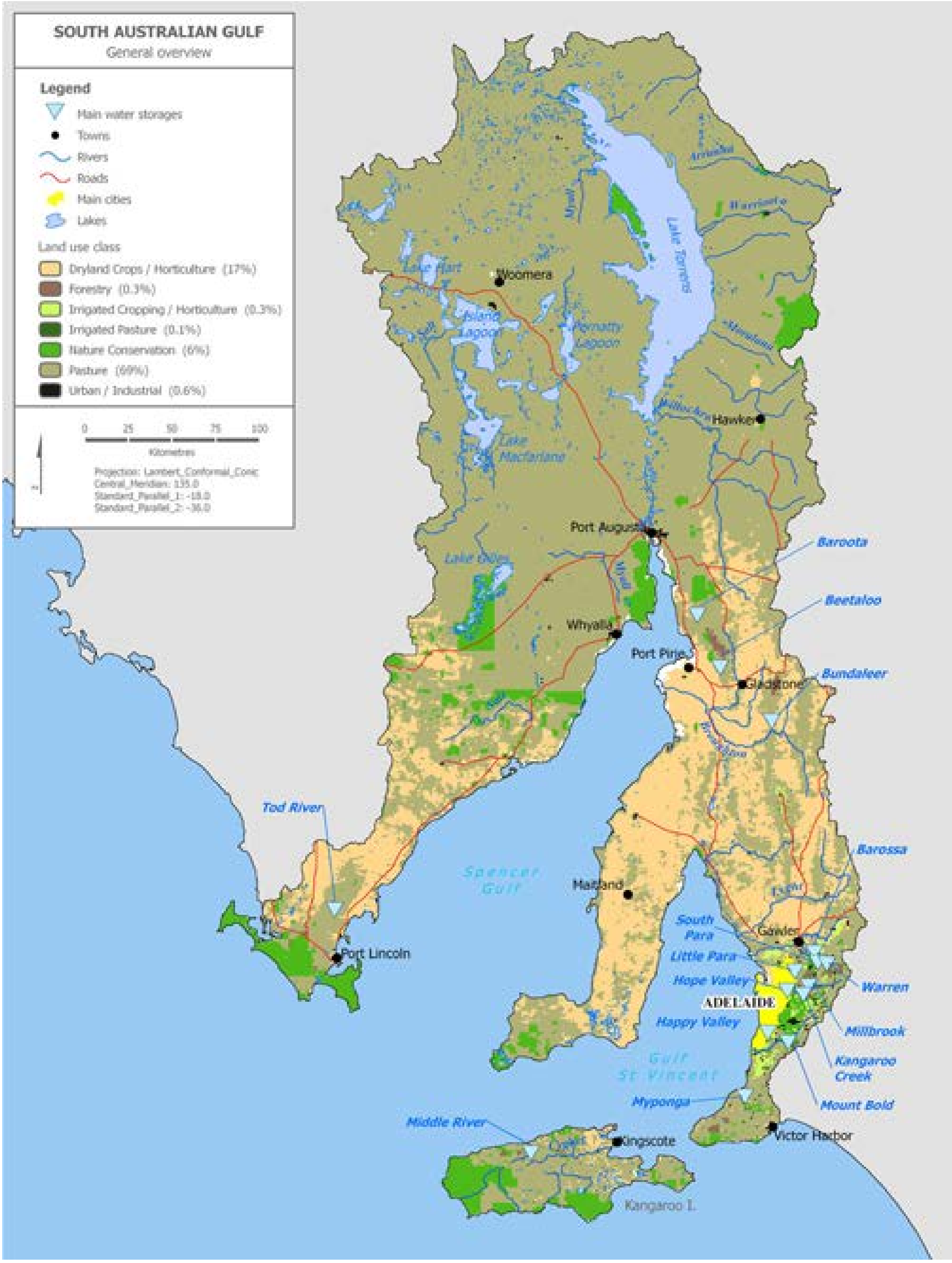


Figure 8-2. Key landscape and hydrological features of the South Australian Gulf region (land use classes based on Bureau of Rural Sciences 2006)

8.3 Description of region (continued)

Groundwater use in the South Australian Gulf is largest in areas with surficial sediments and underlying aquifers. Figure 8-3 shows major aquifer groups present at the watertable. Aquifer groups that provide potential for groundwater extraction as labelled in the figure are:

- lower mid-Tertiary aquifer (porous media – unconsolidated)
- upper Tertiary aquifer (porous media – unconsolidated)
- upper Tertiary/Quaternary aquifer (porous media – unconsolidated).

The sediments of the Great Artesian Basin are present along the northern boundary of the region but are not dominant for water provision.

Figure 8-4 shows the salinity of groundwater in watertable aquifers. Most parts of the region are considered to have saline groundwater that is usually not suitable for irrigation. Non-saline groundwater occurs in those groundwater management units that are also Prescribed Areas.

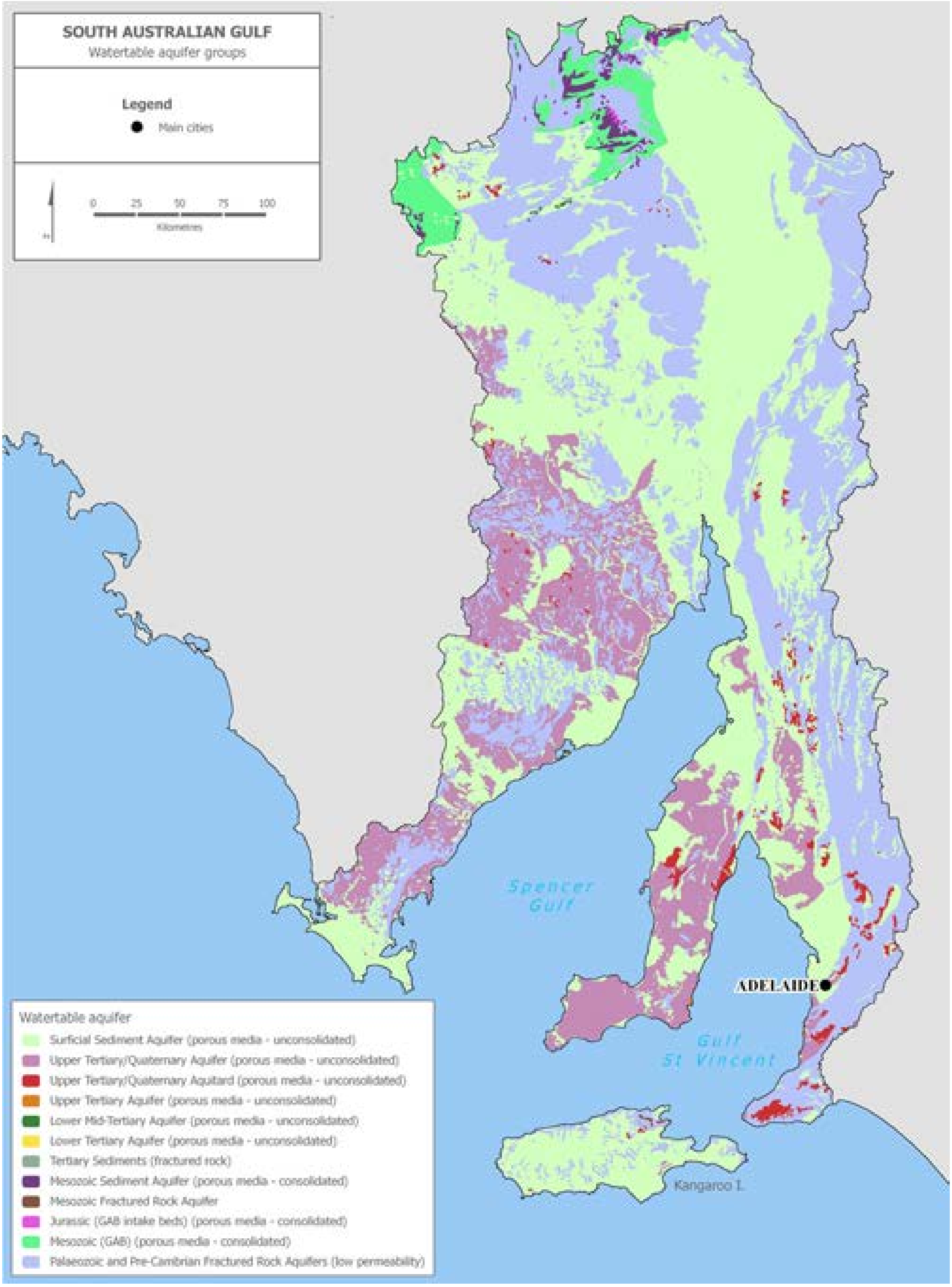


Figure 8-3. Water table aquifer groups in the South Australian Gulf region (Bureau of Meteorology 2011e)

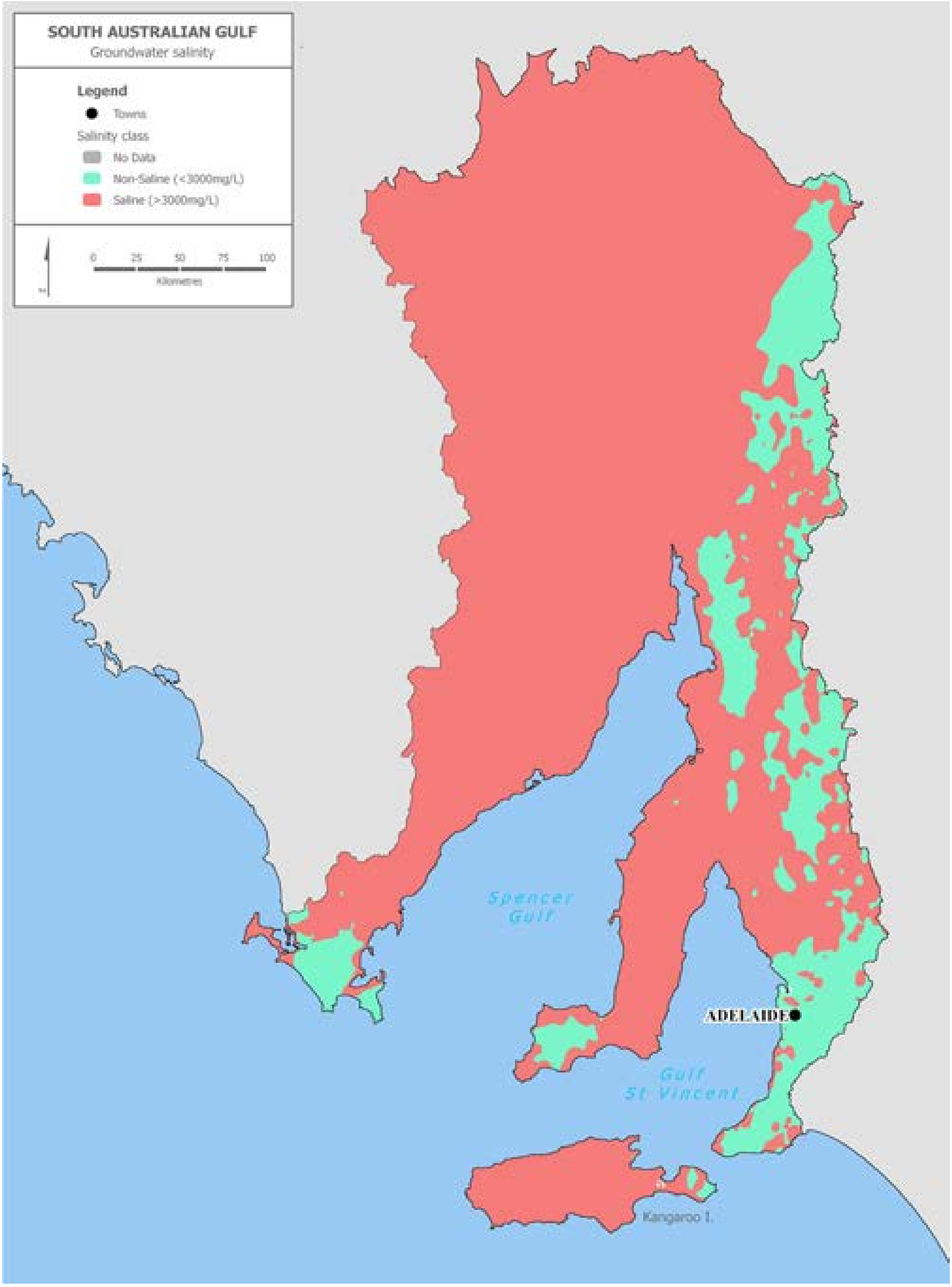


Figure 8-4. Watertable salinity classes within the South Australian Gulf region (Bureau of Meteorology 2011e)

8.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Some areas of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data or absence of model parameter data for areas such as salt lakes, salt pans and inland water. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 8-5 shows that the South Australian Gulf region generally experiences wet winters and lower summer rainfall, with relatively high levels of variability in monthly rainfall throughout 2009–10. The year began with generally normal to slightly above normal rainfall conditions between July and October 2009 followed by very much above average rainfall for November 2009. A major rain event affected much of South Australia, as well as Victoria and far western New South Wales at the end of November 2009 (Bureau of Meteorology 2010a). Rainfall for December 2009 through to March 2010 was generally normal. Wet conditions returned to the region during April and May 2010.

Monthly evapotranspiration was generally within the normal range through much of 2009–10. Higher than normal evapotranspiration occurred following the very high summer rainfall of November 2009 and April 2010, when rainfall significantly exceeded evapotranspiration losses.

Modelled landscape water for the region is usually low throughout the year as a consequence of high evapotranspiration losses relative to rainfall inputs, particularly between September 2009 and March 2010. During 2009–10, landscape water yield was higher than normal for November 2009 and April 2010 in response to very high rainfall during these months.

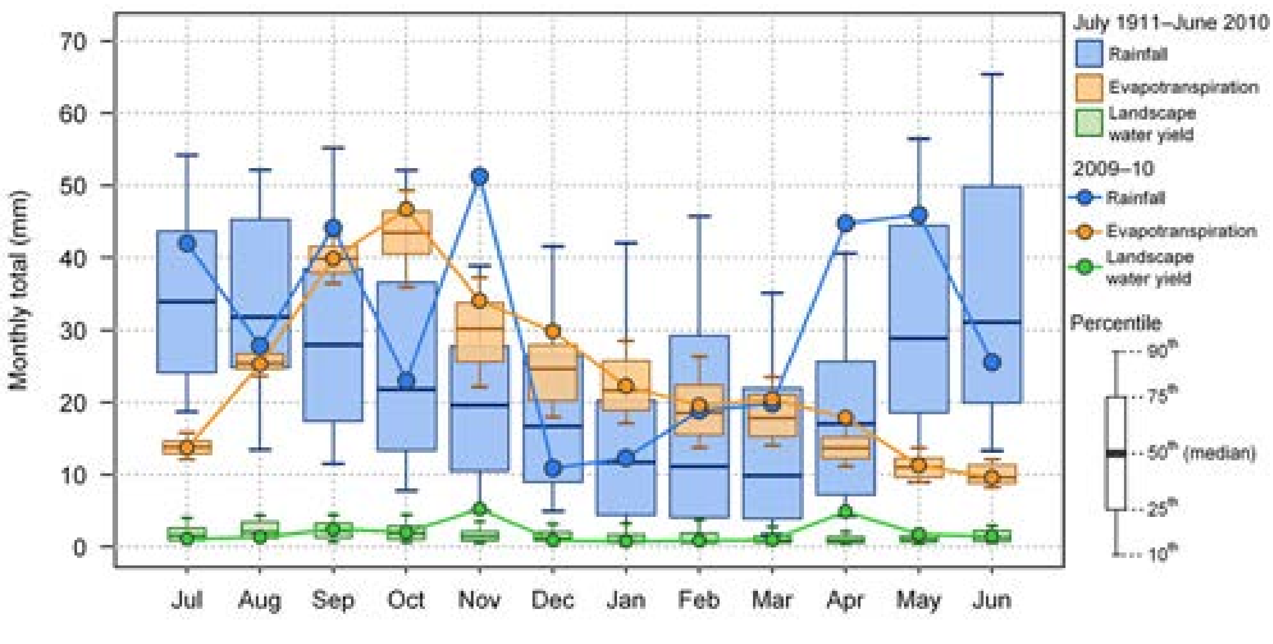


Figure 8-5. Monthly landscape water flows in 2009–10 compared with the long-term record (July 1911 to June 2010) for the South Australian Gulf region

8.4.1 Rainfall

Rainfall for the South Australian Gulf region for July 2009 to June 2010 was estimated to be 367 mm, which is 20 per cent above the region's long-term (July 1911 to June 2010) average of 306 mm.

Figure 8-6 (a)[3] shows that during 2009–10, the highest rainfall generally occurred over the south and southeast of the region with the lowest rainfall experienced across inland areas towards the north of the region. Rainfall deciles for 2009–10, shown in Figure 8-6 (b), indicate that annual rainfall was above average across most of the region. Very much above average rainfall was experienced in the far north. Average conditions occurred in the southeast of the region in areas surrounding Adelaide.

Figure 8-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 192 mm (1982–83) to 491 mm (1992–93). The annual average for the period was 307 mm. The data show that rainfall for 2009–10 represents the region's highest annual total in 17 years, since the exceptionally wet year of 1992–93.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 8-7 (b). The data reflect the general climate seasons of the region, which are generally characterised by higher rainfall during the winter. A shift in the seasonal averages is identified towards the end of the 30-year period, with an apparent increase in summer rainfall averages and a continued decrease in winter rainfall.

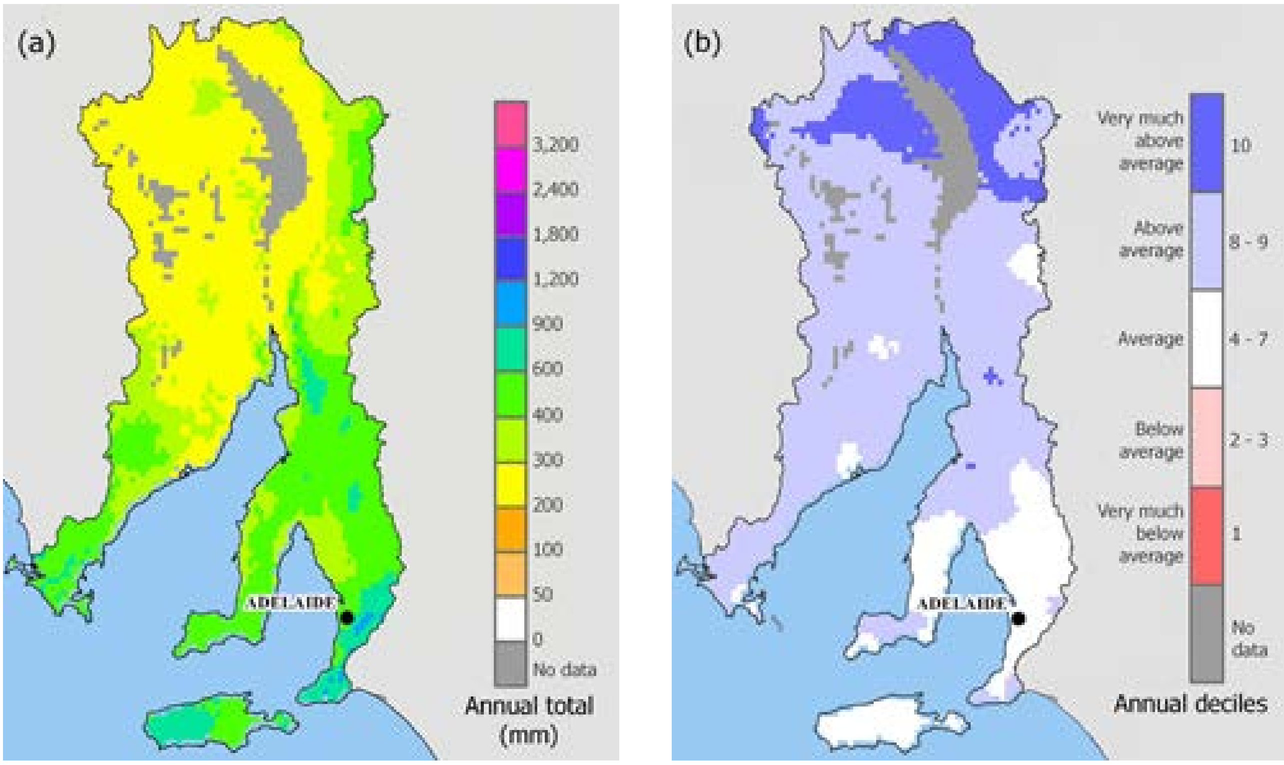
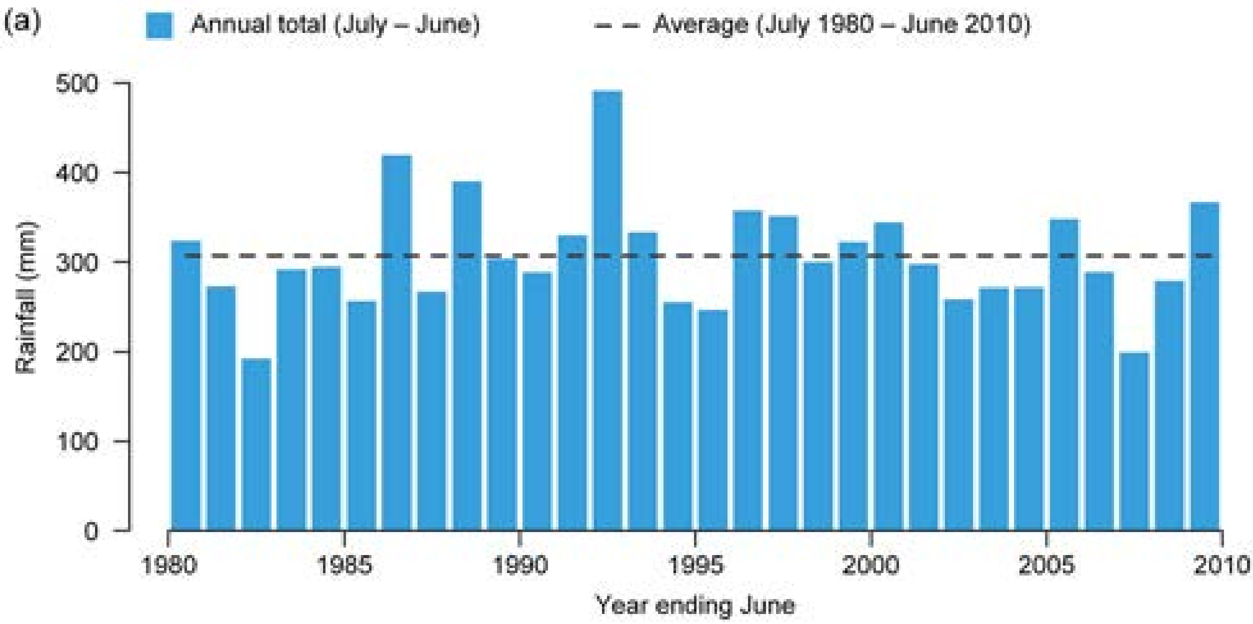


Figure 8-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Australian Gulf region

3. The South Australian Gulf region includes large areas that are excluded from the landscape water balance modelling due to absent parameter data (classified as 'No data'). Typically these areas may represent salt lakes, salt pans, and inland water. More details are presented in the Technical supplement.



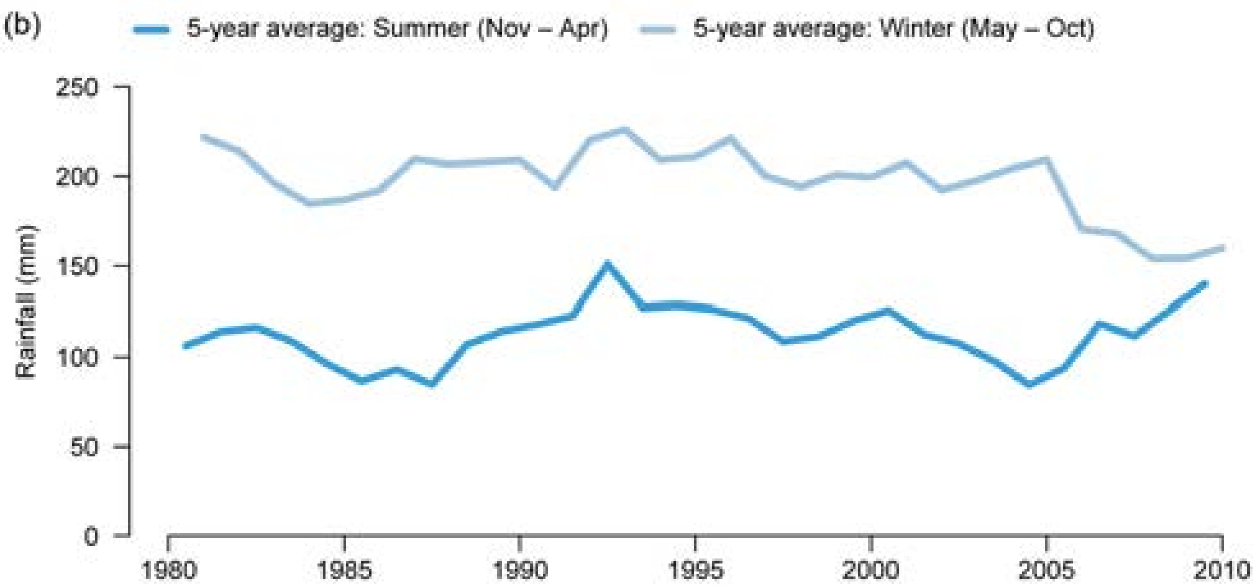


Figure 8-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the South Australian Gulf region

8.4.1 Rainfall (continued)

Figure 8-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis of the summer rainfall period indicates slight increases in rainfall across most of the region over the past 30 years. The winter period shows slight decreases in rainfall across most of the region, particularly across the east of the region and Kangaroo Island.

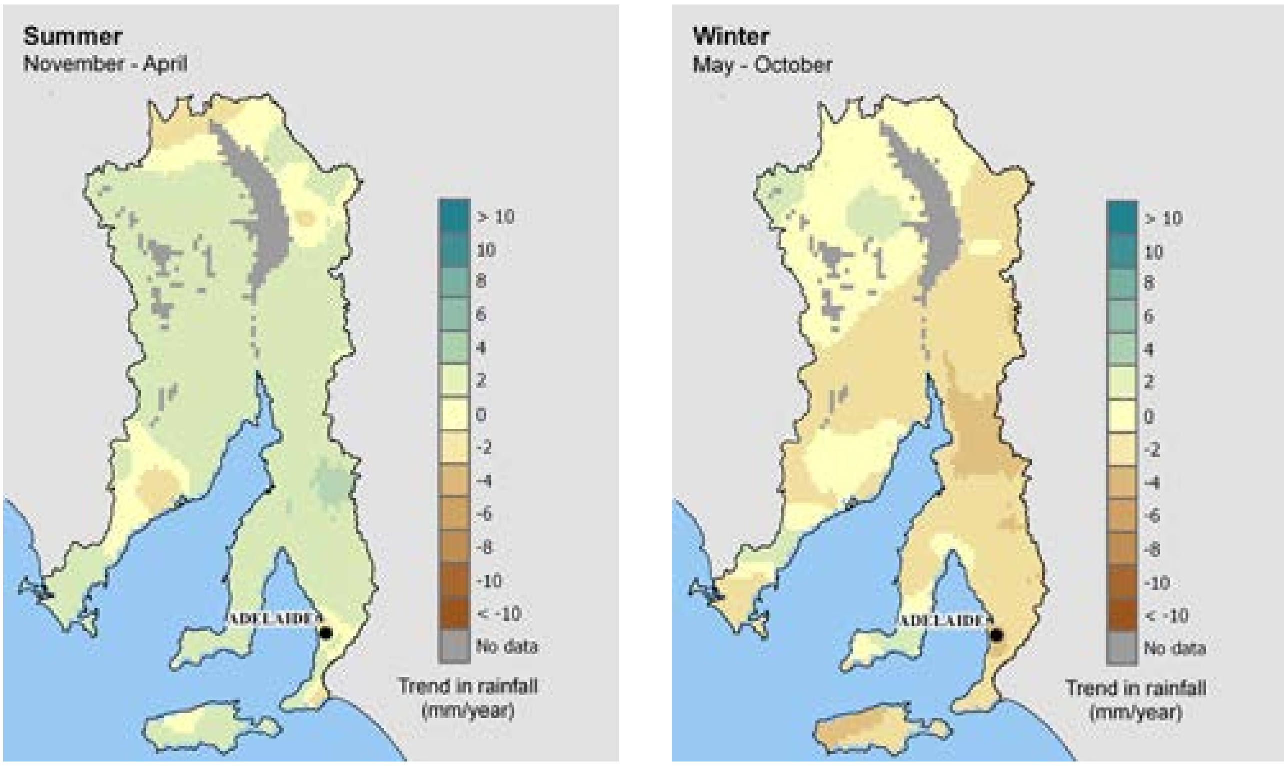


Figure 8-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the South Australian Gulf region. The statistical significance of these trends is often very low

8.4.2 Evapotranspiration

Evapotranspiration for the South Australian Gulf region for 2009–10 was estimated to be 291 mm, which is seven per cent above the region's long-term (July 1911 to June 2010) average of 272 mm.

Figure 8-9 (a) shows that evapotranspiration for 2009–10 was closely related to the distribution of annual rainfall with the highest values to the south and southeast of the region. Evapotranspiration deciles for 2009–10, shown in Figure 8-9 (b), indicate that above average and very much above average evapotranspiration was experienced over much of the north and far south of the region. The centre of the region generally shows average values with below average values observed in very limited south-central areas.

Figure 8-10 (a) shows annual evapotranspiration over the past 30 years (July 1980 to June 2010). Over the 30-year period, evapotranspiration ranged from 223 mm (1982–83) to 308 mm (1986–87). The annual average for the period was 272 mm. The above average evapotranspiration for 2009–10 follows three consecutive drier years with below average totals.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 8-10 (b). Seasonal evapotranspiration is shown to be approximately equal for both summer and winter periods. Over the 30 years, the summer period evapotranspiration shows more interannual variability compared to the more stable winter period.

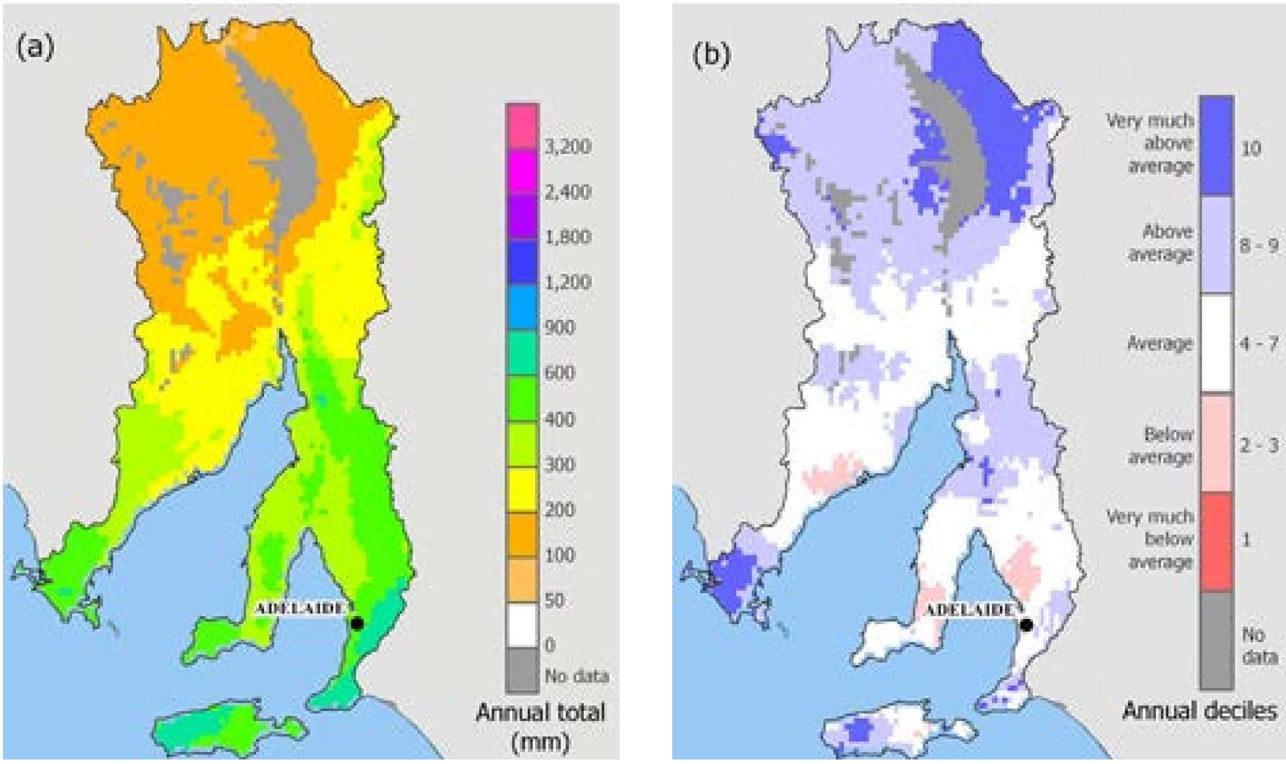


Figure 8-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Australian Gulf region

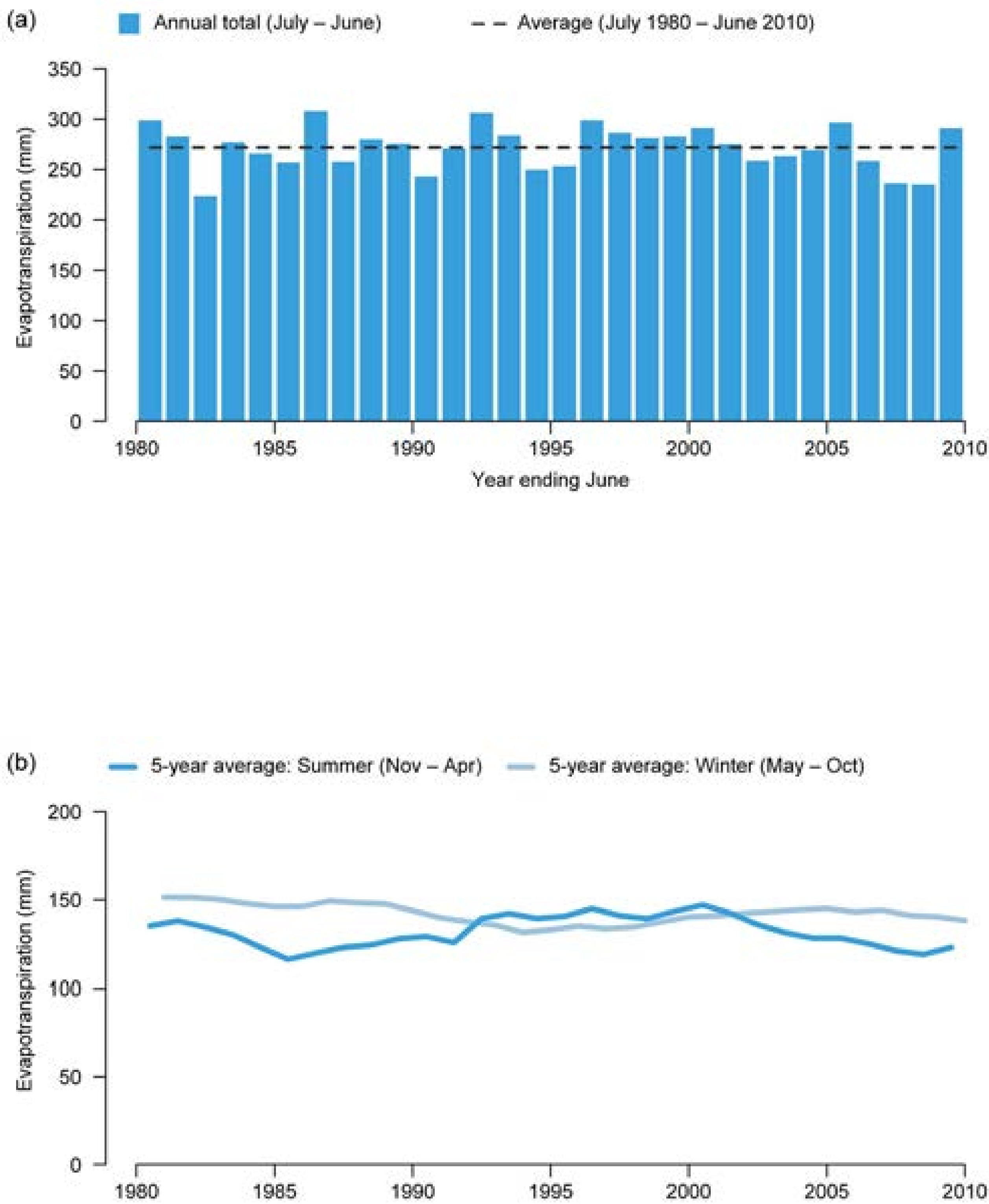


Figure 8-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the South Australian Gulf region

8.4.2 Evapotranspiration (continued)

Figure 8-11 provides a spatial representation of trends in summer (November–April) and winter (May–October) evapotranspiration throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis indicates a mixed pattern of both increasing and decreasing evapotranspiration across the region over the 30-year period. Winter period evapotranspiration shows slight decreasing trends across much of the centre of the region.

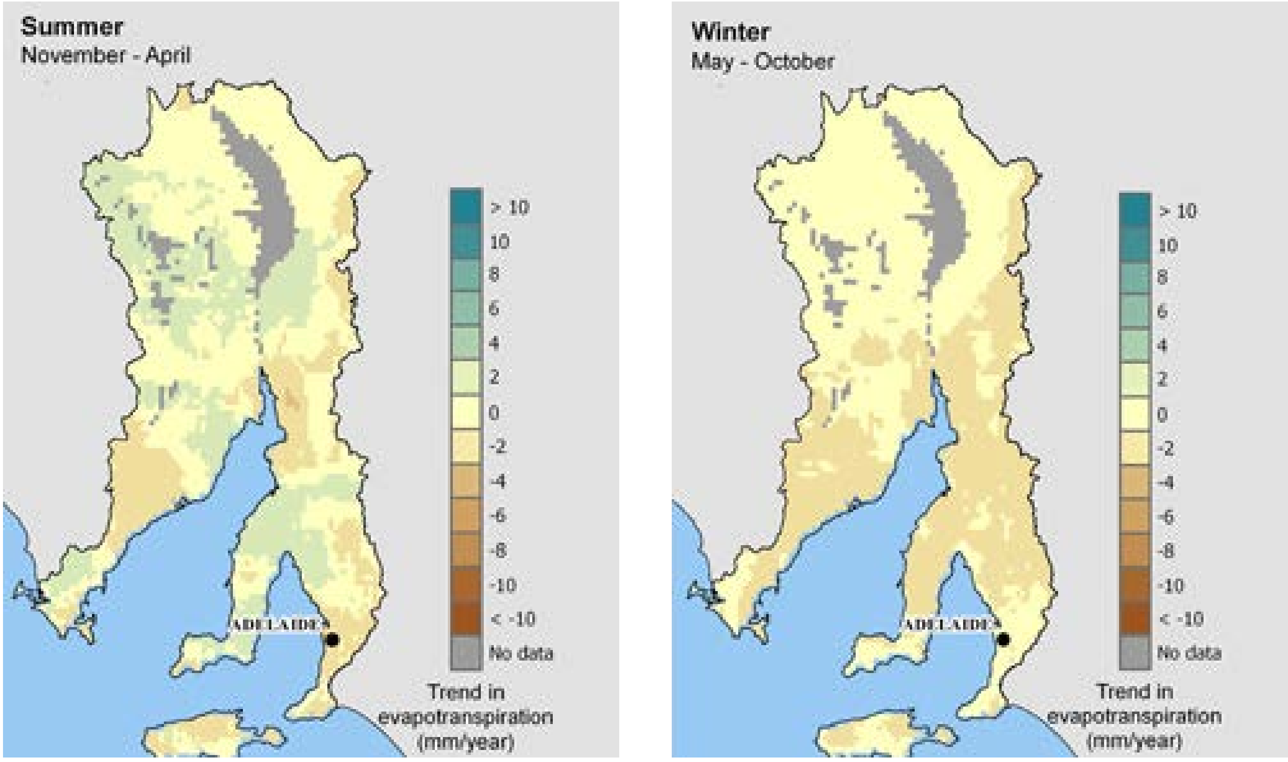


Figure 8-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the South Australian Gulf region The statistical significance of these trends is often very low

8.4.3 Landscape water yield

Landscape water yield for the South Australian Gulf region for 2009–10 was estimated to be 24 mm, which is four per cent above the region's long-term (July 1911 to June 2010) average of 23 mm.

Figure 8-12 (a) shows that during 2009–10, landscape water yield was low (below 50 mm) across much of the region. Highest values occurred in the north and southeast of the region, to the east of Adelaide, as a result of the very much above average rainfall experienced in these areas.

Landscape water yield deciles for 2009–10, shown in Figure 8-12 (b), indicate average and above average values across the much of the region. Very much above average values are identified to the north and centre of the region. Below average conditions were experienced across the southeast of the region with very much below average values identified across a limited area to the north of Adelaide.

Figure 8-13 (a) shows annual landscape water yield over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water ranged varied from 9 mm (1982–83) to 84 mm (1992–93). The annual average for the period was 25 mm.

In spite of above average rainfall for the 2009–10 year (see Figure 8-7 [a]), annual landscape water yield for the region was just below average. The data show landscape water yield was relatively low throughout much of the past 30 years. The extremely high total for the wet year of 1992–93 represents the region's highest annual landscape water yield in the past 30 years and the second highest total in the past 99 years (July 1911 to June 2010).

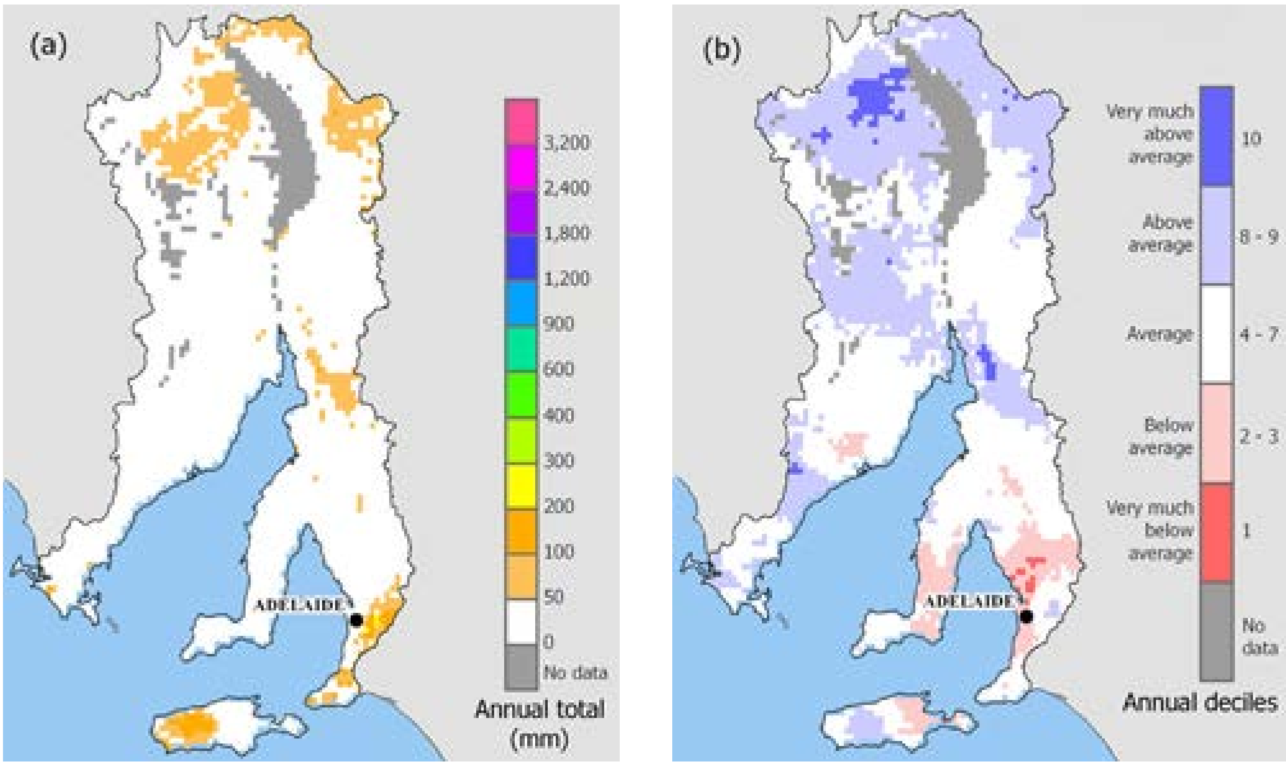
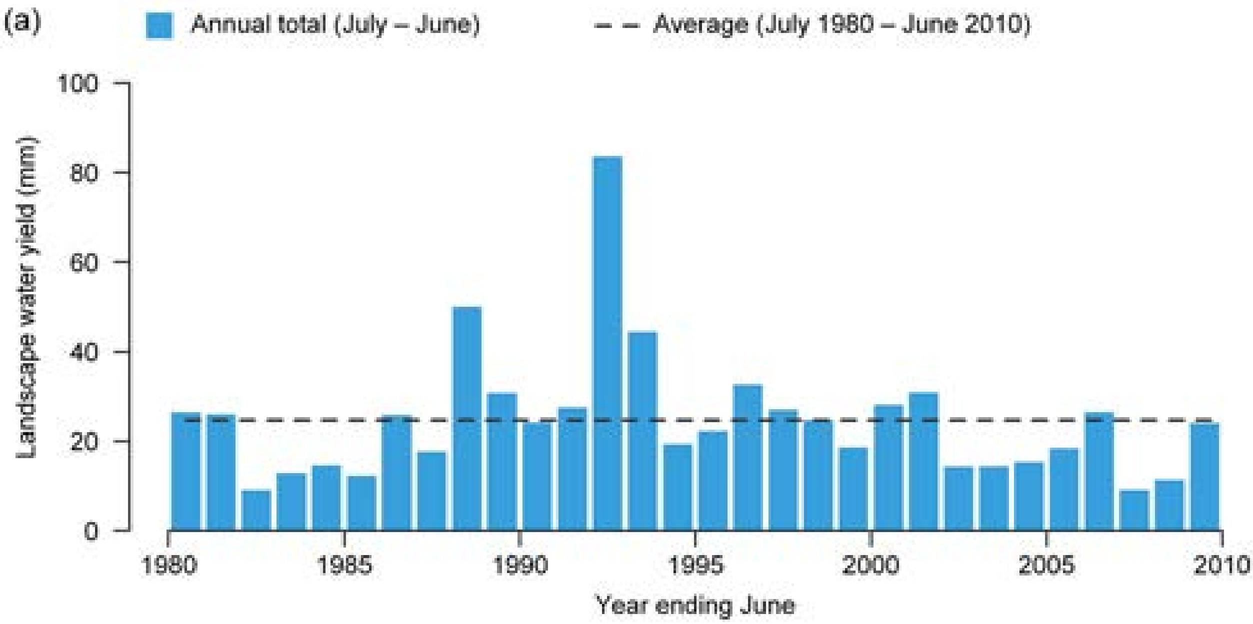


Figure 8-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Australian Gulf region



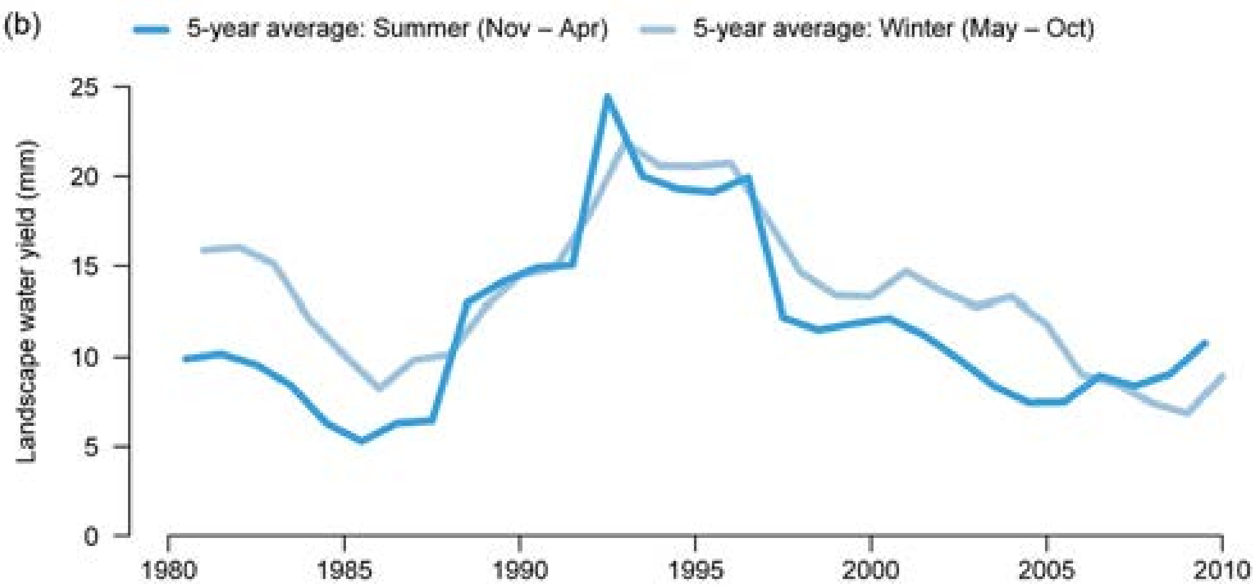


Figure 8-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the South Australian Gulf region

8.4.3 Landscape water yield (continued)

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 8-13 (b). Seasonal landscape water yield averages are shown to be similar for both summer and winter periods, with considerable variability in water yield over the 30-year period. This variability in the data is largely influenced by the relatively wet period through the late 1980s and early 1990s, particularly the extremely high total of 1992–93.

Figure 8-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The generally low level of landscape water yield across the region, for both the summer and winter periods, means trends are generally not clearly defined over the past 30 years.

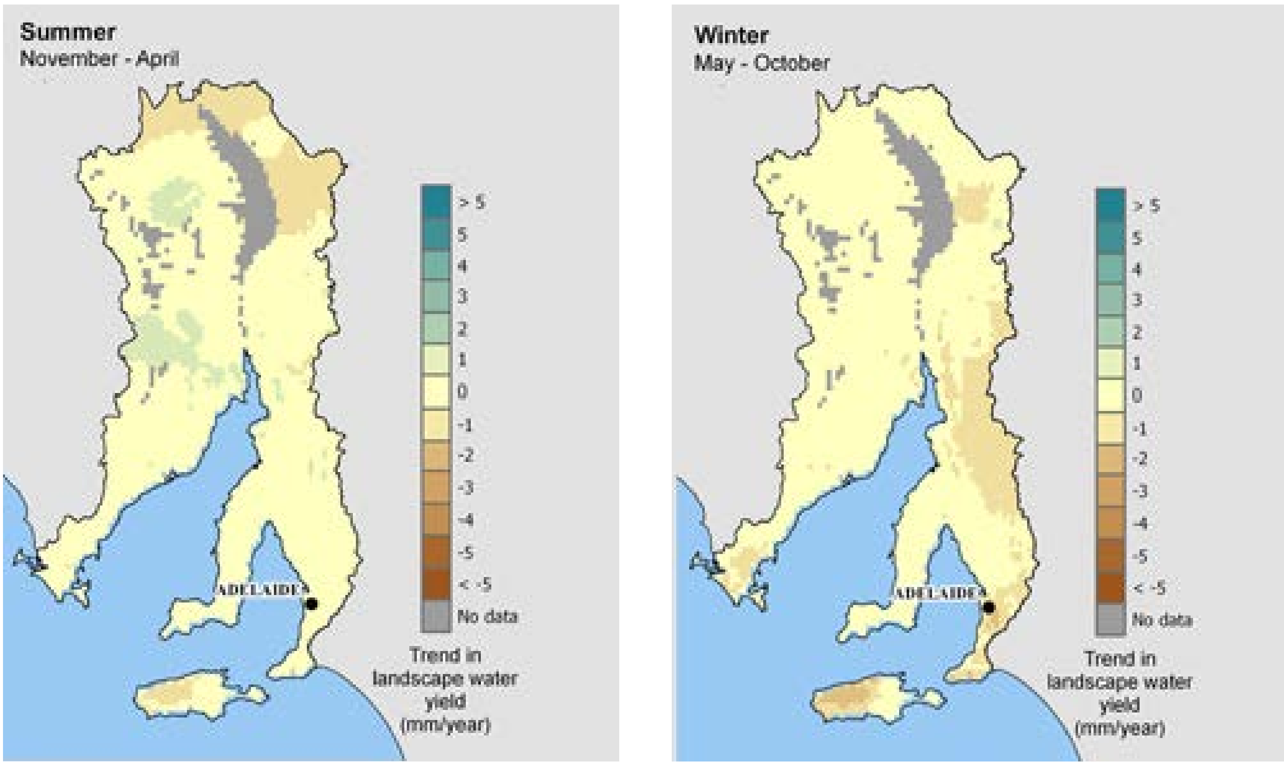


Figure 8-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the South Australian Gulf region. The statistical significance of these trends is often very low

8.5 Rivers, wetlands and groundwater

At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available to conduct analyses of streamflow in the South Australian Gulf region in 2009–10 or on patterns of river inflows to important wetlands.

However, data were available for ten flood gauges allowing reporting on flood occurrence and severity at those gauges (Figure 8-15).

The groundwater management units within the region (Figure 8-16) are administrative boundaries that are used to manage the extraction of groundwater through planning mechanisms. These areas are usually created to identify a significant groundwater resource and to provide a boundary within which resource management effort can be focused. Prescription is the legal mechanism for implementing a water resource management regime in South Australia. A prescribed water resource is managed through an allocation and licensing system where the emphasis is on groundwater. These areas are known as Water Resources Prescribed Areas and Prescribed Well Areas.

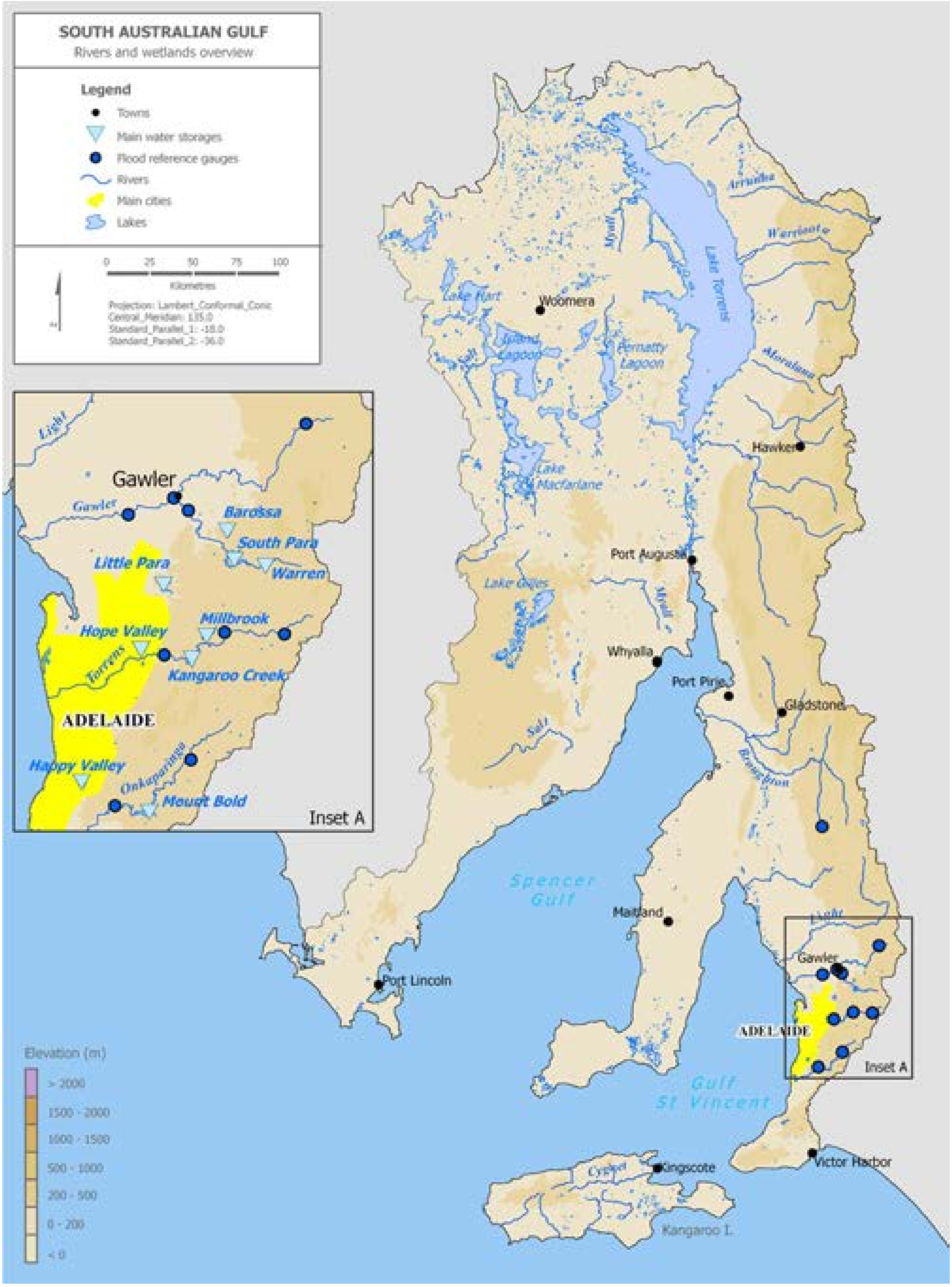


Figure 8-15. Stream gauges selected for flood analysis in the South Australian Gulf region

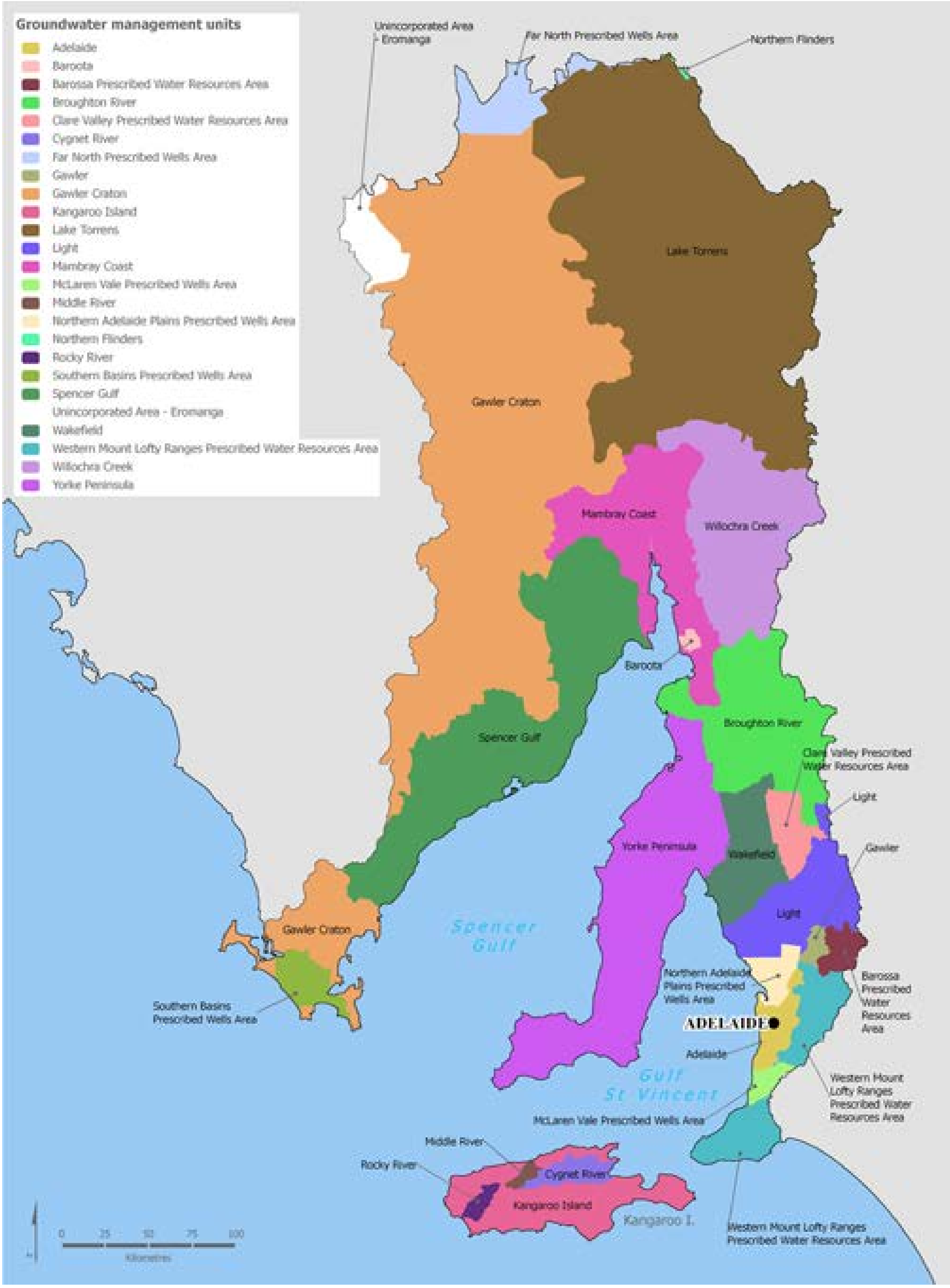
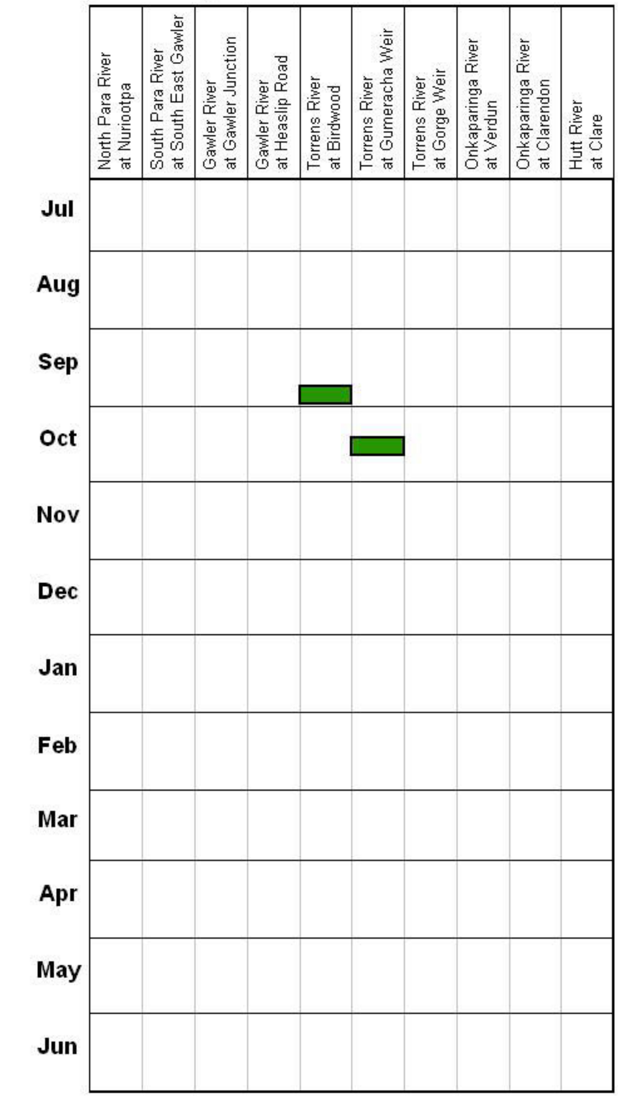


Figure 8-16. Major groundwater management units in the South Australian Gulf region (Bureau of Meteorology 2011e)

Table 8-2. Weekly flood classifications for key flood gauging sites within the region (flood classes are derived in consultation with emergency services and local agencies; the peak height for the year is also included)

South Australian Gulf region
Weekly River Height Peaks from July 2009 to June 2010



Peak flood level (m)

North Para River at Nuriootpa	South Para River at South East Gawler	Gawler River at Gawler Junction	Gawler River at Heaslip Road	Torrens River at Birdwood	Torrens River at Gumeracha Weir	Torrens River at Gorge Weir	Onkaparinga River at Verdun	Onkaparinga River at Clarendon	Hutt River at Clare
-	-	-	-	on 25/09/2009	on 14/10/2009	-	-	-	-
-	-	-	-	-0.3	1.0	-	-	-	-

River height classes (m)

	North Para River at Nuriootpa	South Para River at South East Gawler	Gawler River at Gawler Junction	Gawler River at Heaslip Road	Torrens River at Birdwood	Torrens River at Gumeracha Weir	Torrens River at Gorge Weir	Onkaparinga River at Verdun	Onkaparinga River at Clarendon	Hutt River at Clare
Major	3.3	2.8	7.0	8.0	0.7	2.1	12.0	4.6	12.4	1.8
Moderate	2.9	2.5	5.7	5.5	0.2	1.8	11.6	4.1	11.9	1.5
Minor	2.5	1.9	4.7	4.0	-0.4	1.0	11.3	3.6	11.2	1.1

Colour codes:

- Below flood level
- Annual flood peak
- Major flooding
- Moderate flooding
- Minor flooding

8.5.1 Streamflow and flood report

At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available to conduct analyses of streamflow in the South Australian Gulf region in 2009–10. Due to this, no analysis was conducted on streamflow in the South Australian Gulf region.

Through flood monitoring partnership arrangements, data were available for a number of flood gauges allowing reporting on flood occurrence and severity at those sites. Ten gauges were selected as indicative stations for the South Australian Gulf region and are situated on the Onkaparinga, Torrens, Gawler and Hutt rivers (Table 8-2). The stations were also selected on the basis of data quality and coverage for the 2009–10 period.

A rainfall event around the Adelaide area in mid-September 2009 led to stream rises in all of the selected south flood reference gauges on the Onkaparinga, Torrens and Gawler rivers and even further north on the Hutt River at Clare. The stream rise was significant in the upper part of the Torrens catchment with minor flooding at Birdwood on 25 September 2009.

In the only other flood event for 2009–10, persistent overnight showers resulted in steady stream rises and minor flood levels at Gumeracha Weir on 14 October 2009.

8.5.2 Inflows to wetlands

At the time of writing, suitable quality controlled and assured data from the Australian Water Information System (Bureau of Meteorology 2011a) were not available for the analysis of the pattern of wetland river inflows for the region. Due to this, no analysis was conducted on the pattern of inflow to wetlands.

8.5.3 Groundwater status

The status of groundwater levels in the region is evaluated for the Adelaide Plains and McLaren Vale aquifers. These aquifers are associated with three of the most important groundwater management units (prescribed well areas) shown in Figure 8-16.

The trends in groundwater levels over the past five years are evaluated using a 5 x 5 km grid across each aquifer. A linear trend in groundwater levels is evaluated for each bore with at least 20 level measurements since 2005.

The linear trend in groundwater levels for a 5 x 5 km grid cell is assessed as:

- decreasing (where more than 60 per cent of the bores in the grid cell have a negative trend in levels lower than -0.1 m/year)
- stable (where the trend is lower than 0.1 m/year and higher than -0.1 m/year for more than 60 per cent of the bores)
- increasing (where more than 60 per cent of the bores have a positive trend in levels higher than 0.1 m/year)
- variable (where there is no dominant trend in groundwater levels amongst the bores within a 5 km grid cell).

Groundwater levels for bores used in this assessment are extracted from the South Australian groundwater database. Example bore hydrographs are presented for each aquifer. Aquifers considered include (in order of depth from surface):

- Adelaide Plains
  – watertable
  – Tertiary aquifer 1 (T1)
  – Tertiary aquifer 2 (T2).
- McLaren Vale
  – watertable
  – Willunga
  – Maslin.

8.5.3 Groundwater status (continued)

Adelaide Plains aquifers

Figure 8-17 illustrates the spatial and temporal trends in groundwater levels of the Adelaide watertable aquifer over the period 2005–10. There are few bores available to represent the watertable system. Trends in groundwater levels were analysed in data rich areas only. As shown in Figure 8-17, in the area where there is high monitoring bore density, groundwater levels are stable. In other areas, the levels are declining.

Selected bores 1 and 2 show variability in groundwater levels from 1990 to 2010 but no significant trend over the period. In contrast, bore 3 shows stable levels throughout the period. The fluctuations in water levels in bores 1 and 2 may be in response to infrequent recharge events.

The hydrographs in Figure 8-18 which relate to T1 and T2 aquifers show large within-year variability that is most likely to be the result of seasonal groundwater extraction.

In general, there is a small falling trend in groundwater levels within the 5 x 5 km grid cells over the past five years in T1 aquifer. Within some grid cells no dominant trend is visible. The selected hydrographs indicate that variability in levels within a year is much larger than the interannual trend in levels. Bores 1 and 2 are located near the downstream end of the Gawler River while bore 4 is located near the upstream end of the Little Para River.

The analysis for T2 aquifer indicates declining trends in all grid cells. This is most likely in response to groundwater extraction. The selected bores show wide annual fluctuations in water levels due to pumping and declining water levels over the past five years. Among the selected bores, 1, 3 and 5 are located at the upstream end of Salt Creek, the upstream end of Gawler River, and the downstream end of River Torrens, respectively.

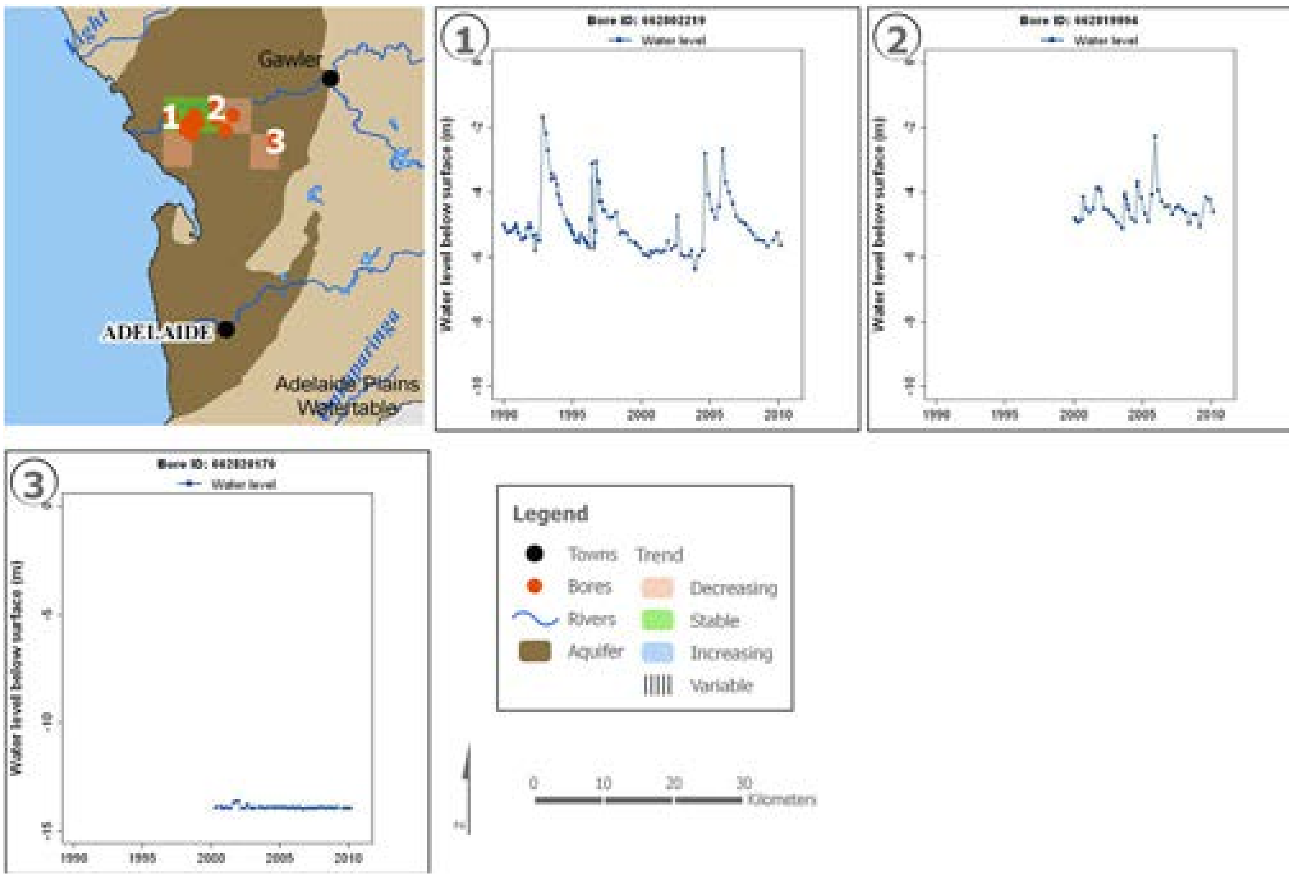


Figure 8-17. Spatial distribution of trends in groundwater levels for the Adelaide watertable aquifer for the 2005–10 period and selected hydrographs showing groundwater levels fluctuations post-1990

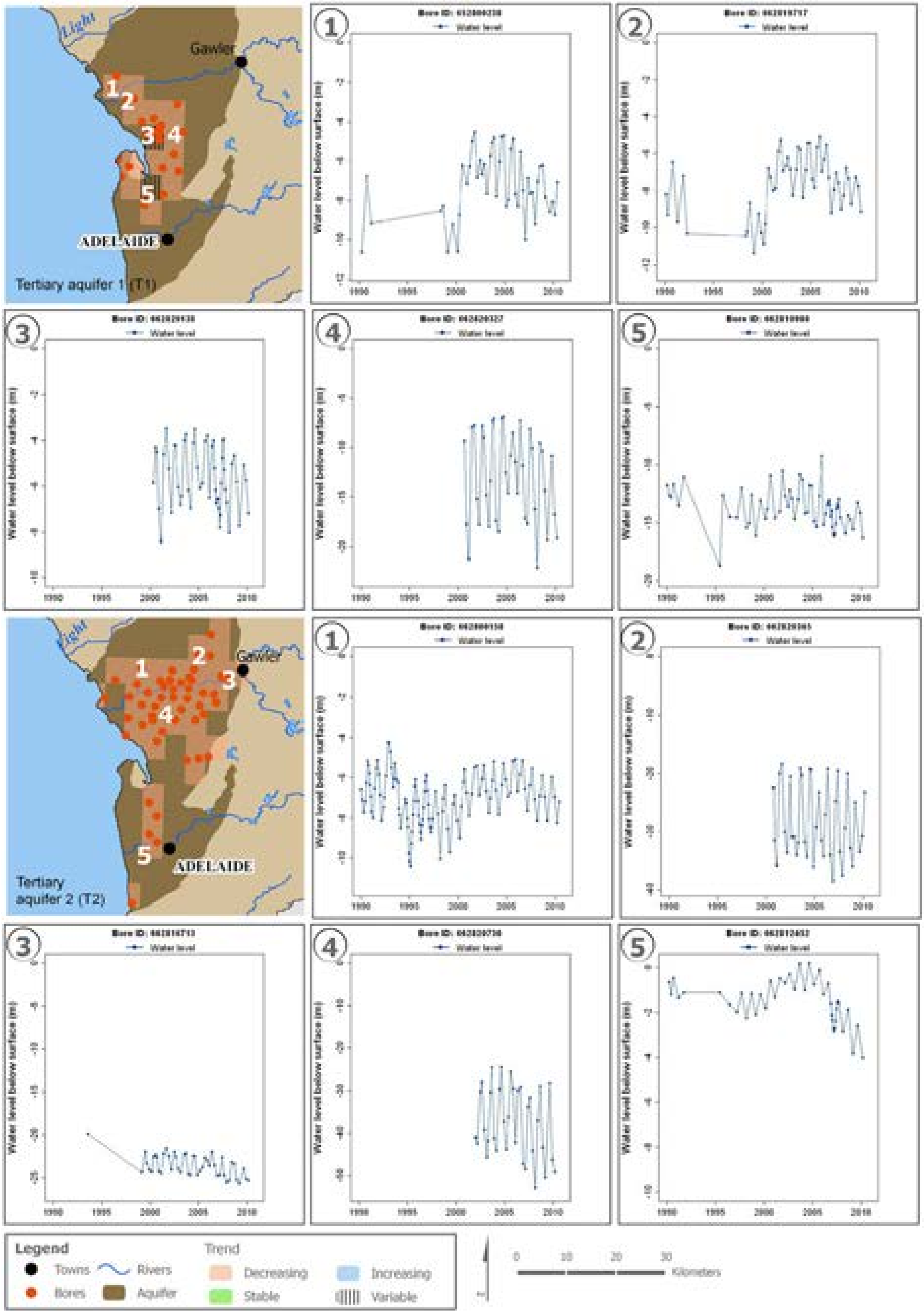


Figure 8-18. Spatial distribution of trends in groundwater levels for the Tertiary aquifer T1 and Tertiary aquifer T2 for the 2005–10 period and selected hydrographs showing groundwater levels fluctuations

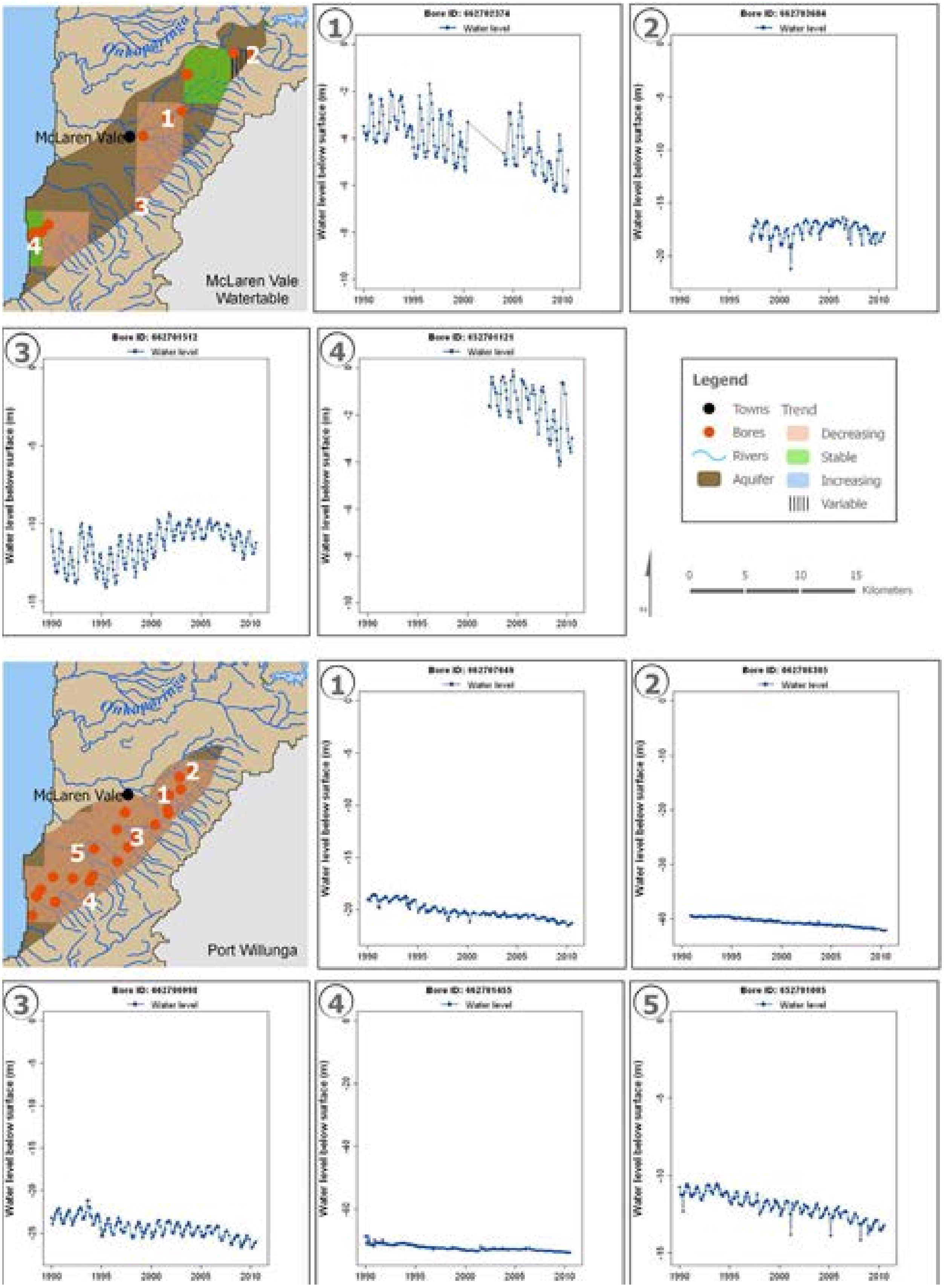


Figure 8-19. Spatial distribution of trends in groundwater levels for the McLaren Vale watertable and the Port Willunga aquifers for the 2005–10 period and selected hydrographs showing groundwater levels fluctuations

8.5.3 Groundwater status (continued)

McLaren Vale aquifers

Groundwater levels within the McLaren Vale watertable aquifer are mostly declining or stable (Figure 8-19). From the selected bores, hydrographs 1, 3 and 4 indicate relatively wide annual fluctuations in water levels that are most likely caused by extraction from the nearby bores. Hydrographs for bores 1 and 4 indicate continuing declines in water level while bores 2 and 3 show variable but relatively stable groundwater levels.

Grid analyses of trends in groundwater levels within the underlying Willunga aquifer (Figure 8-19) show consistently declining levels for the period 2005–10. All the selected bores also show declining levels from at least 1990, with small annual fluctuations in groundwater levels. Of the selected bores, bores 2 and 4 located at the northern and southern ends of the aquifer respectively show relatively low levels of both annual fluctuation and long-term trends in groundwater levels. The greater annual fluctuations in levels in bores 1, 3 and 5 are most likely due to seasonal groundwater extraction nearby.

Grid analyses of trends in groundwater levels within the Maslin aquifer indicate mostly decreasing or stable groundwater levels over the period 2005–10 (Figure 8-20). The hydrograph from bore 1 shows a generally falling trend in water level from 2004. Bores 3 and 4 located at eastern and southern ends of the Maslin Sands aquifer have generally stable water levels for the period 2005–10. Bore 5, located at the western end of the aquifer, shows wide annual fluctuations in water level that may be due to pumping from a nearby bore.

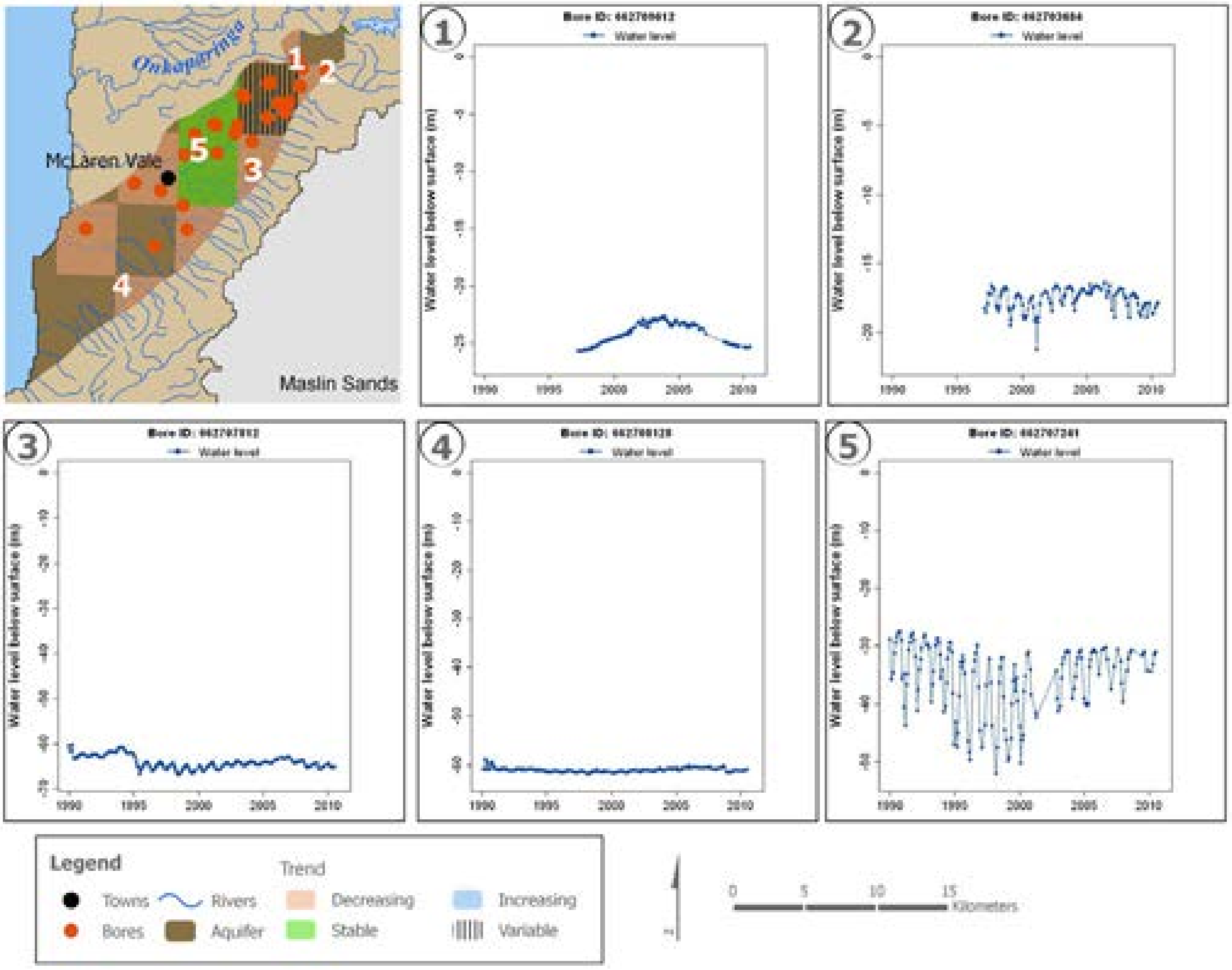


Figure 8-20. Spatial distribution of trends in groundwater levels for the Maslin Sands aquifer for the 2005–10 period and selected hydrographs showing groundwater levels fluctuations

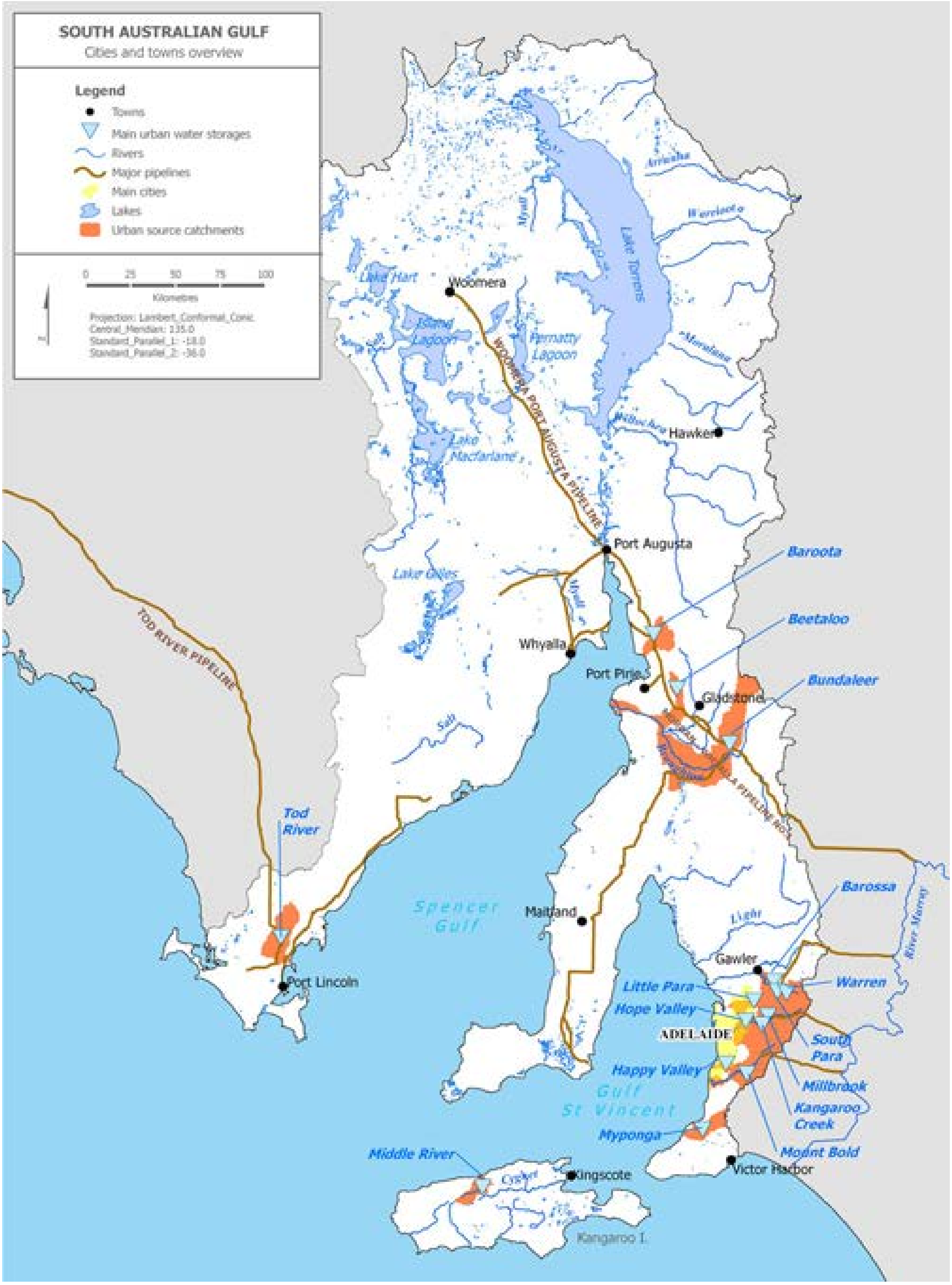


Figure 8-21. Urban areas and supply storages in the South Australian Gulf region

8.6 Water for cities and towns

8.6.1 Regional overview

The South Australian Gulf region has a total population greater than 1.25 million, with more than 1.1 million people residing in Adelaide. The remaining population is sparsely distributed throughout the region (Figure 8-21). Port Augusta, Port Lincoln, Port Pirie and Whyalla are notable townships with populations between 10,000 and 25,000 (Australian Bureau of Statistics 2010b).

Table 8-3 provides the populations of the major urban centres, the river basins in which they are located and their main urban water supply storages.

Table 8-3. Cities and their water supply sources in the South Australian Gulf region

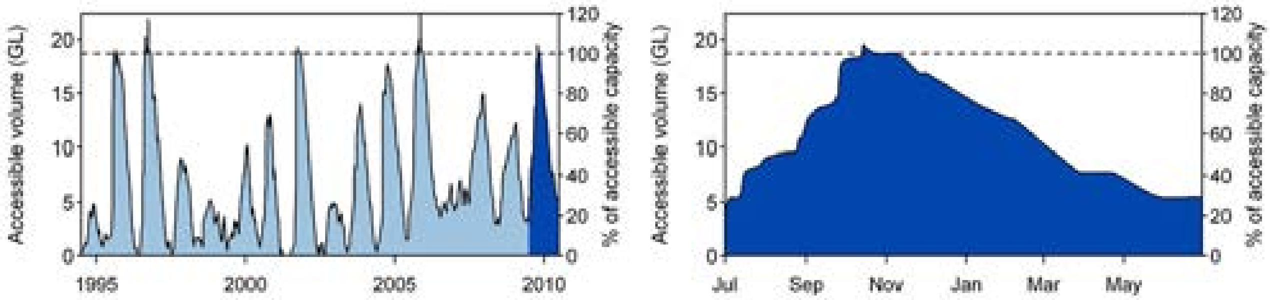
City	Population*	River basin	Major supply storages
Adelaide	1,187,000	Gawler, Torrens, Onkaparinga, Myponga and Fleurieu Peninsula	Myponga, Barossa, Little Para, Kangaroo Creek, Mount Bold, Happy Valley, Hope Valley, Warren, Millbrook and South Para reservoirs
Whyalla	23,200	Spencer Gulf	River Murray (Morgan–Whyalla pipeline)
Port Pirie	14,200	Mambray Coast and Broughton River	Baroota Reservoir, River Murray (Morgan–Whyalla pipeline)
Port Augusta	14,000	Mambray Coast	River Murray (Morgan–Whyalla pipeline)
Port Lincoln	14,000	Eyre Peninsula	Groundwater (Southern Basins)

* Australian Bureau of Statistics (2010b)

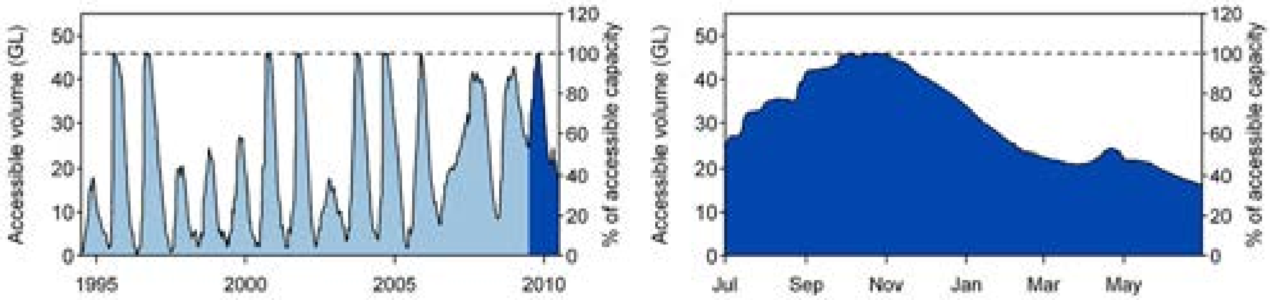
8.6.1 Regional overview (continued)

Figure 8-22 shows the accessible storage volume over recent years for four water storages servicing Adelaide. Their combined accessible volume constitutes 69 per cent of the total system accessible storage volume for Adelaide.

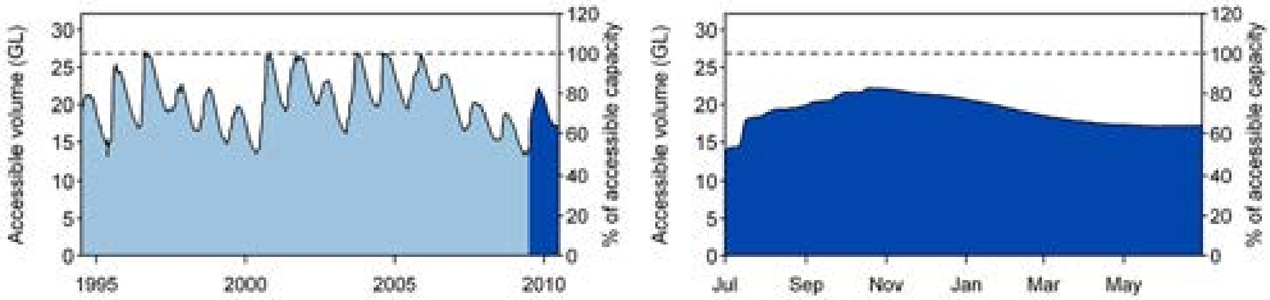
Adelaide (Kangaroo Creek)



Adelaide (Mount Bold)



Adelaide (Myponga)



Adelaide (South Para)

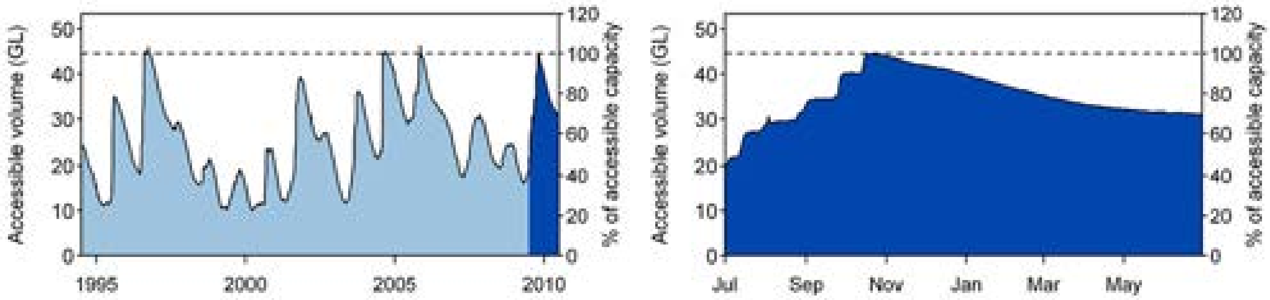


Figure 8-22. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for Adelaide

8.6.2 Adelaide

The Adelaide water supply area encompasses the city of Adelaide and surrounding suburbs, stretching over the Gawler, Torrens, Onkaparinga and Myponga river basins. Water from these river systems, combined with water imported into the region from the River Murray, supply the Adelaide population as well as irrigation throughout the reporting area.

Urban water infrastructure and management

South Australia Water Corporation (SA Water) is the South Australian Government-owned statutory body that owns and manages Adelaide's water supply systems, recycled water systems and wastewater services. SA Water controls surface water diversions, operates water treatment plants and maintains Adelaide's reticulation system.

Figure 8-21 shows the key components of the Adelaide water supply system, including three pipelines importing River Murray water and ten storages totalling 198 GL in capacity. SA Water also operates seven water treatment plants and 12 wastewater treatment plants. A number of privately operated bore fields exist, supplying groundwater primarily for agricultural uses. Some treated water is exported to adjacent regions for urban consumption.

Due to the low rainfall and short rivers of the Adelaide region, the natural run-off from areas such as the Mount Lofty Ranges is not sufficient to meet Adelaide's water demand. Local catchment yields are, therefore, augmented with diversions from the River Murray. The annual volume of diversion is heavily dependent on the winter yield from the Mount Lofty Ranges and the volume in Adelaide's water storages.

The 60 km Mannum–Adelaide pipeline was the first of three pipelines built to deliver River Murray water to the Adelaide region. Commissioned in 1955, the Mannum–Adelaide pipeline supplies water to the Anstey Hill Water Treatment Plant and to a number of storages. The second pipeline to be constructed was the Swan Reach–Stockwell pipeline that was completed in 1969. The Murray Bridge–Onkaparinga pipeline was completed in 1973 and supplies water to the Summit Storage Water Treatment Plant as well as releasing water into the Onkaparinga River for collection and treatment downstream.

There are a number of recent and ongoing infrastructure projects in the Adelaide region aimed at decreasing Adelaide's dependence on River Murray water. The most significant project is a 100 GL/year desalination plant at Lonsdale, south of Adelaide. The plant is expected to start producing water in 2011. A number of recycling schemes that supply treated effluent for agricultural and municipal irrigation and residential (garden and toilet flushing) use also exist, as well as several community or privately operated recycling schemes that supply to viticulture and municipal applications.

Surface storage levels and volumes in recent years

The Mount Bold, South Para, Kangaroo Creek and Myponga storages constitute 69 per cent of the total Adelaide system storage. The South Para Reservoir serves the Northern Adelaide Plains. Kangaroo Creek Reservoir is used to supply water to the northern Adelaide suburbs from Port Adelaide to the Torrens River while Mount Bold Reservoir serves the southern Adelaide suburbs from the Torrens River to the Onkaparinga River. Water from the Myponga Reservoir is distributed along the coast from the Onkaparinga River to Normanville.

Figure 8-23 (top) shows the annual diversions from the River Murray since 1997–98 (Murray–Darling Basin Authority 2011). Figure 8-23 (middle) shows the combined volume of the four water storages listed in the preceding paragraph since July 1994. Figure 8-23 (bottom) shows the combined storage volume for 2009–10.

The storage volume in Figure 8-23 (middle) displays a large annual variation, with storages generally filling over July to October and drawdown the rest of the year, as seen in Figure 8-23 (bottom). Inflows are primarily from Mount Lofty Ranges catchments. Depending on these inflows, the River Murray diversion can range from 40 per cent of the total water sourced in high rainfall years to 90 per cent in years of very low rainfall.

Figure 8-23 (top and middle) shows that, in years where there were low stream inflows from the Mount Lofty Ranges, the storages have not filled. This occurred in years such as 1997–98 to 1999–2000, 2002–03 and 2006–07. Increased diversions from the River Murray were required in these years to meet the demand for water.

8.6.2 Adelaide (continued)

The high diversion in 2002–03 (double the diversion of 2001–02) was due to diminished inflows from the Mount Lofty Ranges coupled with high demand resulting from dry, hot weather. In the severe drought conditions of 2006–07, record low inflows into the Murray–Darling Basin were recorded for 11 consecutive months. Flows from the Mount Lofty Ranges were also severely impacted (South Australia Water Corporation 2010). These dry and hot conditions resulted in the small storage volume increase and large diversion from the River Murray that can be seen in Figure 8-23 (top) for that year. The 203 GL diversion in 2006–07 was initially restricted to 143 GL but was later increased by 60 GL to improve water quality. This additional 60 GL was for use in 2007–08 and the diversion in that year was correspondingly less (Murray–Darling Basin Authority 2011).

Figure 8-23 (bottom) shows that in 2009–10 the Adelaide storages filled to almost 100 per cent before experiencing a relatively typical drawdown.

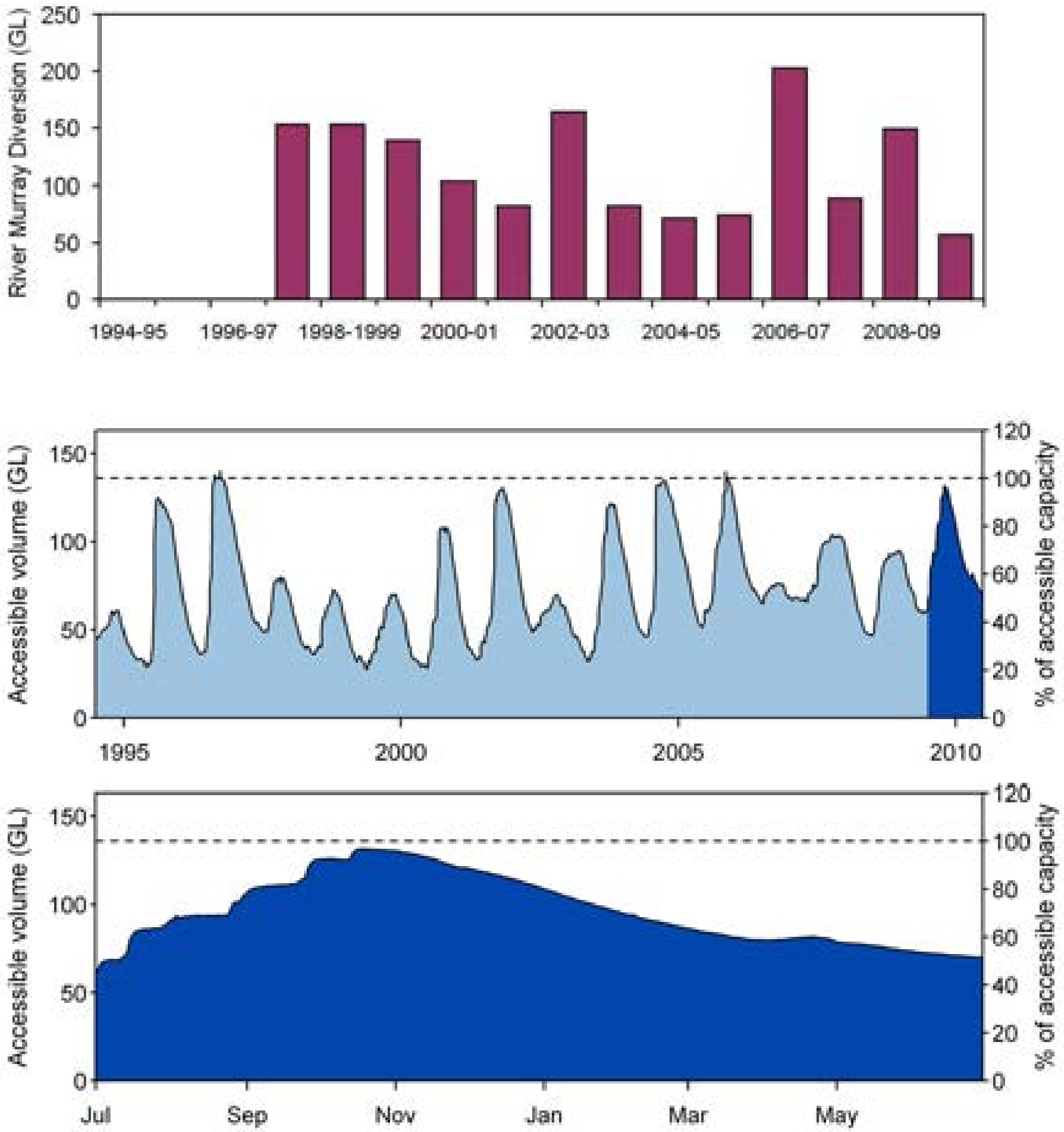


Figure 8-23. Annual River Murray diversion since 1997–1998 (top) and combined surface water storage volumes in Mount Bold, South Para, Kangaroo Creek and Myponga since 1993 (middle) and during 2009–10 (bottom)

8.6.2 Adelaide (continued)

Water restrictions in recent years

The water restriction scheme for Adelaide is not operated in direct response to the total available water in storage. Water restrictions in Adelaide are instead dependent on flows from the Mount Lofty Ranges and also on conditions in the Murray–Darling Basin, including volumes in the Hume and Dartmouth storages. Restrictions applied to Adelaide outdoor water consumption are shown against combined storage volumes (for Mount Bold, South Para, Kangaroo Creek and Myponga) in Figure 8-24.

In the early 2000s, local storages, catchments and the River Murray were stressed as a result of drought conditions within the region and the Murray–Darling Basin. As a result, level 2 water restrictions were introduced in July 2003 for four months. Permanent Water Conservation Measures (PWCM) were introduced in October 2003, promoting long-term water conservation. The restrictions reduced average per capita total consumption (including residential, industrial, commercial and other) from 460 L/p/d (litres per
person per day) in 2002–03 to 423 L/p/d in 2003–04 (National Water Commission 2009b). The per capita consumption continued to drop to 420 L/p/d and 412 L/p/d for 2004–05 and 2005–06, respectively.

In October 2006, after a record dry winter and record low inflows into the River Murray, enhanced level 2 restrictions were introduced. They were quickly replaced in January 2007 by level 3 restrictions and per capita consumption for 2006–07 decreased to 399 L/p/d. The following year saw significant adoption of water conservation practices causing the per capita consumption in 2007–08 to drop to 350 L/p/d (National Water Commission 2011a).

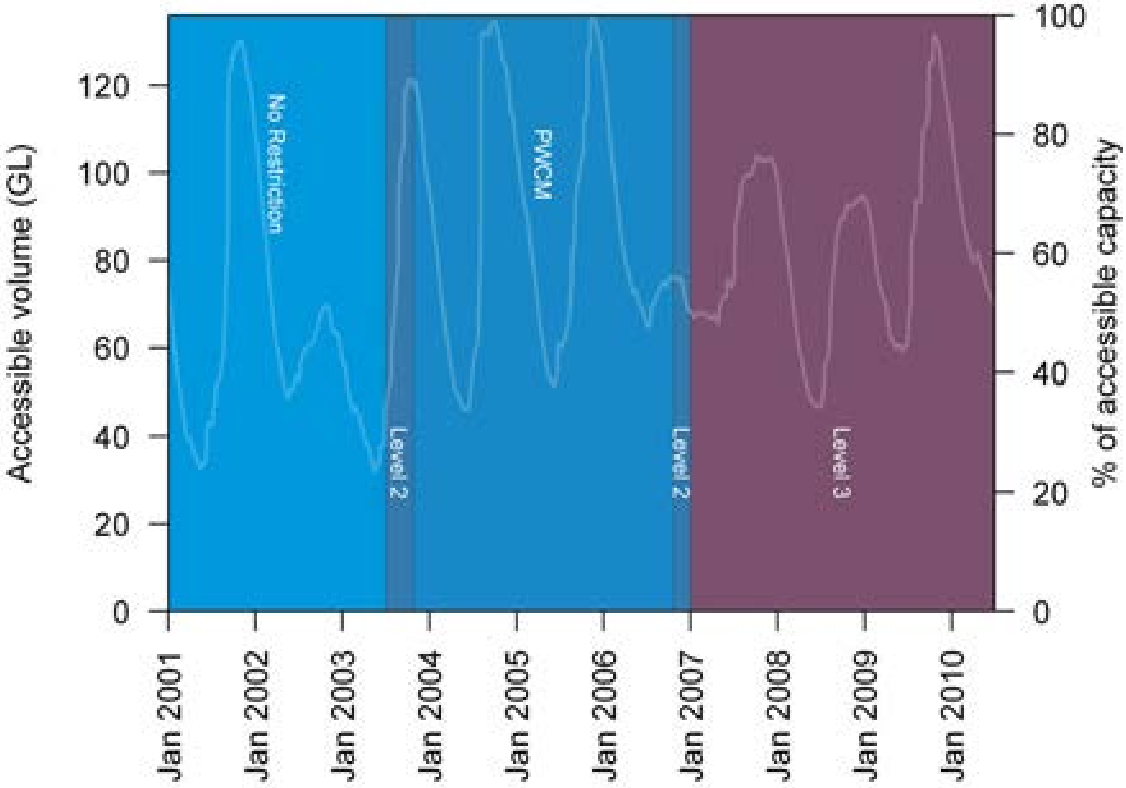


Figure 8-24. Urban water restriction levels for the Adelaide water supply area since 2005 shown against the combined accessible water volume of Mount Bold, South Para, Kangaroo Creek and Myponga

8.6.2 Adelaide (continued)

Level 3 restrictions remained through to 2009–10 with only minor changes to outdoor watering hours. The South Australian Government put on a temporary cessation of all outdoor watering in July 2007 which was extended through August and September due to low winter flows. In October 2007, Adelaide residents were permitted to water for three hours a week which was increased to five hours and then seven hours in April 2010 and May 2010, respectively.

Source and supply of urban water in recent years

Figure 8-25 shows the total volume of water sourced from surface water and recycled water for supply to Adelaide (National Water Commission 2011a). Total water sourced in 2009–10 was 164 GL. Between 2005–06 and 2009–10, the highest volume of water sourced was 181 GL in 2006–07, which was an extremely dry and hot year. Over the following three years, the volume of water sourced was lower and constant as a result of demand management through water restrictions.

In 2005–06, recycled water comprised ten per cent of total water sourced for Adelaide. For the remaining years shown in Figure 8-25, approximately 15 per cent of the total water sourced was recycled water. No groundwater or desalinated water is sourced by SA Water for Adelaide's water supply.

Figure 8-26 shows the total volume of water delivered to residential, commercial, municipal and industrial consumers in Adelaide from 1995–96 to 2009–10. The 1995–96 to 2001–02 data were sent to the Bureau as required under the regulations in the Commonwealth *Water Act 2007* while the 2002–03 to 2009–10 data are based on information from the National Water Commission's National Performance Reports (2011a). Consumption steadily increased from 1995–96 to 2000–01, with peak annual water consumption coinciding with the 2002–03 drought. Since 2002–03 and the introduction of water restrictions, water consumption declined.

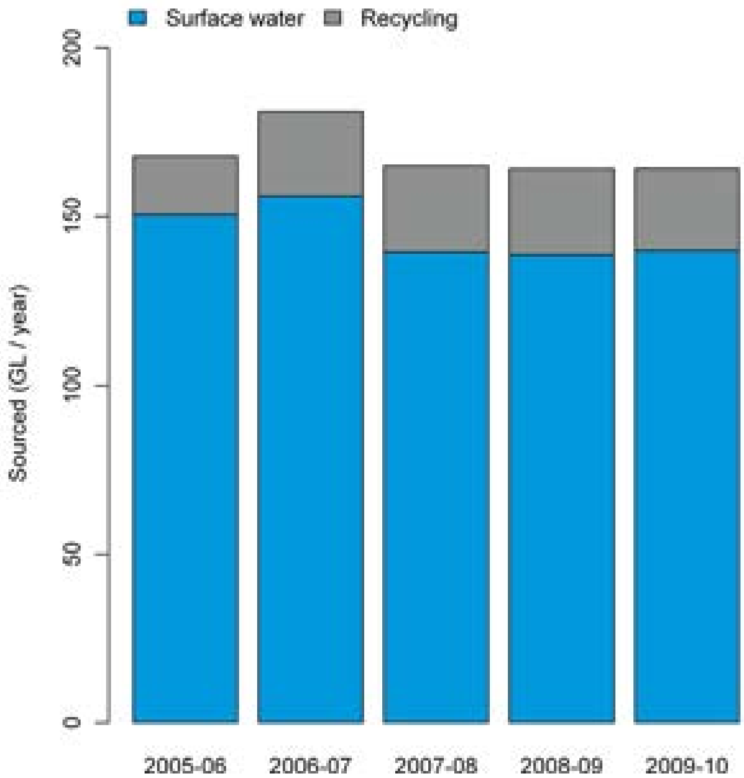


Figure 8-25. Total urban water sourced for the Adelaide water supply area from 2005–06 to 2009–10

8.6.2 Adelaide (continued)

Residential water use constitutes between 65 per cent and 75 per cent of Adelaide's total water consumption. Residential water use in Adelaide peaked in 2002–03 when more than 123 GL were supplied for residential use. As discussed above, water restrictions and conservation measures subsequently had a marked influence on residential water use. These were introduced in 2003 and helped to maintain reduced water consumption through to 2006–07 when extremely dry conditions saw residential consumption increase slightly. The level 2 and level 3 restrictions introduced in 2006–07 reduced annual residential consumption to an average of 94 GL over the period 2007–08 to 2009–10.

Commercial, municipal and industrial water consumption in Adelaide peaked in 1997–98 at more than 45 GL. By 2007–08, consumption by the commercial, municipal and industrial sectors fell to 32 GL. By 2009–10, it was only 16 GL, almost a third of the 1997–98 consumption.

Since the introduction of water restrictions in 2003, the per capita consumption in Adelaide (including residential, commercial, industrial and other uses) was greatly reduced from an unrestricted consumption of 460 L/p/d in 2002–03 to 306 L/p/d in 2009–10 (National Water Commission 2011a).

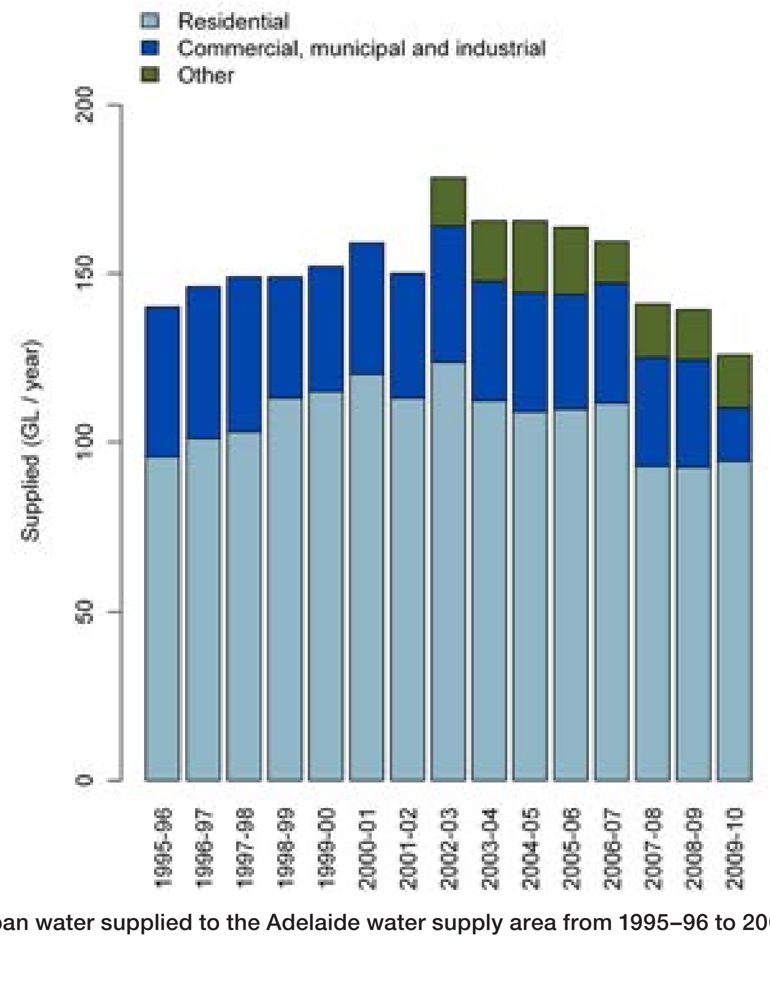


Figure 8-26. Total urban water supplied to the Adelaide water supply area from 1995–96 to 2009–10

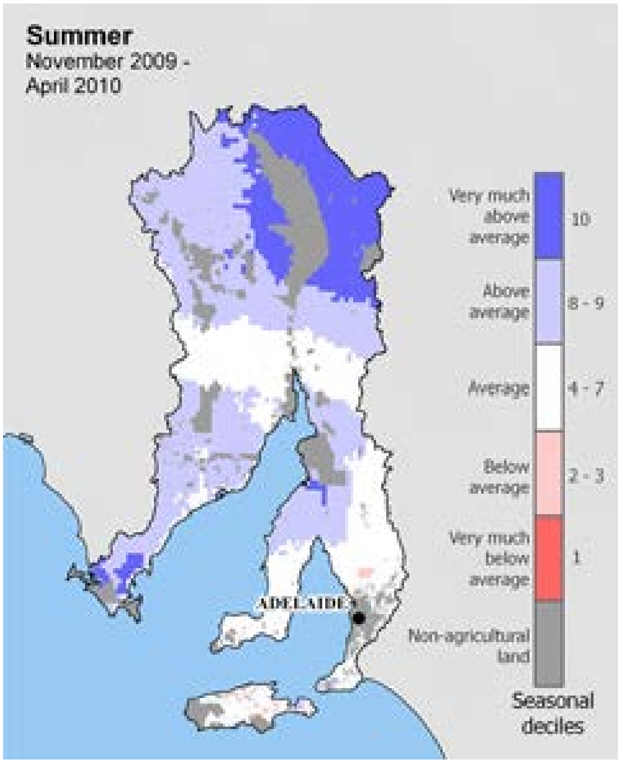
8.7 Water for agriculture

The South Australian Gulf region includes some productive agricultural land in addition to extensive native grasslands. In the northern arid river basins, grazing is the main land use. Dryland pasture and cropping is more concentrated in the south in the Wakefield, Gawler and Broughton river basins.

8.7.1 Soil moisture

In the summer of 2009–10 (November 2009 to April 2010), upper soil moisture was above average to very much above average on agricultural land in northern areas of the region (Figure 8-27). By comparison, agricultural land in southeastern areas had generally average upper soil moisture conditions.

During winter 2010 (May to October), upper soil moisture conditions were estimated to have increased across much of the region following consistently above average rainfall, particularly between August and October. Above average and very much above average conditions are indicated across much of the region. Average soil moisture conditions were limited to areas in the far southeast of the region and Kangaroo Island (Figure 8-27).



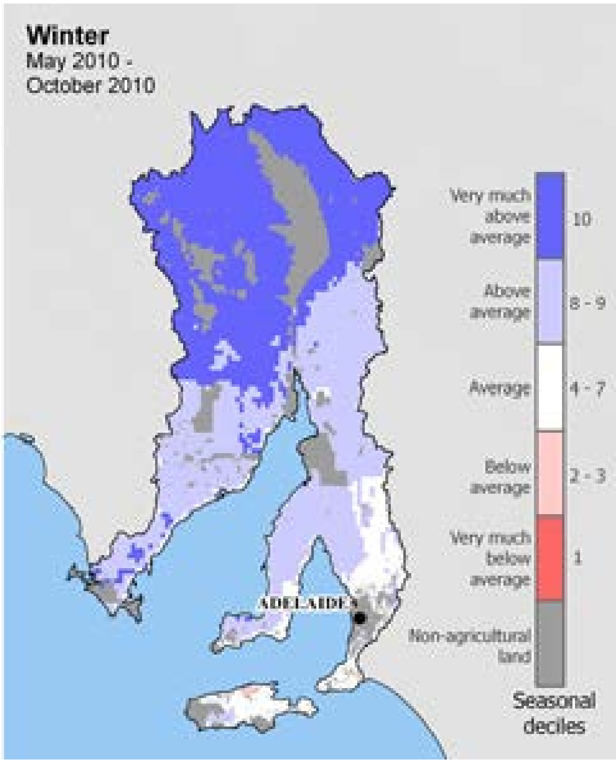


Figure 8-27. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the South Australian Gulf region

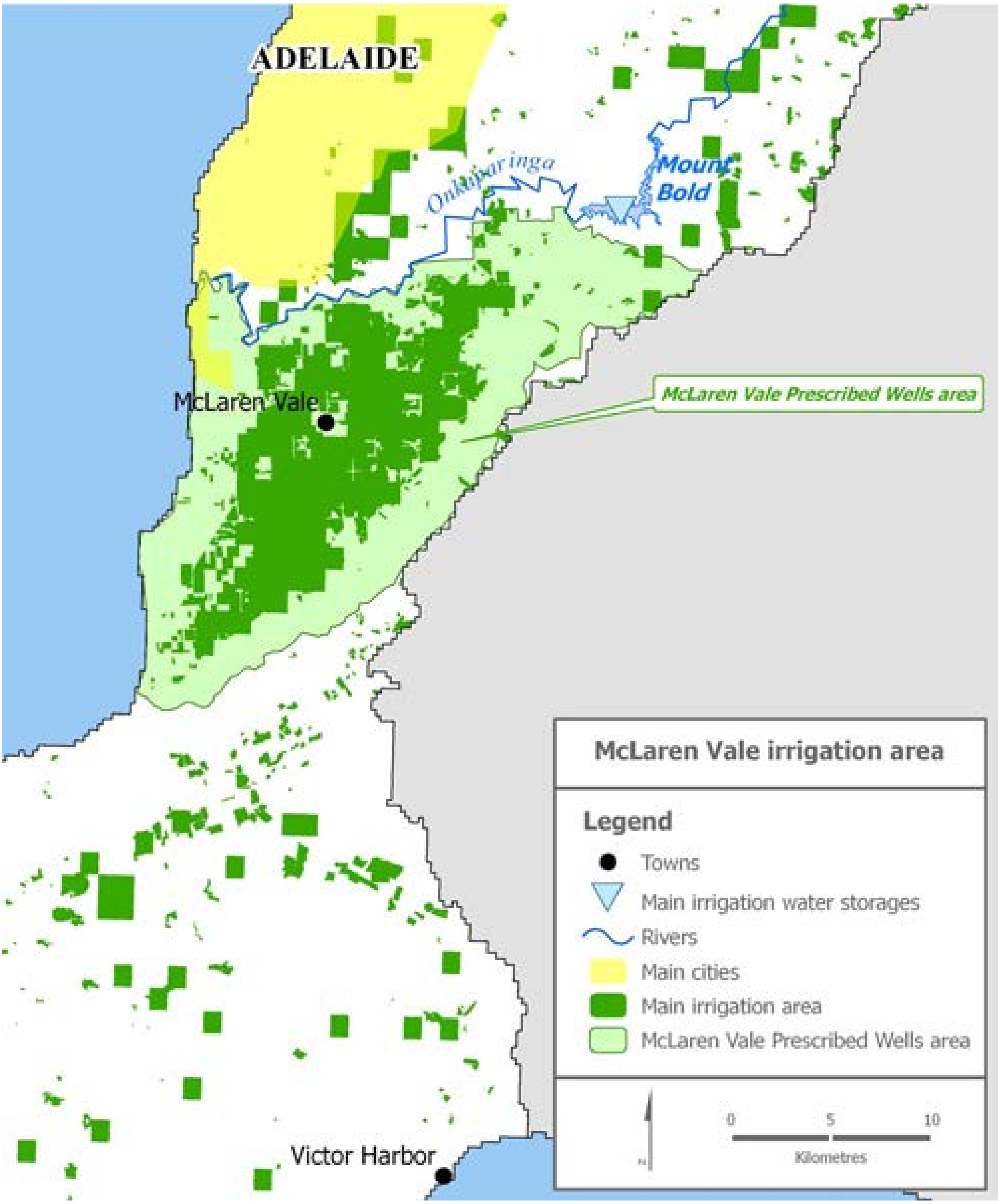


Figure 8-28. Irrigation areas in the Onkaparinga River basin

8.7.2 Irrigation areas

Irrigated agriculture in the South Australian Gulf region is mostly for viticulture and wine grape production, the most important regions of which are concentrated in the Onkaparinga catchment (Figure 8-28). Water for these enterprises is sourced from the Mount Lofty Ranges and River Murray diversions. Mount Bold Reservoir on the Onkaparinga River is the largest storage in the region with an accessible capacity of 46.4 GL. In most years, inflows to the storage are supplemented by water pumped from the River Murray via a pipeline from Murray Bridge.

A comparison of annual irrigation water use in parts of the region for the period between 2005–06 and 2009–10 is shown by natural resource management regions in Figure 8-29 and Figure 8-30. Data were sourced from the *Water Use of Australian Farms* reports (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011). The majority of irrigated water use occurs in the southeastern areas where viticulture is concentrated.

The McLaren Vale Prescribed Wells Area (Figure 8-28) in the Onkaparinga catchment is described in Section 8.7.3 as an example of irrigated agriculture water use in the South Australian Gulf region.

8.7.3 McLaren Vale

The McLaren Vale Prescribed Wells Area is located within the Onkaparinga catchment and managed by the Onkaparinga Catchment Water Management Board. It covers an area of 320 km^2 with a population of approximately 174,000. The Onkaparinga River forms part of the northern boundary while the south-eastern boundary mostly follows the ridge of the Sellicks Range (Figure 8-28).

The McLaren Vale Prescribed Wells Area was formed after amalgamating the Willunga Basin Prescribed Wells Area and the Upper Willunga Catchment Moratorium Area in 2000. This was done to address concerns about the long-term sustainability of water resources as a result of low rainfall and high extraction, which led to substantial declines in groundwater levels.

The climate of the area is Mediterranean, with cool, wet winters and hot, dry summers. Annual rainfall varies significantly, from around 400 mm to around 900 mm. Land use in the area is dominated by dryland pasture enterprises. However, irrigated viticulture provides the major source of income, accounting for more than 85 per cent of the region's irrigation. Orchards and other irrigated crops account for the remainder.

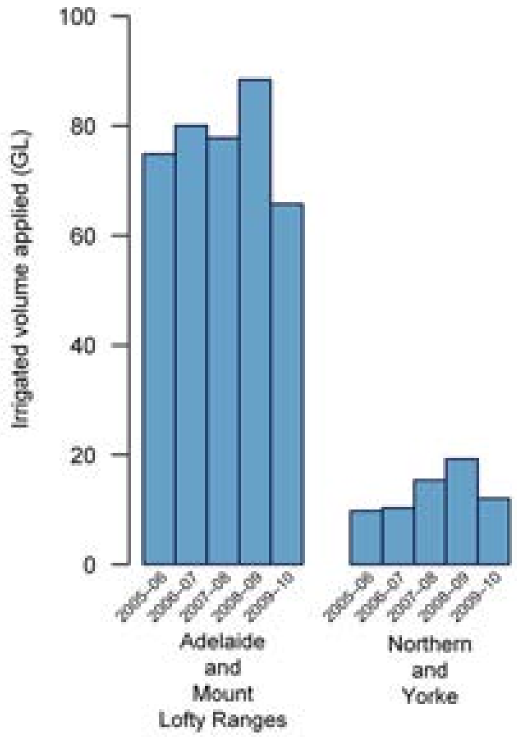


Figure 8-29. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the South Australian Gulf region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

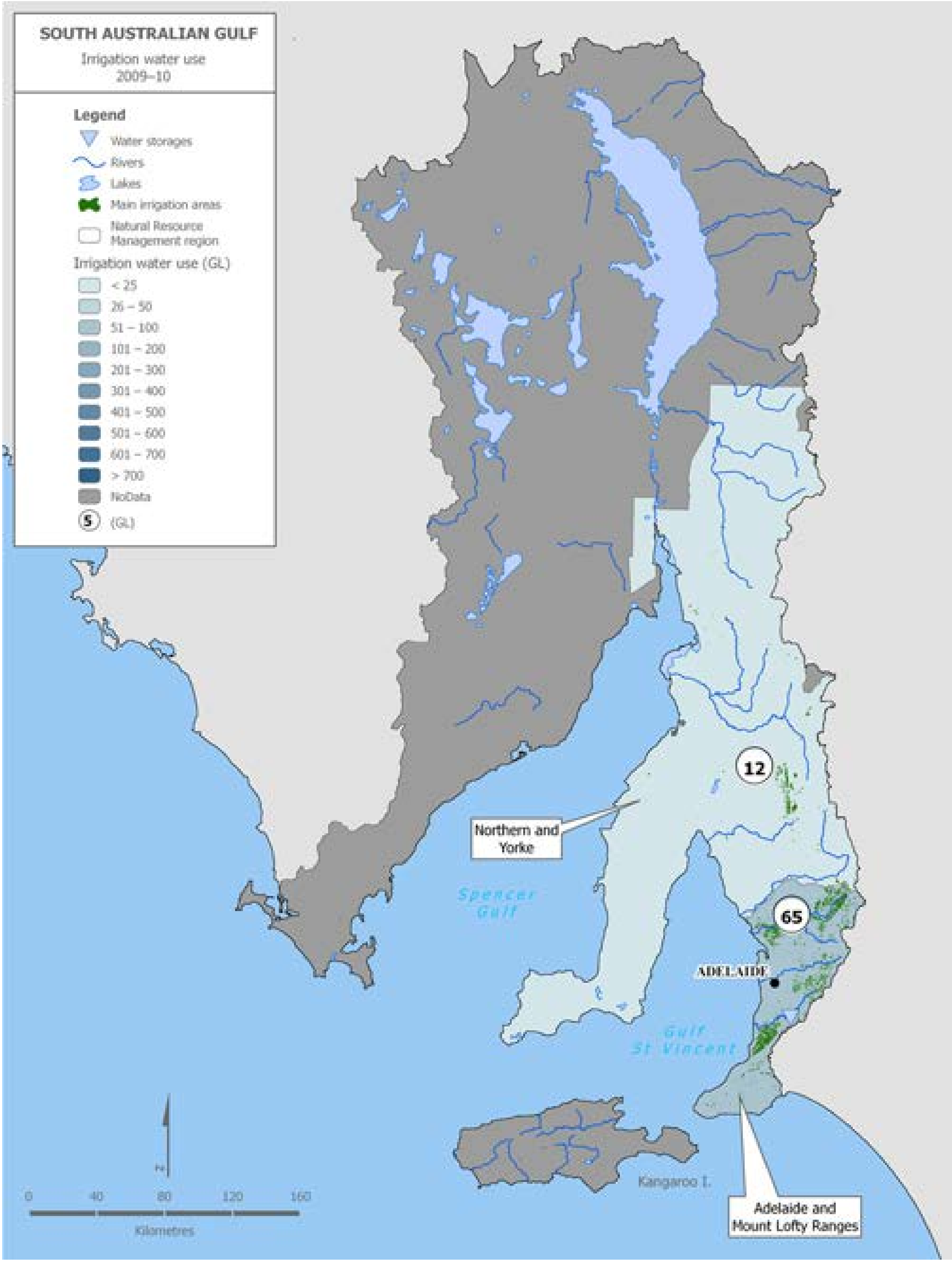


Figure 8-30. Annual irrigation water use per natural resource management region for 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

8.7.3 McLaren Vale (continued)

Around 75 per cent of water used for irrigation in the McLaren Vale Prescribed Wells Area is sourced from groundwater, with the remainder sourced predominantly from mains water and treated water from the Christies Beach Waste Water Treatment Plant. The area contains an estimated 3–5 million ML of groundwater (Government of South Australia 2000).

Prescription is the legal mechanism for implementing a water resource management regime in South Australia. A prescribed water resource is managed through an allocation and licensing system.

The McLaren Vale Water Allocation Plan was adopted in November 2000. Average allocation in McLaren Vale is 1.5 ML/ha for vines and 2.8 ML/ha for other crops. Restrictions on access to groundwater and the high value of irrigated activities raised the market prices for permanent groundwater entitlements. The high cost of groundwater encouraged the development of alternative water sources by irrigators such as mains water and secondary treated water from the Christies Beach Waste Water Treatment Plant to irrigate vines, predominantly through drip irrigation.

Groundwater in the McLaren Vale Irrigation Area

The aquifer system in the McLaren Vale Prescribed Wells Area is complex but can be grouped into four aquifers: the Quaternary sediments, Willunga Formation, Maslin Sands and fractured basement rock. These aquifers are interconnected and, as such, withdrawals from one aquifer will impact others (Australian Bureau of Agricultural and Resource Economics 2003). Furthermore, the aquifers are not all present at all locations in McLaren Vale. The Willunga aquifer supplies 64 per cent of groundwater extracted for irrigation, with the Maslin Sands and fractured basement rock aquifers supplying 20 per cent and 16 per cent respectively (Australian Bureau of Agricultural and Resource Economics 2003).

The Quaternary aquifer is formed from sands and inter-bedded clays where a perched aquifer develops within the sand sediments. Recharge is mainly through local rainfall and from run-off provided by streams. The Quaternary aquifer is generally shallow and of poor quality. However, it plays an important role in supporting groundwater dependent ecosystems, such as Aldinga Scrub, and by providing base flow to creeks and streams along the coastal margin (Government of South Australia 2007).

The Willunga aquifer is the most utilised groundwater resource in McLaren Vale and comprises sand and limestone. Recharge to this aquifer system principally occurs in the unconfined portion of the aquifer near McLaren Vale and McLaren Flat. The aquifer is confined by Quaternary sediments in the south and southwest.

The Maslin Sands aquifer overlies the fractured rock aquifer and comprises fine to coarse sands and clays. The aquifer is unconfined in the northeast of the area. Like the Willunga aquifer, recharge is via direct rainfall infiltration in unconfined areas as well as from streams and inflow from surrounding fractured rocks.

The fractured rock aquifer outcrops east of the Willunga fault, along the northern extent of the area following the Onkaparinga Gorge. This aquifer is recharged by rainfall in outcropping areas. Groundwater flows through fractures and fissures in the formation and is influenced by the size, density and orientation of the fractures. This water source is accessed by deep bores, generally around 100 m in depth.

The Willunga observation well monitoring network provides critical water level and salinity information on the groundwater systems in the McLaren Vale Prescribed Wells Area (Figure 8-31). The observation well network was established in the 1970s.

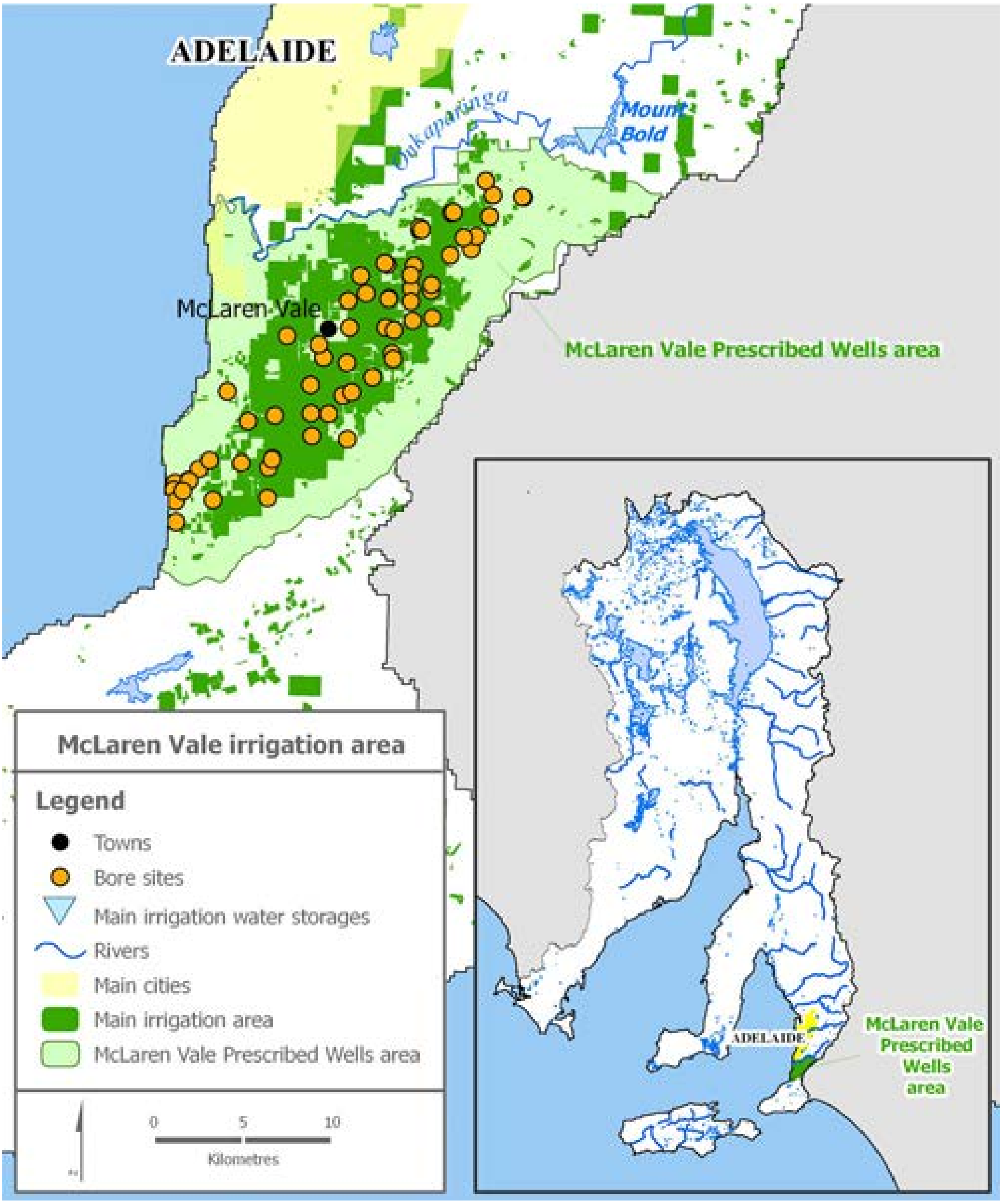


Figure 8-31. The McLaren Vale Prescribed Wells Area with groundwater bore sites, including a location map of the area

8.7.3 McLaren Vale (continued)

There is often a very strong relationship observed in shallow aquifer systems between changes in groundwater levels and rainfall, which occur as a result of rapid recharge to these systems from rainfall (Department of Water, Land and Biodiversity Conservation 2007). Therefore, years of above average rainfall will result in rising groundwater levels, while years of below average rainfall will result in declining groundwater levels.

Trends in the groundwater levels were evaluated for the watertable (Quaternary) aquifer at five selected sites using data between 1990 and 2010 (Figure 8-32). The figure also shows the rainfall residual mass (cumulative difference between monthly rainfall and long-term average monthly rainfall) and the absolute monthly rainfall for the period. A positive slope on the rainfall residual mass curve equates to a period of above average rainfall, while a negative residual mass slope equates to a period of lower than average rainfall. The figure illustrates that, except for one bore, the groundwater response to trends in rainfall is prominent. It also shows that groundwater recharge in the watertable aquifer is driven by seasonal cycles in rainfall. All wells show a decline in water level after 2007. This was as a result of below average rainfall conditions in the region (see rainfall residual mass in Figure 8-32). The pattern and magnitude of change in groundwater level is also influenced by the change in the pattern of extraction across the area.

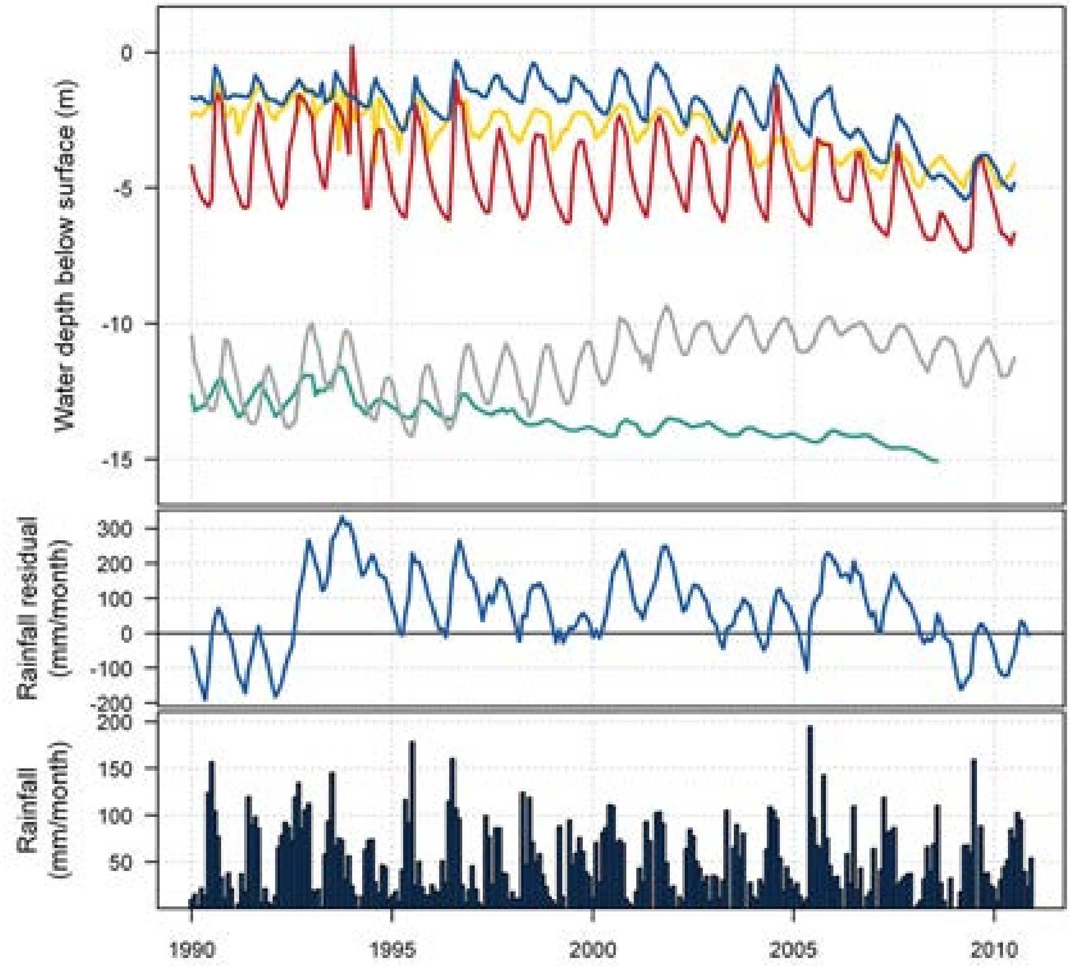


Figure 8-32. Groundwater levels between 1990 and 2010 of the Quaternary aquifer at five bore sites in the McLaren Vale irrigation area compared with rainfall residuals (middle panel) and daily rainfall (lower panel) at Willunga

8.7.3 McLaren Vale (continued)

Groundwater level status

Figure 8-33 shows the median groundwater depth in the three aquifers in the McLaren Vale area during 2009–10. Groundwater levels for the McLaren Vale watertable, Port Willunga and Maslin Sands aquifers are shown together. The watertable bores are mostly located in the Quaternary aquifer. Figure 8-34 shows deciles of depth in 2009–10 compared to the past 20 years.

The bores in the McLaren Vale watertable aquifer indicated shallow groundwater levels in some locations during 2009–10, but other locations showed levels among the deepest of the past 20 years. Groundwater depth in the Willunga aquifer in 2009–10 was 10 m below land surface or deeper. The recorded groundwater levels were among the deepest of the past 20 years. In the Maslin Sands, groundwater levels in 2009–10 were also deep, but decile rankings varied significantly at different bores, reflective of local conditions related to recharge and extraction. Overall, groundwater levels in the area generally declined concurrent with the expansion of irrigated land.

Groundwater salinity status

At the time of writing, suitable quality controlled and assured time-series data on groundwater salinity from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Therefore groundwater salinity status of the McLaren Vale aquifers has not been described.

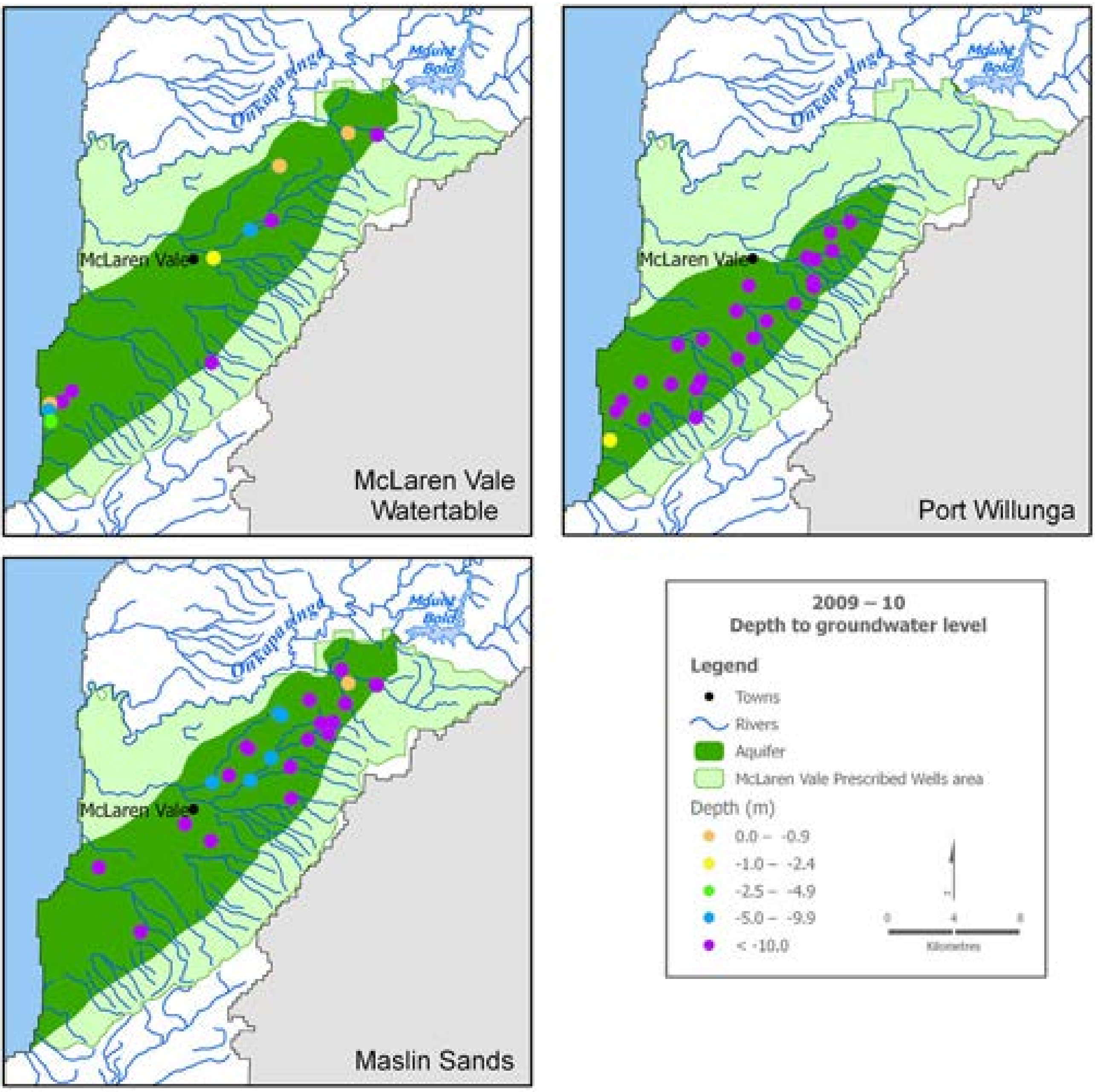


Figure 8-33. Median groundwater levels below surface for the McLaren Vale watertable, Port Willunga and Maslin Sands aquifers in 2009–10

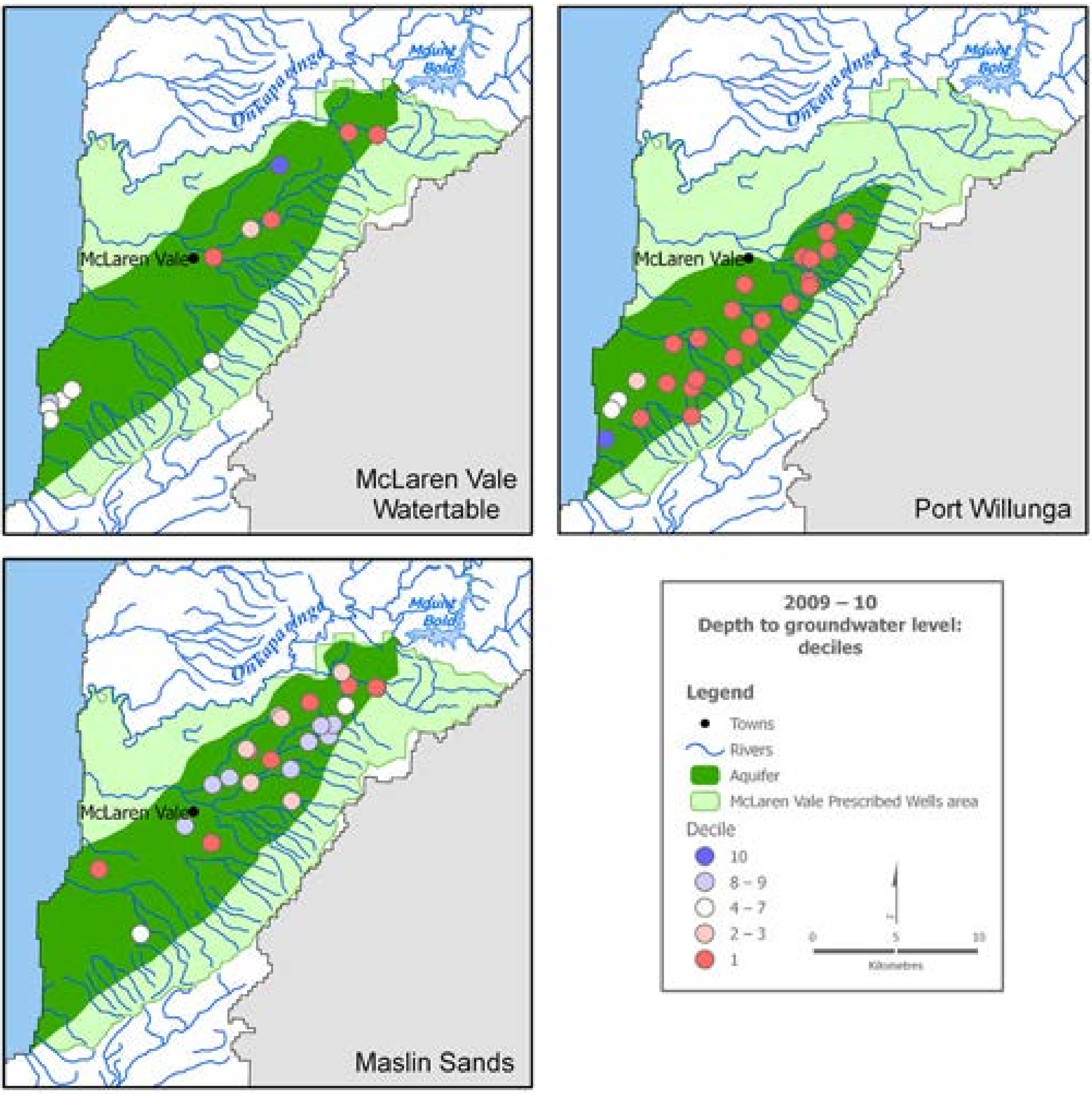


Figure 8-34. Deciles of groundwater levels below surface for the McLaren Vale watertable, Port Willunga and Maslin Sands aquifers in 2009–10 compared to the 1990–2010 reference period

9. South Western Plateau

9. South Western Plateau

9.1 Introduction

This chapter examines water resources in the South Western Plateau region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level.

Details for selected rivers, wetlands, groundwater, urban areas and agriculture are not addressed. At the time of writing, suitable quality controlled and assured information were not identified in the Australian Water Resources Information System (Bureau of Meteorology 2011a).

The chapter begins with an overview of key data and information on water flows in the region in recent times followed by a description of the region.

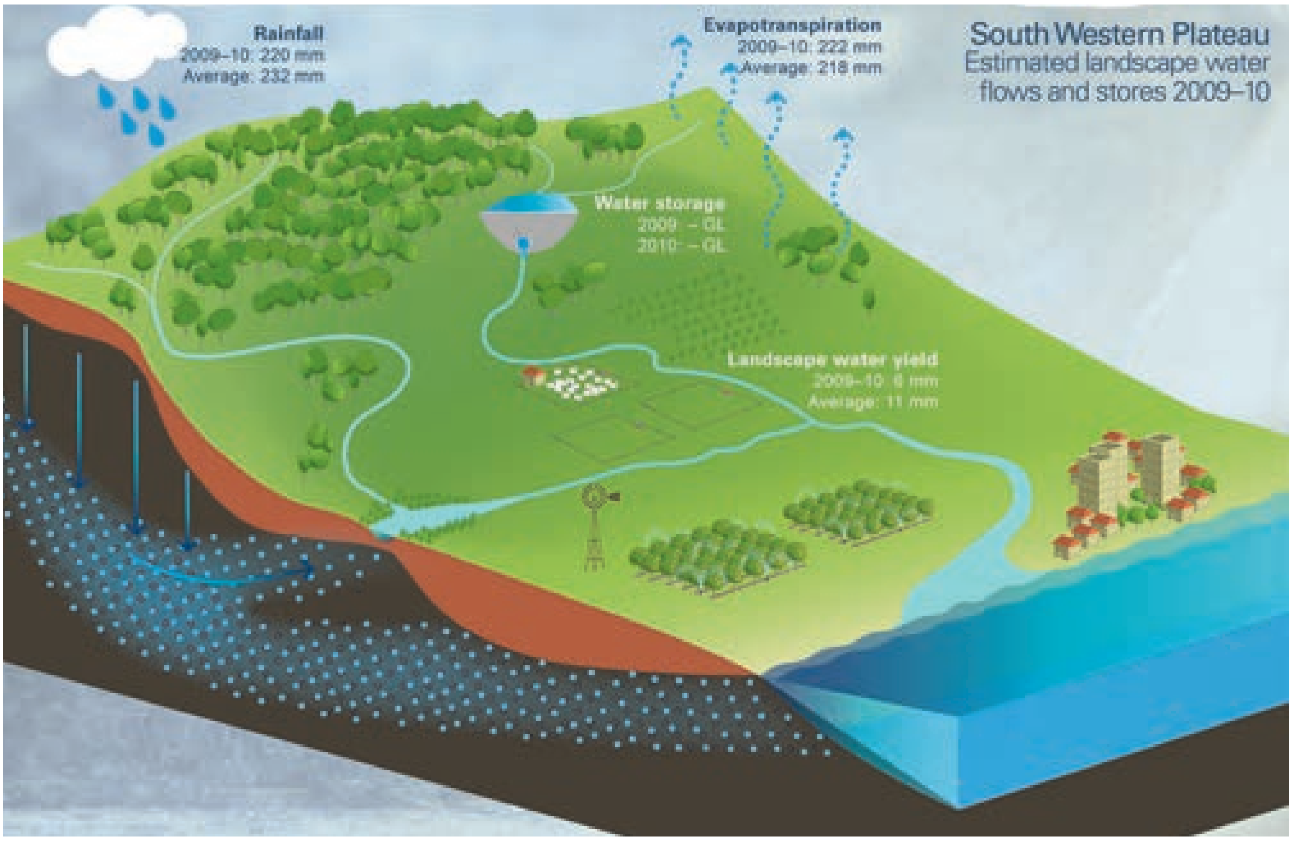


Figure 9-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) for the South Western Plateau region

9.2 Key data and information

Figure 9-1 presents the 2009–10 annual landscape water flows in the South Western Plateau region (no information is available for major storages in the region). The region experienced a slight rainfall deficit for the year, with total evapotranspiration marginally higher than total rainfall, and this contributed to lower than average landscape water yield[1]. The dryer conditions for 2009–10 were more dominant on the western side of the region.

Table 9-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 9 1. Key information on water flows in the South Western Plateau region[2]

Landscape water balance	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	220 mm	-5%	48	357 mm (1999–00)	165 mm (2007–08)
Evapotranspiration	222 mm	+2%	55	275 mm (1999–00)	193 mm (1990–91)
Landscape water yield	6 mm	-43%	29	41 mm (1994–95)	6 mm (1985–86)

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

9.3 Description of region

The South Western Plateau region covers 1,093,000 km^2 of mostly sandy or stony desert within Western Australia, South Australia and the Northern Territory. The region borders the South Australian Gulf region to the east, Lake Eyre Basin region to the northeast, Tanami – Timor Sea Coast and North Western Plateau regions to the north, and the Pilbara–Gascoyne and South West Coast regions to the west. The Southern Ocean is on the southern boundary of the region.

The South Western Plateau is the driest region in Australia. Except for the western and eastern parts of the region, which are semi-arid, the vast area in the centre is arid.

The region includes the Nullarbor Plain in the south and a major part of the Great Victorian desert in the north. Vegetation is sparse with trees largely non-existent. The region is predominantly flat with some relief along the edges of the Nullarbor Plain.

A substantial number of predominantly dry lakes are present in the west and east of the region as well as more sporadically in the north. Some small rivers discharge to the Southern Ocean surrounding Esperance in Western Australia and Ceduna in South Australia.

The region currently includes two Ramsar wetland sites (Lake Gore and the Lake Warden system), which are of international biological and ecological importance, mainly due to the presence of large populations of rare bird species. They are located near Esperance in Western Australia.

The region has a total population of over 60,000 which is sparsely distributed with 28,000 people residing in Kalgoorlie–Boulder and 12,000 in Esperance. Other towns such as Ceduna, Coolgardie, Kambalda West and Streaky Bay have between 2,000 and 3,000 inhabitants.

The State Government-owned South Australian Water Corporation manages the water supply to most towns and cities throughout South Australia, including areas of the South Western Plateau region. Groundwater is the main source of water for the South Australian portion of the region, with storm and rainwater also being used. The Tod River pipeline supplies water via an extensive pipeline system to towns from Port Lincoln in the South Australian Gulf region to Ceduna in the South Western Plateau region. A commercial scale solar desalination farm is planned to provide 200 ML of drinking water per year to communities.

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

9.3 Description of region (continued)

Water supply to town centres in the Western Australia part of the region is the responsibility of the Water Corporation, a State Government-owned statutory body. A major supply scheme to the towns in the eastern part of the region is the 560 km Goldfields pipeline. The over-100-year-old pipeline takes water from Lake C.Y. O'Connor at Mundaring Weir near Perth, and delivers it to Coolgardie and Kalgoorlie, with extensions serving Kambalda and Norseman. Other towns in the west of the region, such as Esperance, Laverton, Leonora and Wiluna rely heavily on groundwater for urban water supply.

An average of 3.5 GL of surface water per annum is supplied to homes and businesses in Kalgoorlie and Boulder, with half consumed by the residential sector and half by the commercial, municipal and industrial sector (National Water Commission 2011a). Kalgoorlie–Boulder has a substantial wastewater re-use regime, supplying recycled water for the irrigation of parklands, schools grounds and playing fields, golf courses and community facilities. In 2005–06, 38 per cent of the collected effluent was recycled, producing about 1 GL of recycled water. By 2009–10, 75 per cent of collected effluent was recycled, producing 2 GL of recycled water (National Water Commission 2011a).

There are no reported major storages in the region and only very locally orientated irrigated agriculture.

The mix of land use in the region is illustrated in the Figure 9-2. Most of the region comprises nature conservation, including much of the Nullarbor Plain and the Great Victorian desert. To the west and east, large areas of pasture are present, with some areas of dryland agriculture on the Eyre Peninsula (southeast) and north of Esperance (southwest).

The hydrogeology of the region is dominated by a large area of outcropping fractured basement rock. The groundwater systems in fractured rock typically offer restricted low volume groundwater resources. In contrast, there are significant groundwater resources in localised sedimentary aquifers. The major management units with significant groundwater use include Goldfield, East Murchison, Nullarbor and Musgrave.

The major watertable aquifers present in the region are given in Figure 9-3 (extracted from the Bureau of Meteorology's Interim Groundwater Geodatabase). Groundwater systems that provide potential for extraction are labelled as:

- Mesozoic (porous media – consolidated)
- surficial sediment aquifer (porous media – unconsolidated)
- upper mid-Tertiary aquifer (porous media – unconsolidated).

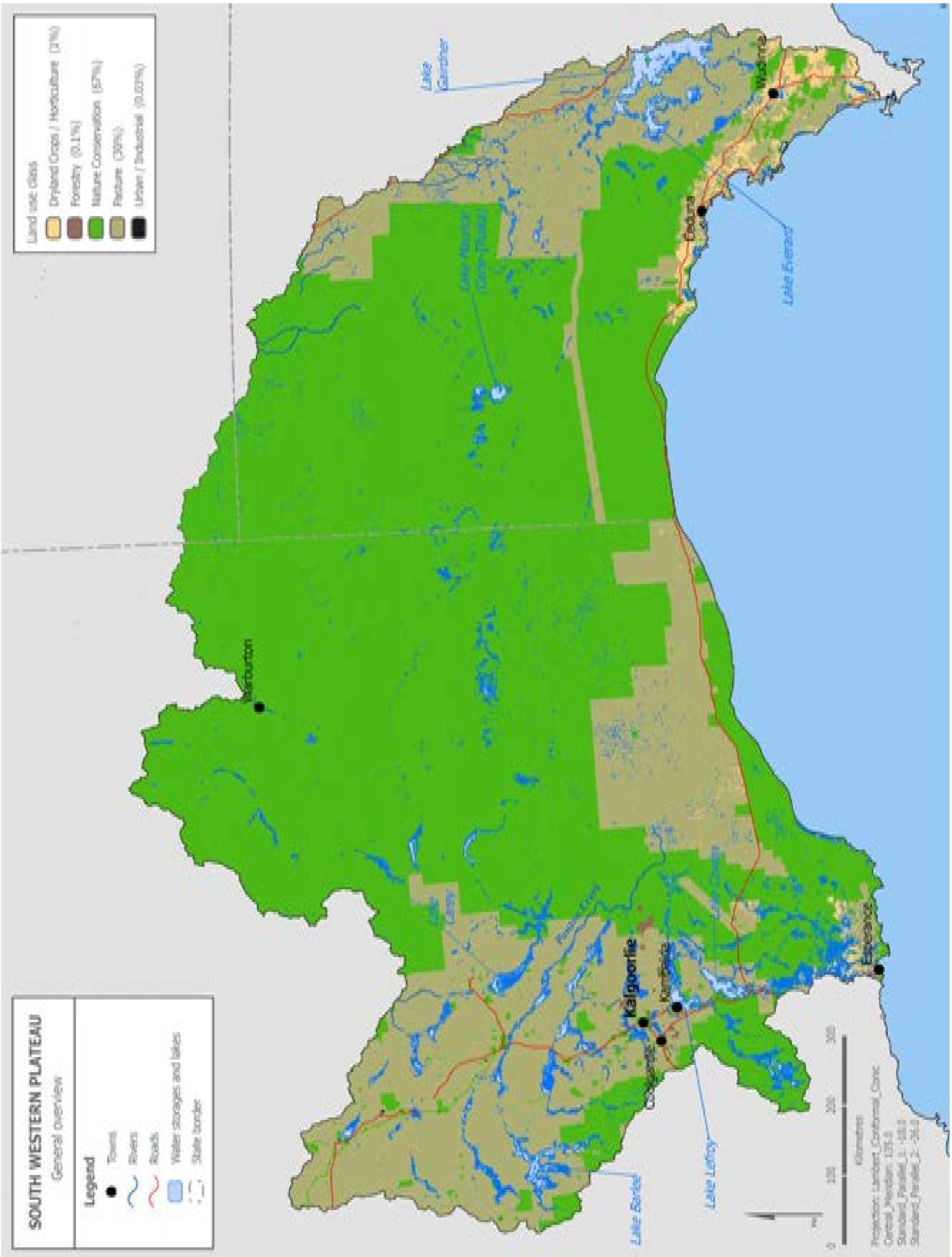


Figure 9-2. Key landscape and hydrological features of the South Western Plateau region (land use classes based on Bureau of Rural Sciences 2006)

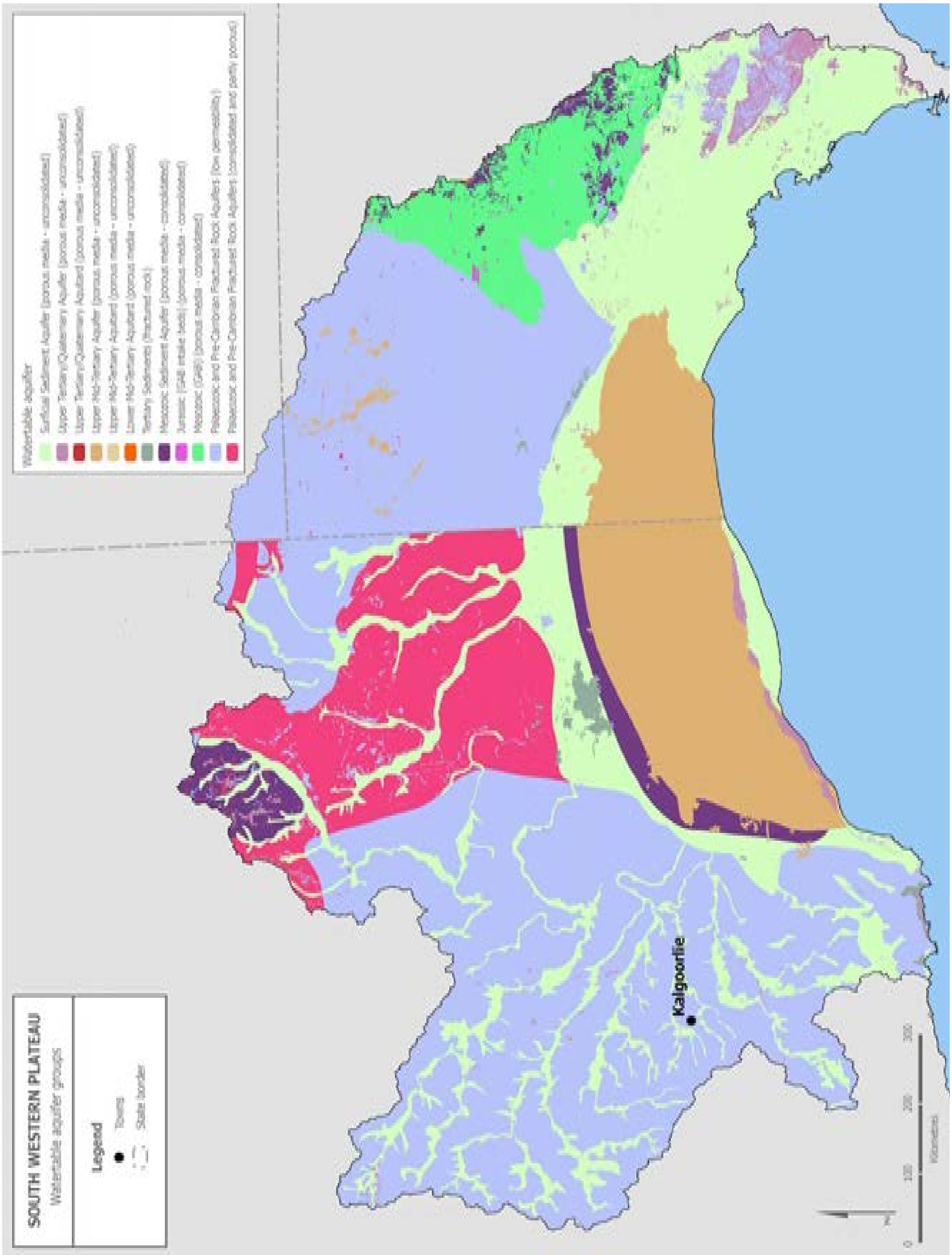


Figure 9-3. Watertable aquifer groups in the South Western Plateau region (Bureau of Meteorology 2011e). The discontinuity in aquifers across the State border is the result of two different State-based aquifer classification systems

9.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Large areas of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data for these areas. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 9-4 shows that the South Western Plateau region has a predominantly arid climate with very little seasonal variation and low rainfall throughout the year. Areas in the far southwest and southeast of the region experience a more temperate climate with wetter winters and low summer rainfall. Monthly rainfall for 2009–10 was generally between the 25th and 75th percentiles, varying between slightly above and slightly below normal.

The long-term record shows monthly evapotranspiration is almost equivalent to inputs of rainfall through much of the year. In 2009–10, evapotranspiration was between the 25th and 75th percentiles and was higher than rainfall from August 2009 through to February 2010, with the exception of November 2009. Modelled landscape water yield for the region was consistently low as a consequence of the region's low rainfall and relatively high evapotranspiration.

9.4.1 Rainfall

Rainfall for the South Western Plateau region for 2009–10 was estimated to be 220 mm, which is five per cent below the region's long-term (July 1911 to June 2010) average of 232 mm. Figure 9-5 (a)[3] shows that during 2009–10, the highest rainfall occurred in the coastal areas to the southwest and southeast of the region. Rainfall deciles for 2009–10, shown in Figure 9-5 (b), indicate rainfall was at an average level across much of the region. Below average rainfall occurred in the west of the region and eastern areas experienced wetter than average conditions.

Figure 9-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 165 mm (2007–08) to 357 mm (1999–2000). The annual average for this period was 256 mm. The data indicate that the region experienced a relatively wet period from the mid 1990s to mid 2000 with noticeably higher annual rainfall.

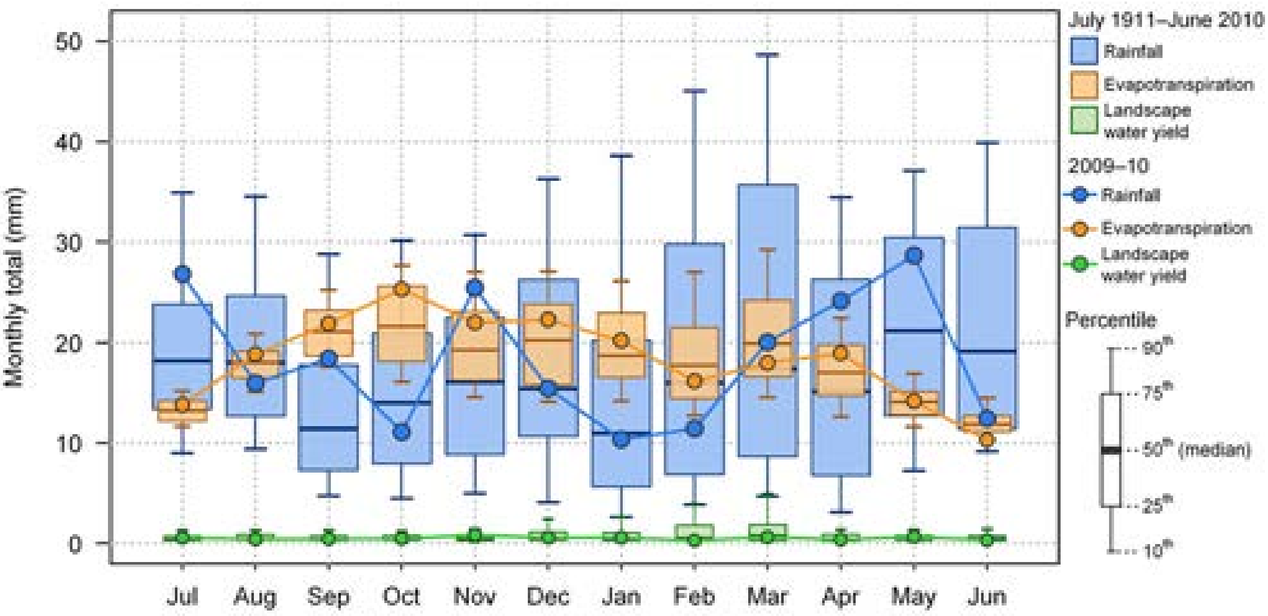


Figure 9-4. Monthly landscape water flows for the South Western Plateau region in 2009–10 compared with the long-term record (July 1911 to June 2010)

3. Areas where rainfall interpolation was assessed to be greater than 20 per cent unreliable for any period of the long-term record were excluded from the landscape water balance modelling (classified as 'No data'). More details are presented in the Technical supplement.

9.4.1 Rainfall (continued)

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 9-6 (b). The data indicate that over the second half of the period there was an increasing dominance of summer rainfall with a consistent reduction of the winter period averages.

Figure 9-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years and should be considered in the context of data shown in Figure 9-6.

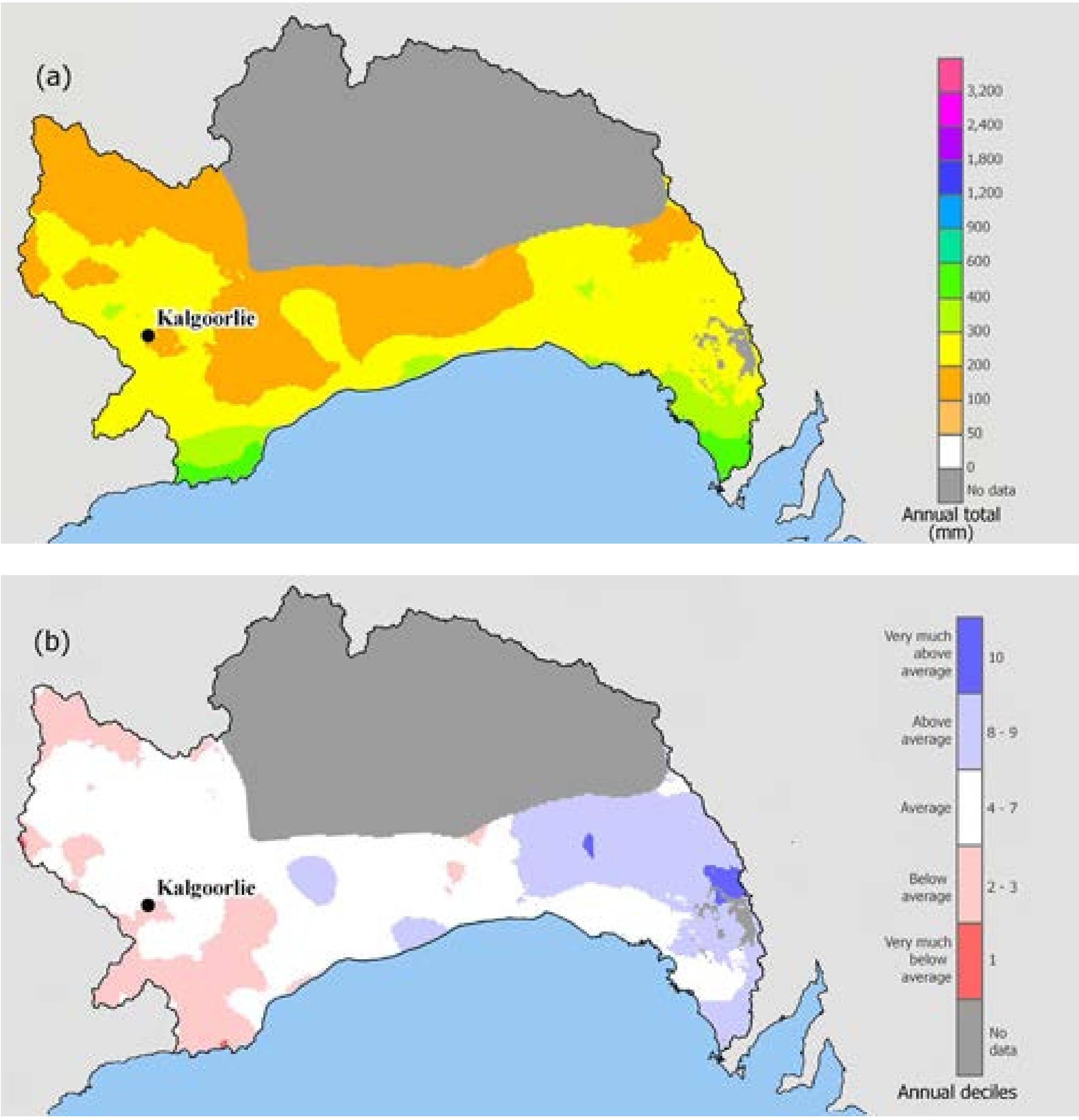
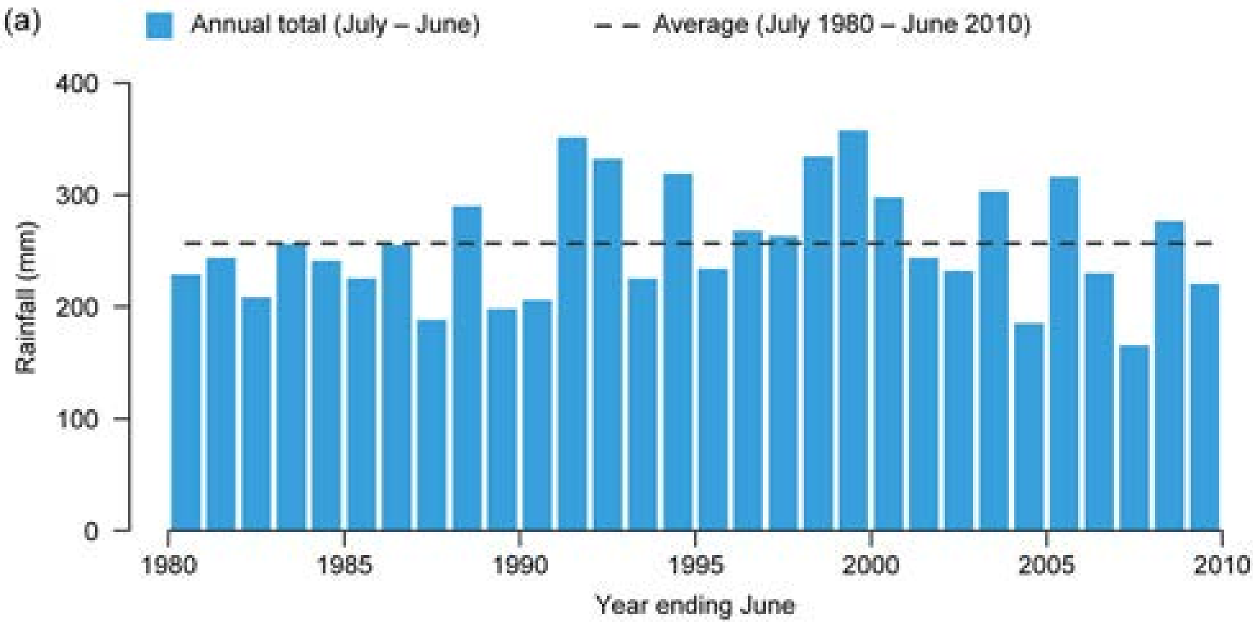


Figure 9-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Western Plateau region



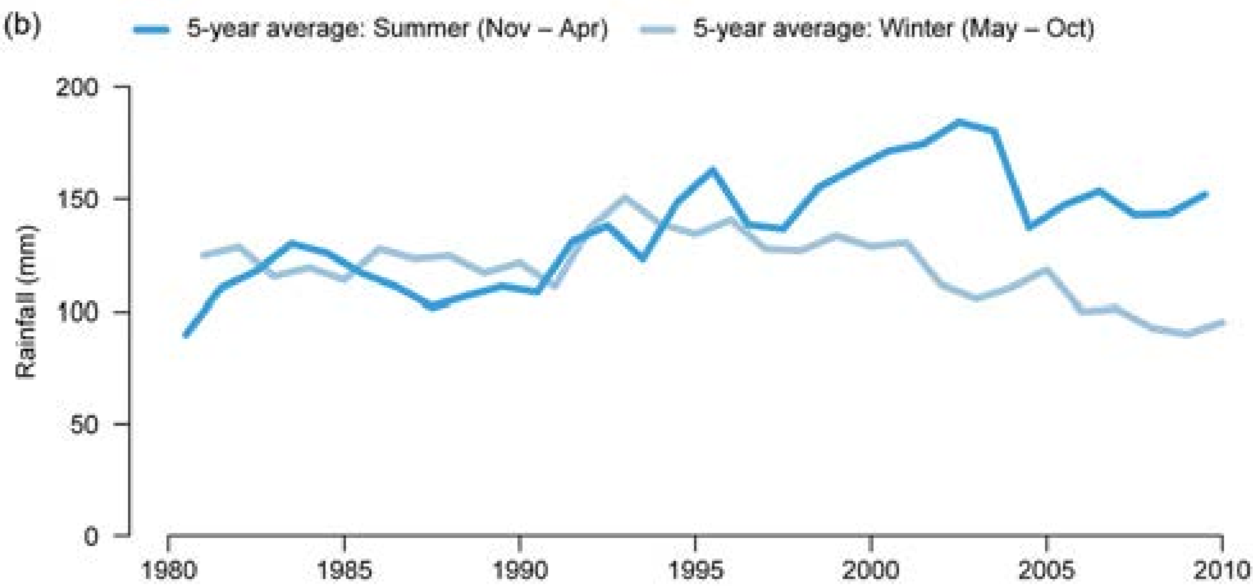


Figure 9-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the South Western Plateau region

9.4.1 Rainfall (continued)

The analysis of summer rainfall shows generally increasing rainfall across much of the region. Slight negative trends are identified for limited areas to the east of the region. The equivalent analysis of the winter rainfall shows reductions in rainfall across the western half of the region. The eastern side of the region shows a mix of increasing and decreasing rainfall. The general increase in summer rainfall and reduction in winter rainfall are also apparent in the region's seasonal moving averages shown in Figure 9-6 (b).

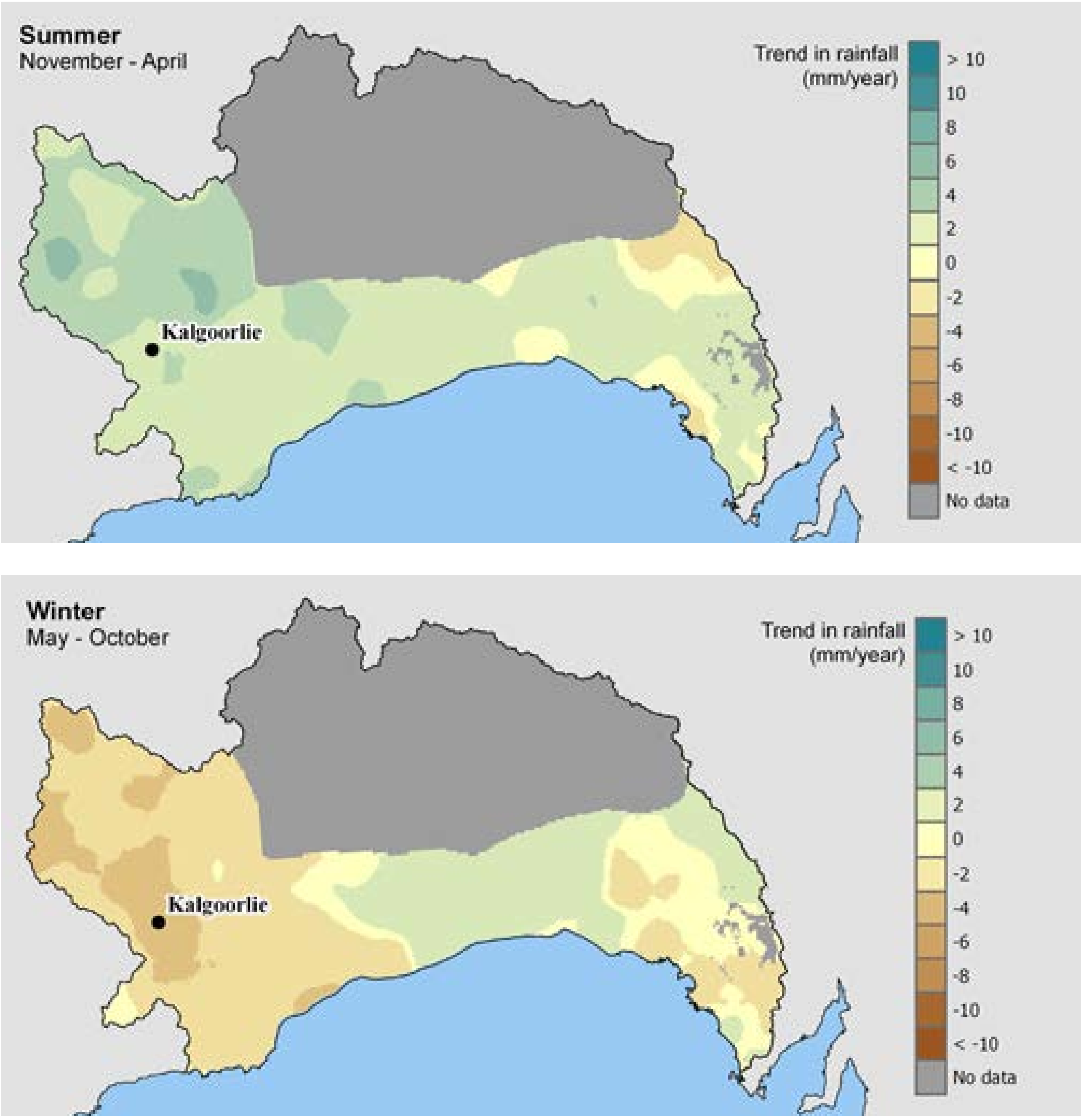
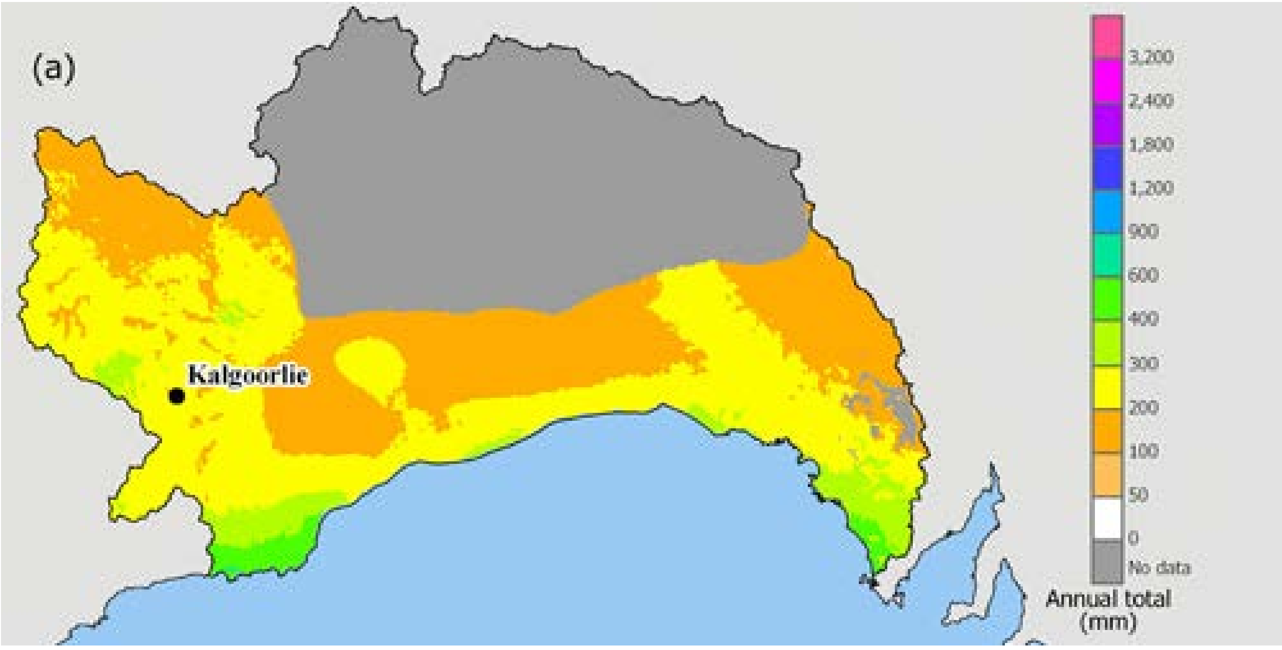


Figure 9-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the South Western Plateau region. The statistical significance of these trends is often very low

9.4.2 Evapotranspiration

Evapotranspiration for the South Western Plateau region for 2009–10 was estimated to be 222 mm, which is nearly equal to the region's long-term (July 1911 to June 2010) average of 218 mm. The distribution of annual evapotranspiration, shown in Figure 9-8 (a), is strongly related to the distribution of rainfall (Figure 9-5 [a]) with high evapotranspiration in the far southeast and southwest coastal areas.

Evapotranspiration for 2009–10 was lower across the drier centre, northwest and northeast of the region. Evapotranspiration deciles for 2009–10, shown in Figure 9-8 (b), indicate above average and very much above average values in the east of the region. The centre and west of the region shows a mix of average, below average and above average annual evapotranspiration for the year.



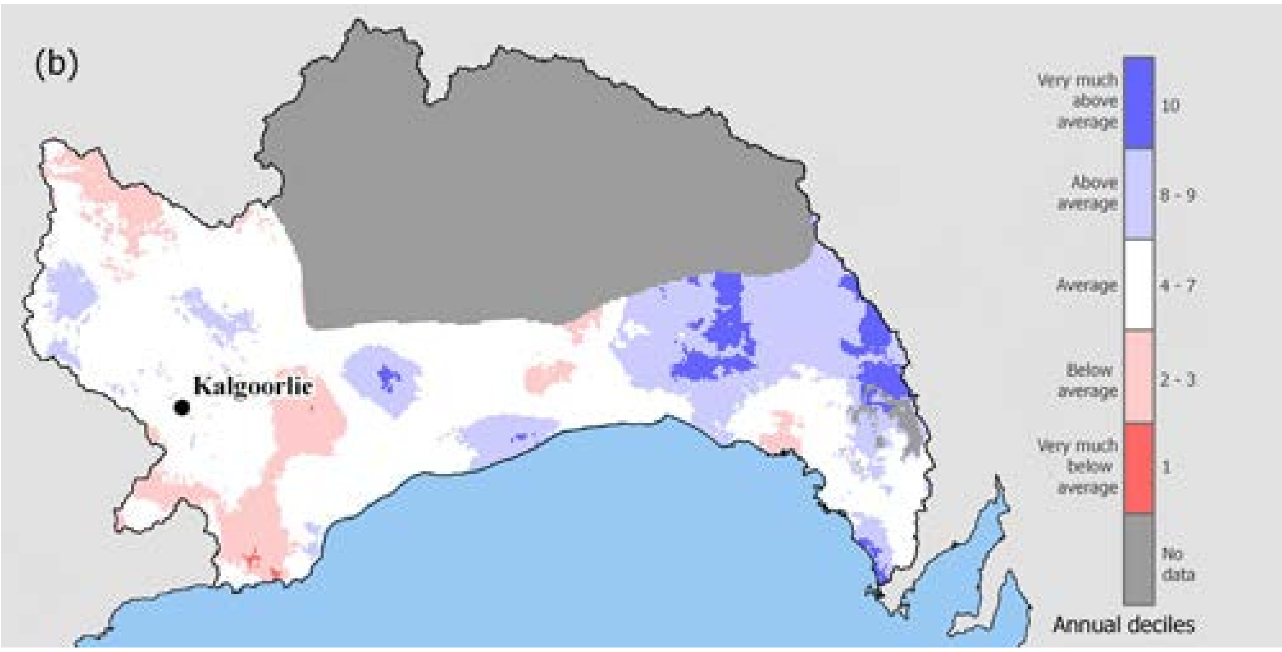


Figure 9-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Western Plateau region

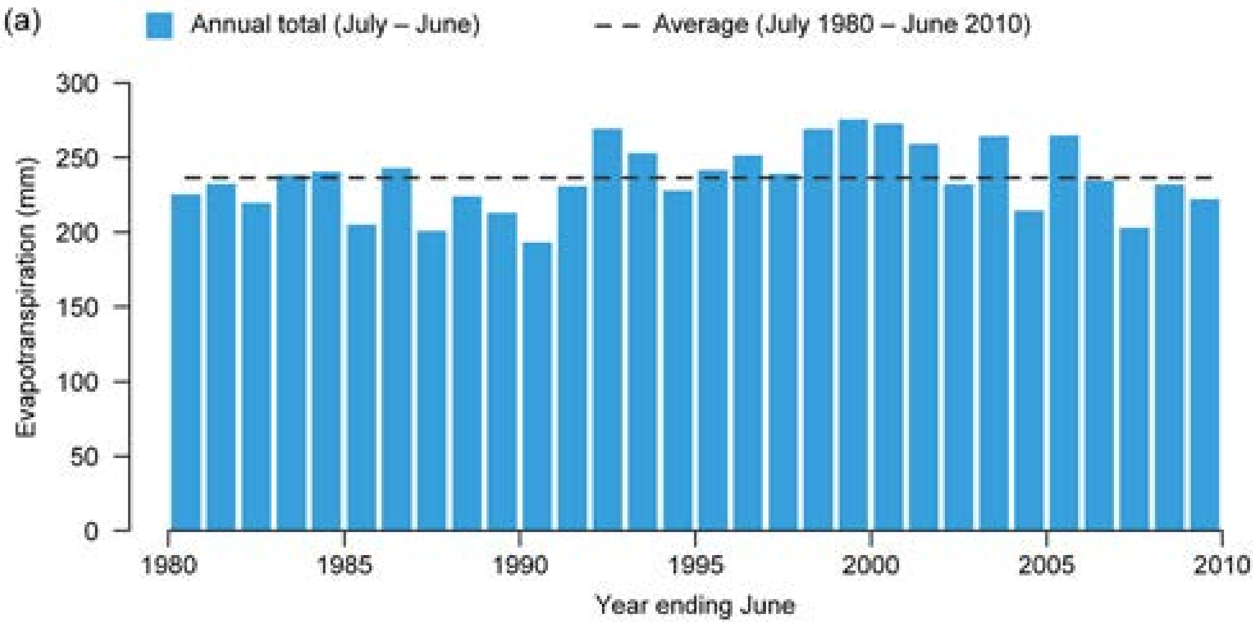
9.4.2 Evapotranspiration (continued)

Figure 9-9 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, evapotranspiration ranged from 193 mm (1990–91) to 275 mm (1999–2000). The annual average for this period was 236 mm. The close relationship between evapotranspiration and rainfall is reflected in the data with low levels observed during the dry years at the beginning of the 30-year period. Evapotranspiration increased through the wetter period from the mid-1990s to mid-2000s.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 9-9 (b). The summer period averages show a general increase over the wetter second half of the period, similar to the pattern observed in seasonal rainfall (Figure 9-6 [b]). Winter period averages remained relatively stable over the 30 years.

Figure 9-10 provides a spatial representation of trends in summer (November–April) and winter (May–October) evapotranspiration throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis indicates slight positive trends in evapotranspiration across much of the region. Slight negative trends are identified in the southeast and limited areas in the southwest. The winter period analysis identifies decreasing trends in evapotranspiration over the 30-year period in the west of the region. Slight increases are shown through the centre.



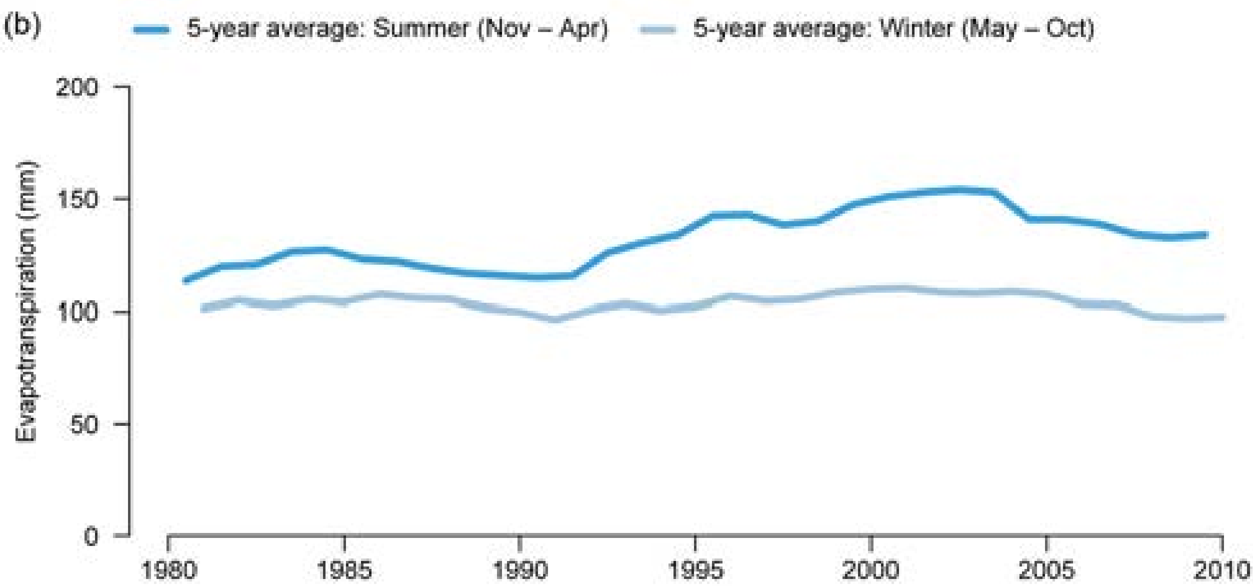


Figure 9-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the South Western Plateau region

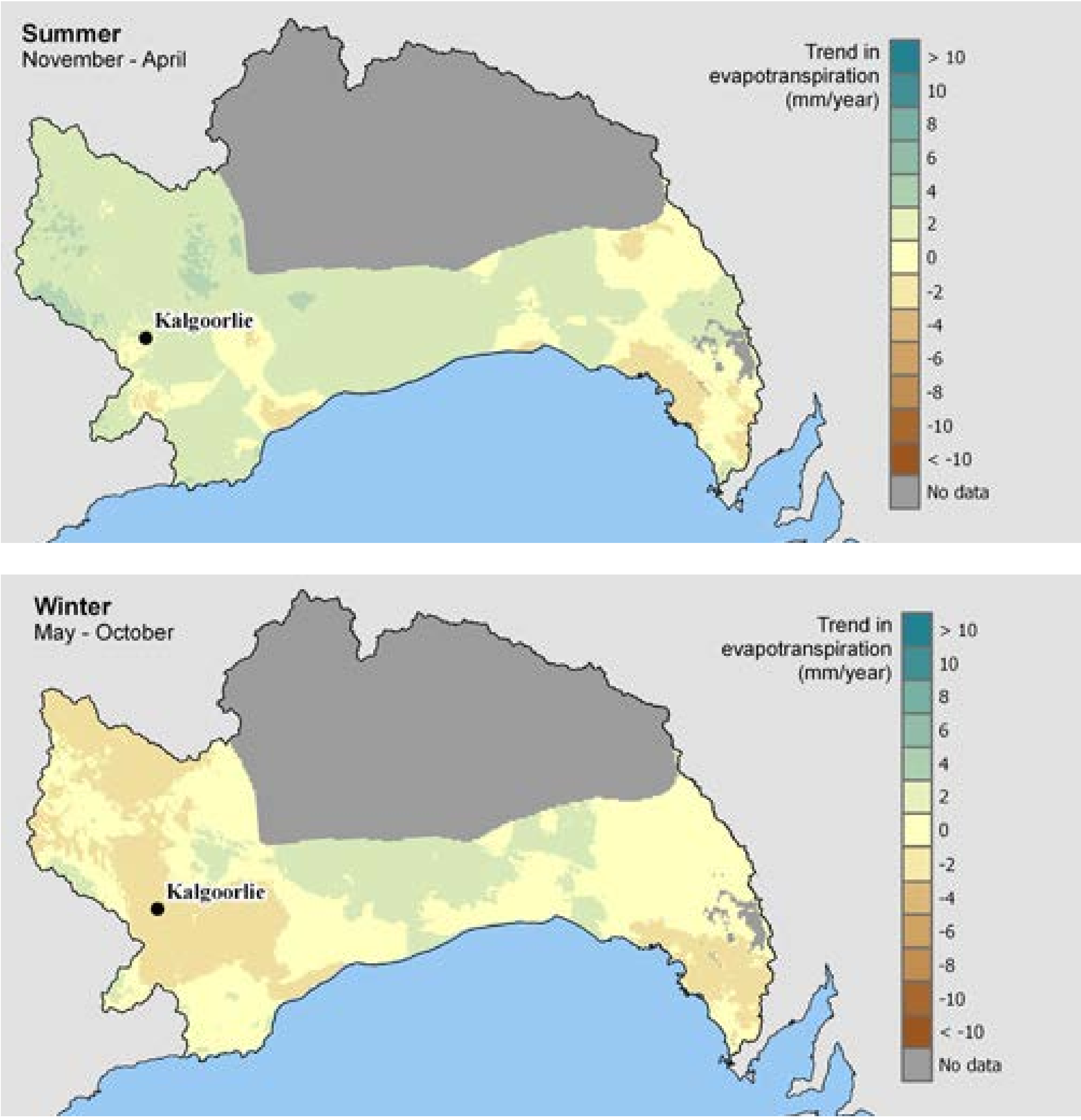


Figure 9-10. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the South Western Plateau region. The statistical significance of these trends is often very low

9.4.3 Landscape water yield

Landscape water yield for the South Western Plateau region for 2009–10 was 6 mm, which is 43 per cent below the region's long-term (July 1911 to June 2010) average of 11 mm. Figure 9-11 (a) shows that for 2009–10, low levels of landscape water yield occurred across the entire of the region. Landscape water yield deciles for 2009–10, shown in Figure 9-11 (b), indicate very much below average values across much of the western side of the region. The central and eastern areas reflect a mix of average, below average and above average levels for the year.

Figure 9-12 (a) shows annual landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 6 mm (1985–86) to 41 mm (1994–95).

9.4.3 Landscape water yield (continued)

The annual average for this period was 16 mm. The data show the contrast between the dry period at the beginning of the 30-year period and the wetter years from the mid-1990s through to the early 2000s.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 9-12.

The data show that the shifts between periods of high and low landscape water yield are reflected in both seasonal period averages. These variations are more apparent in the summer period than the winter. The winter season averages show a consistent decrease over the second half of the 30-year period whereas the summer period averages show a more sudden reduction occurring in the mid-2000s.

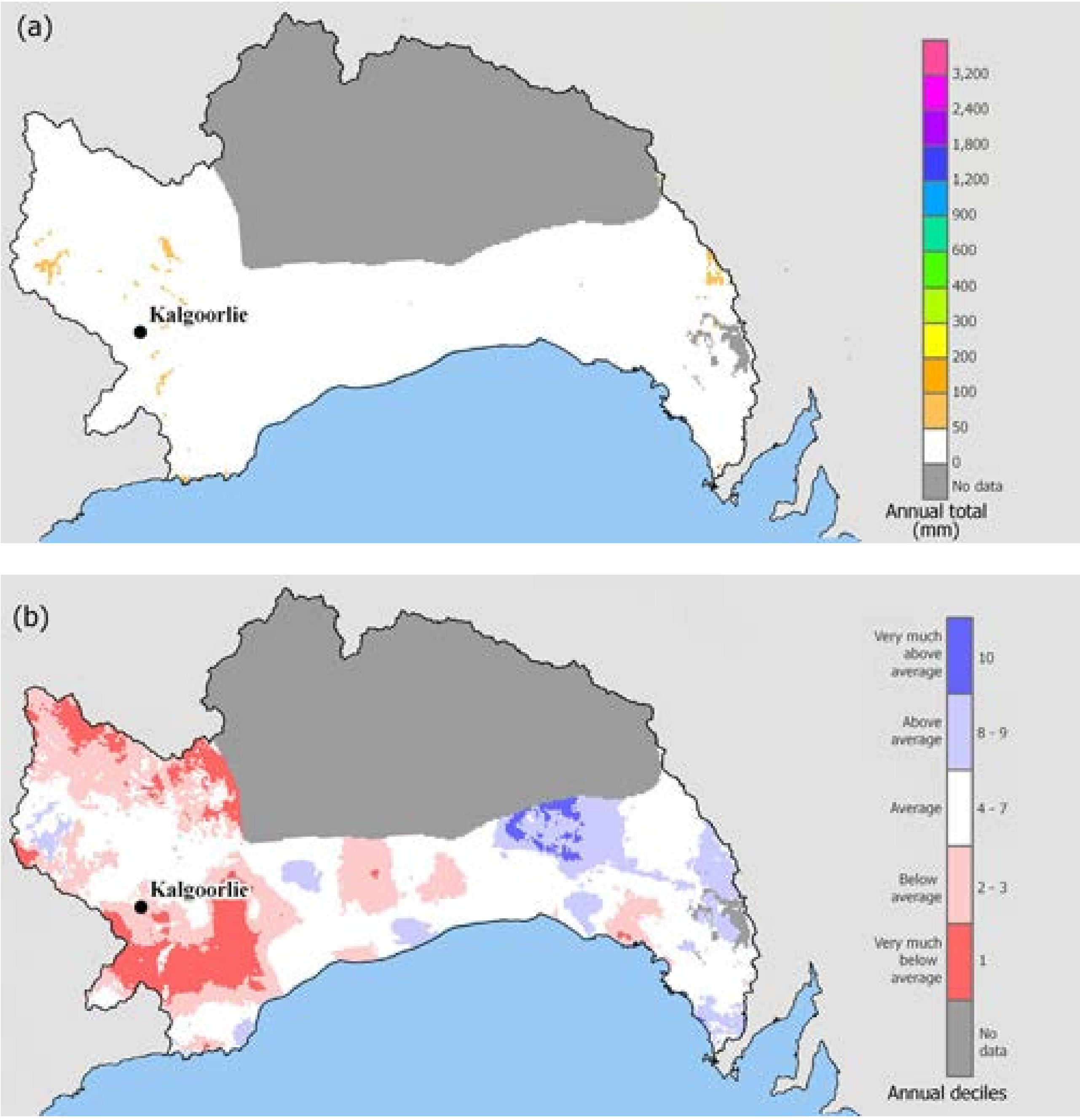
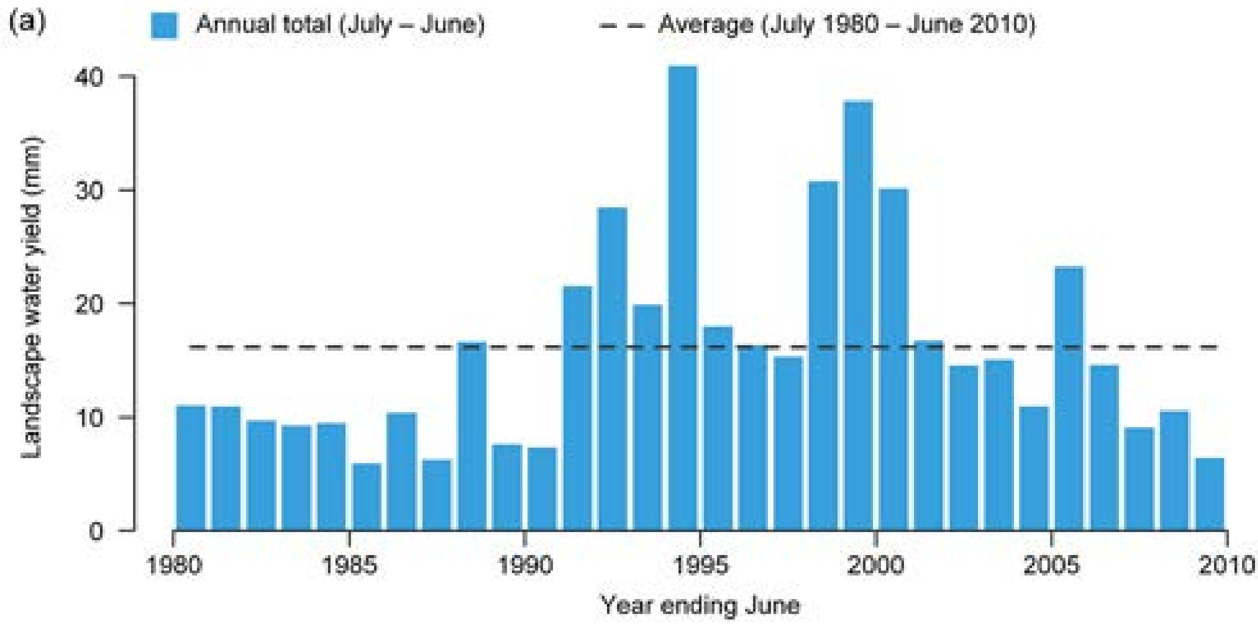


Figure 9-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South Western Plateau region



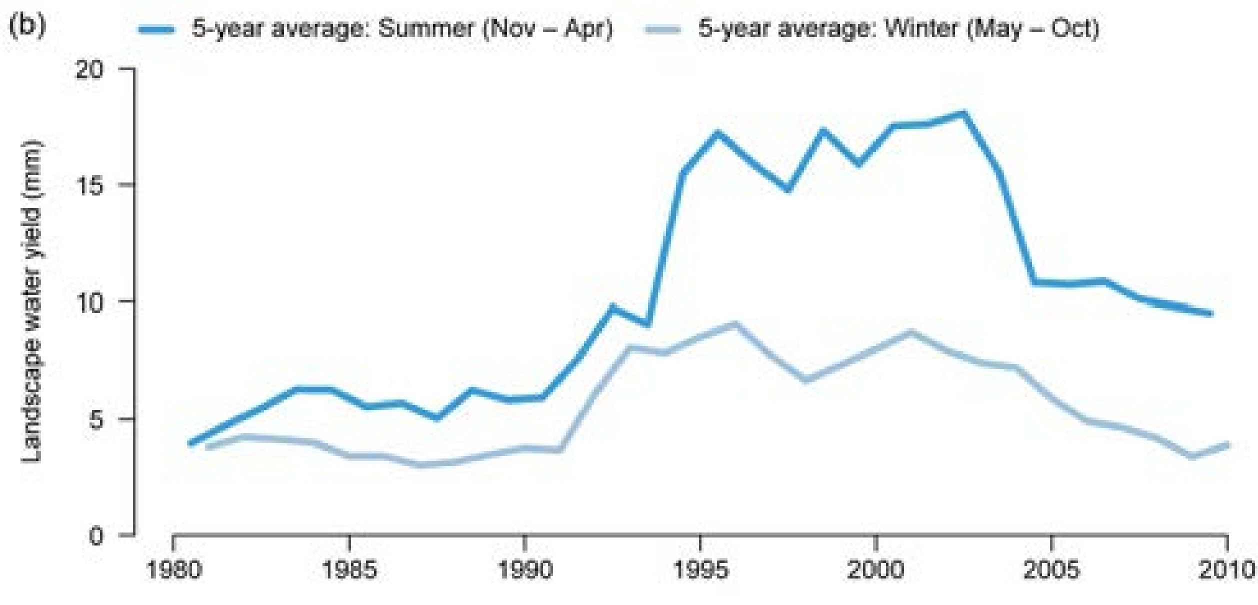


Figure 9-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the South Western Plateau region

9.4.3 Landscape water yield (continued)

Figure 9-13 provides a spatial representation of trends in summer (November–April) and winter (May–October) landscape water yield throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period shows slight increasing trends across west of the region. The winter period analysis shows no clearly identifiable trends in landscape water yield across the region over the 30-year period.

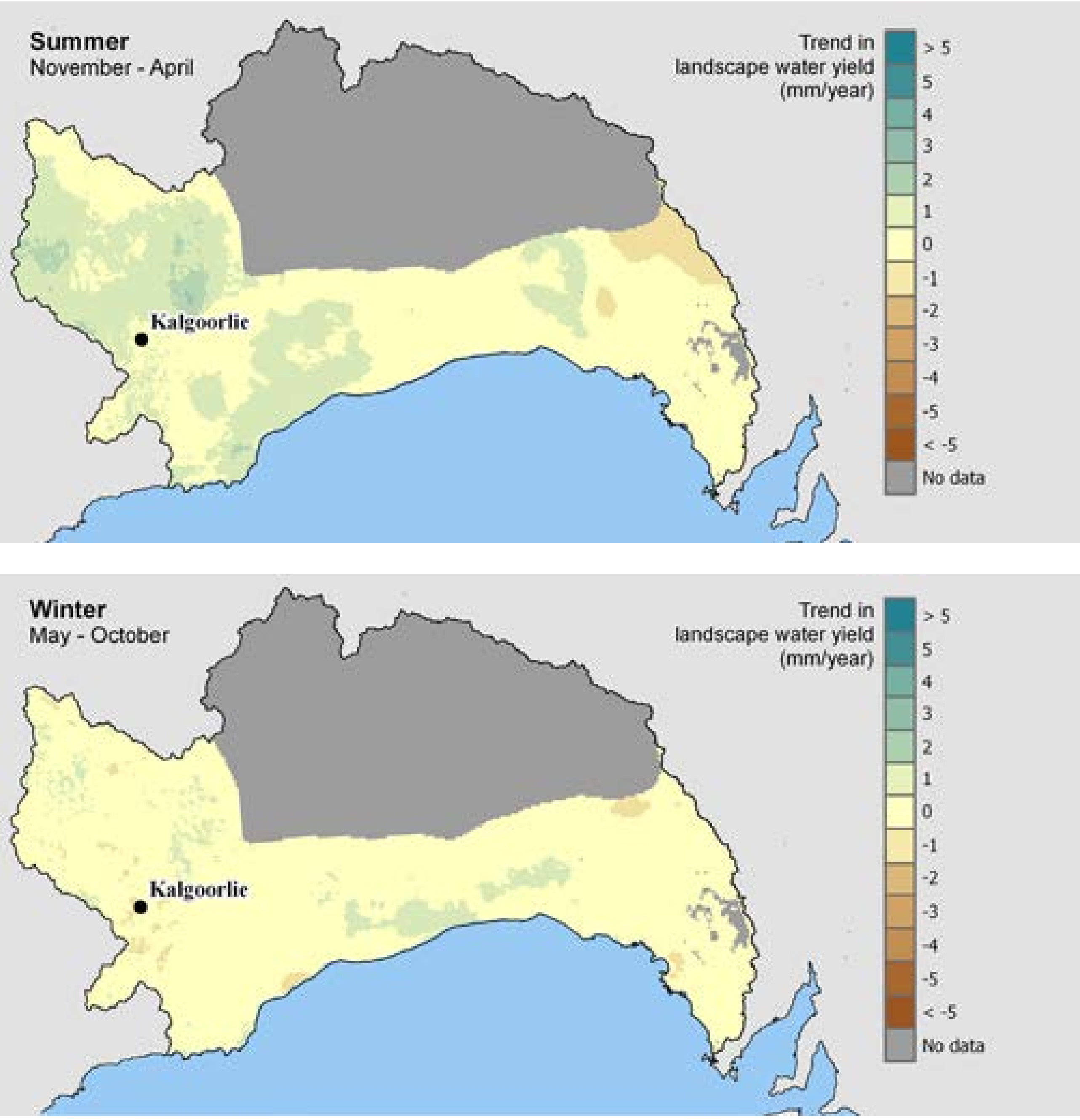


Figure 9-13. Maps of modelled summer (November–April) and winter (May–October) landscape water yield trends over 30 years (November 1980 to October 2010) for the South Western Plateau region

10. South West Coast

10. South West Coast

10.1 Introduction

This chapter examines water resources in the South West Coast region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level and also in more detail at sites for selected rivers. Information on water use is provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

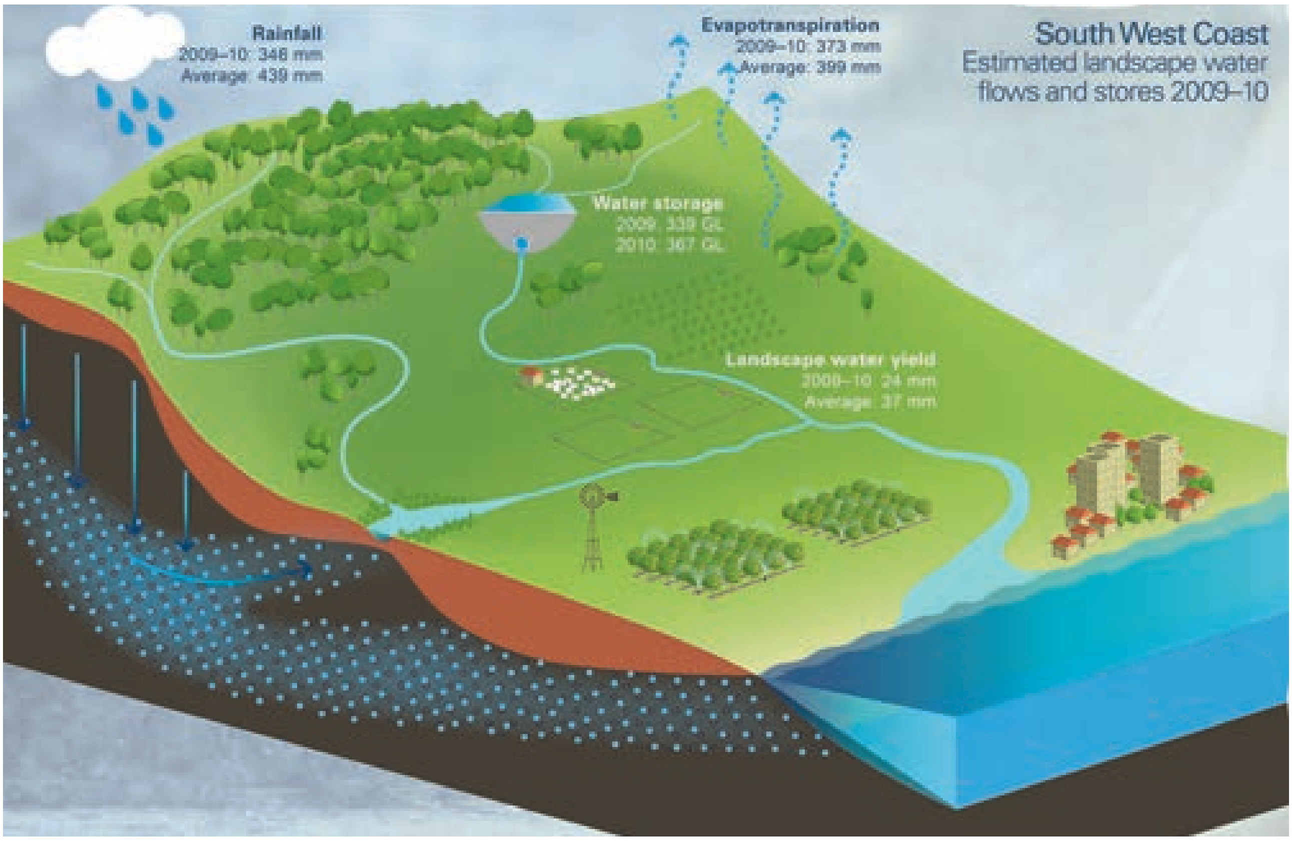


Figure 10-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010)and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the South West Coast region

10.2 Key data and information

Figure 10-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the South West Coast region. The rainfall deficit that occurred (evapotranspiration total is higher than rainfall) resulted in a low regional average landscape water yield[1] and also contributed to further decreases in soil moisture levels (see Table 10-1).
In contrast, accessible surface water storage volumes in the major reservoirs of the region increased slightly, mainly due to the fact that many of these storages are located in catchments where streamflow was at an approximately average level for the year.

Table 10-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

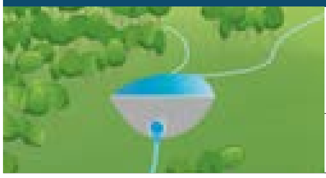
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 10-1. Key information on water flows, stores and use in the South West Coast region[2]

Landscape water balance

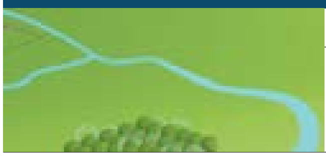
	During 2009–10			During the past 30 years	
	Region average	**Difference from long-term mean**	**Rank (out of 99)***	**Highest value (year)**	**Lowest value (year)**
Rainfall	346 mm	-21%	11	562 mm (1998–99)	340 mm (2000–01)
Evapotranspiration	373 mm	-6%	15	476 mm (1999–2000)	348 mm (1990–91)
Landscape water yield	24 mm	-34%	20	71 mm (1999–2000)	14 mm (2006–07)

Surface water storage (comprising approximately 100% of the region's total surface water storage)



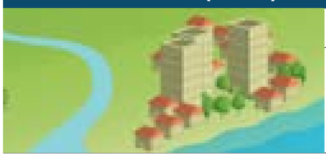
	July 2009		June 2010		
Total accessible capacity	**Accessible volume**	**% of accessible capacity**	**Accessible volume**	**% of accessible capacity**	**% Change**
959 GL	339 GL	35.3%	367 GL	38.3%	+3.0%

Measured streamflow in 2009–10



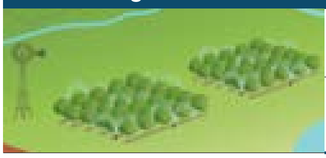
South coast rivers	Southwest coast rivers	North coast rivers
Predominantly above average	Average to above average	Average to below average

Urban water use (Perth)



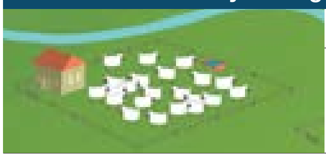
Water supplied 2009–10	Trend in recent years	Restrictions
266 GL	Gradually rising	Steady at level 5 restrictions

Annual irrigation water use in 2009–10 for natural resource management regions



South West	Swan	Northern Agricultural	South Coast	Avon
125 GL	62 GL	3.0 GL	5.6 GL	1.5 GL

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Below average in the coastal areas and parts of the northeast, average across the centre of the region	Very much below average across much of the entire region, average in the far north and southeast

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

10.3 Description of region

The South West Coast region is the most south-westerly drainage division in Australia. It is bounded to the west by the Indian Ocean and to the south by the Great Australian Bight. To the north is the Pilbara–Gascoyne region and to the east is the South Western Plateau region. The region covers approximately 326,000 km^2 of land. The river basins of the region vary in size from 1,100 km^2 to 118,000 km^2.

The region has a temperate climate with warm dry summers and cool winters. Most rainfall occurs in the west (Darling Scarp) with reduced rainfall further inland.

The landscape of the region is generally flat and sandy in inland areas. Higher altitude topographic features include the Darling Scarp which forms an ancient geological boundary to the 30 km wide Swan Coastal Plain along the west coast and the Stirling Range near Albany, which receives occasional snowfalls. 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. The south-western tip of the region is one of only a few temperate and relatively fertile parts of Australia, with many forests, woodlands and lush valleys, including the southern Karri forests and the Margaret River wine region.

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 the loss of surface flows. 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 catchment areas. Streamflow at selected river gauges are summarised in Section 10.5.

The region includes a number of Ramsar wetland sites, the majority of which are coastal or estuarine. These provide important habitats for waterbirds, shorebirds and various aquatic plant and animal species. Many other wetlands of national importance are also in the region and have important biodiversity and conservation values.

The South West Coast region has a population of around 2.1 million with the largest population centre being Perth on the central-west coast with 1.6 million people (Australian Bureau of Statistics 2010b). Other centres with populations greater than 25,000 are Mandurah, Bunbury and Albany along the coast.

Town centres in the region are supplied with water from systems operated by local government councils except for Perth, where water is supplied by the Integrated Water Supply System operated by the Water Corporation (Water Corporation 2011). This system includes multiple groundwater and surface water sources located over a wide geographic area (Bureau of Meteorology 2011c). Supplementary to these, water is supplied by the Kwinana seawater desalination plant, opened in 2006, which provides about 15–20 per cent of Perth's water demands. A second desalination plant is due for completion in 2011 and will double the current supply of desalinated water to the area (Water Corporation 2011). The water supply to significant urban areas is addressed in section 10.6.

There are 21 major storages in the region with a total accessible storage capacity of 959 GL. The largest storages, primarily used for irrigation in the region's largest irrigation district, the Harvey irrigation district, are the Wellington (183 GL), Harvey (55.6 GL) and Stirling (54.2 GL) water storages (Harvey Water 2011).

10.3 Description of region (continued)

The range of land uses in the region is illustrated in Figure 10-2. The north is dominated by pasture, becoming a more complex matrix 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. 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 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.

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 to 50 per cent of the water supplied to the city of Perth is sourced from groundwater. The major aquifers within the Perth region include surficial aquifers of the Gnangara Mound and the confined Leederville and Yarragadee aquifers. A more detailed description of the groundwater occurrence in the region is given in Section 10.5.

Figure 10-3 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)
- upper Tertiary/Quaternary aquifer (porous media – unconsolidated).

Confined aquifer systems, underlying some of the watertable aquifers shown in Figure 10-3, provide an important resource for the region. Most notable are the Leederville and Yarragadee aquifers beneath the Swan Coastal Plain.

Figure 10-4 shows the classification of the groundwater in the watertable aquifer as fresh or saline. As shown in the figure, most parts of the region are considered to have saline groundwater. The coastal regions with usable groundwater resources are those identified as non-saline.

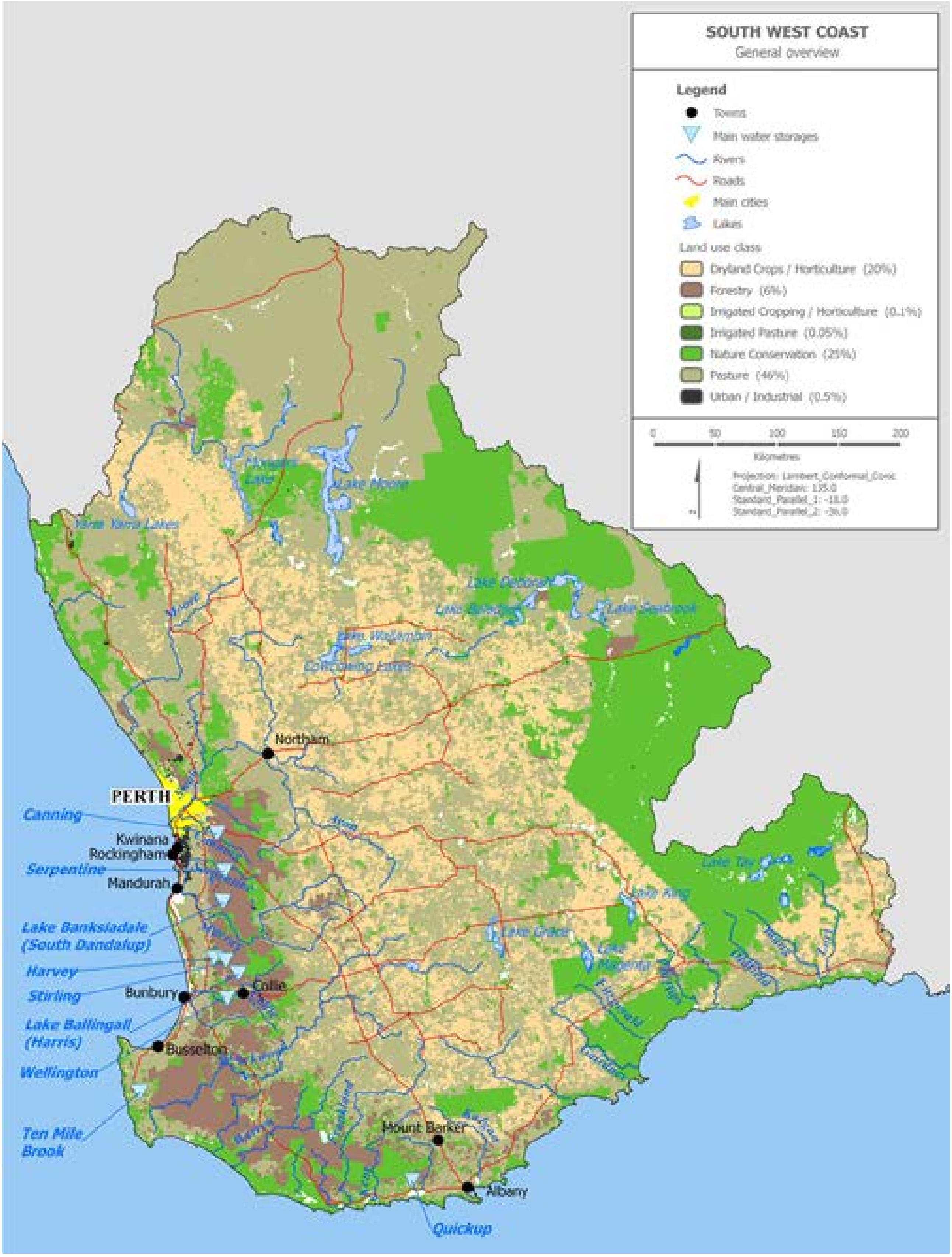


Figure 10-2. Key landscape and hydrological features of the South West Coast region (land use classes based on Bureau of Rural Sciences 2006)

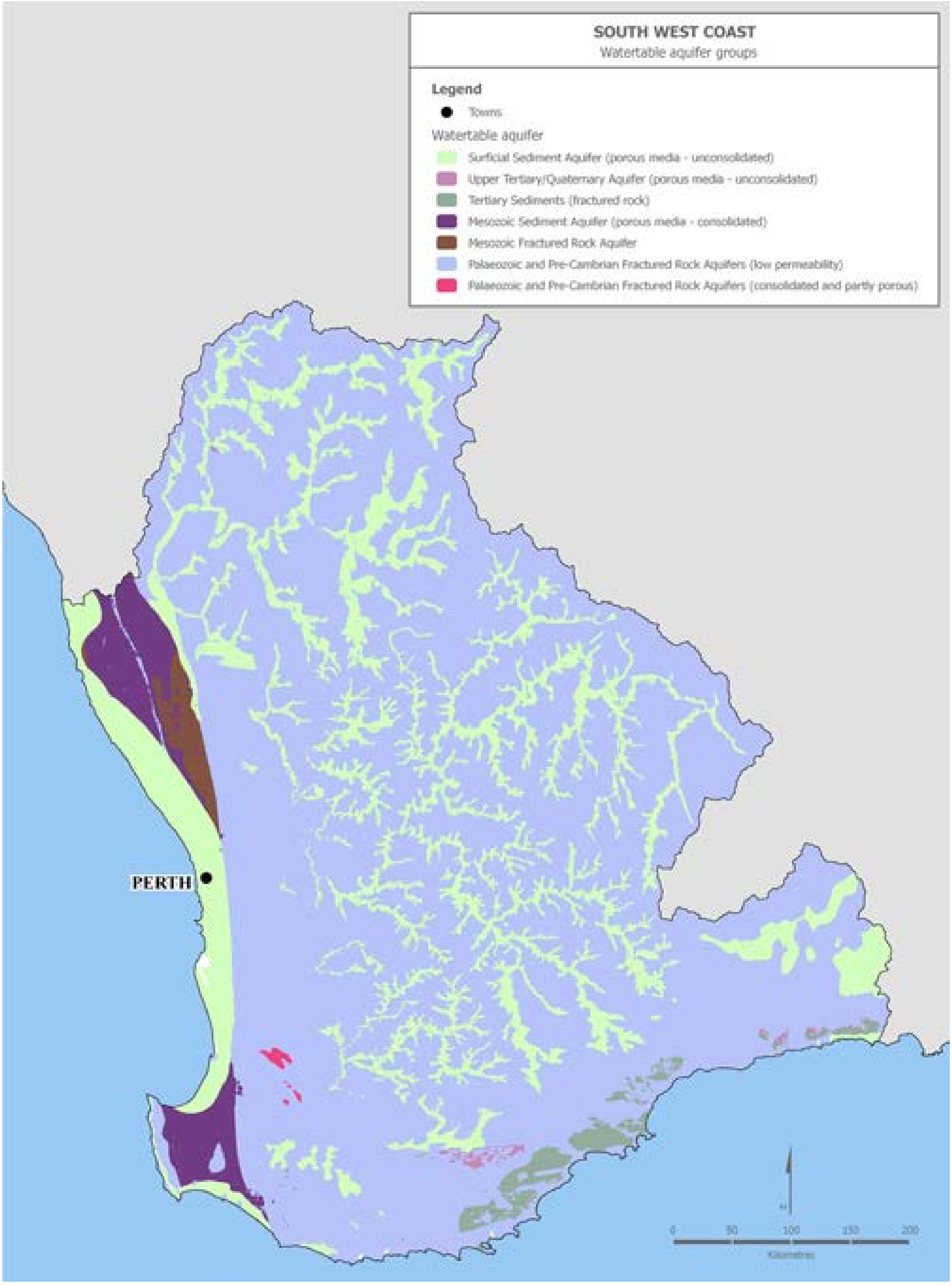


Figure 10-3. Watertable aquifer groups in the South West Coast region (Bureau of Meteorology 2011e)

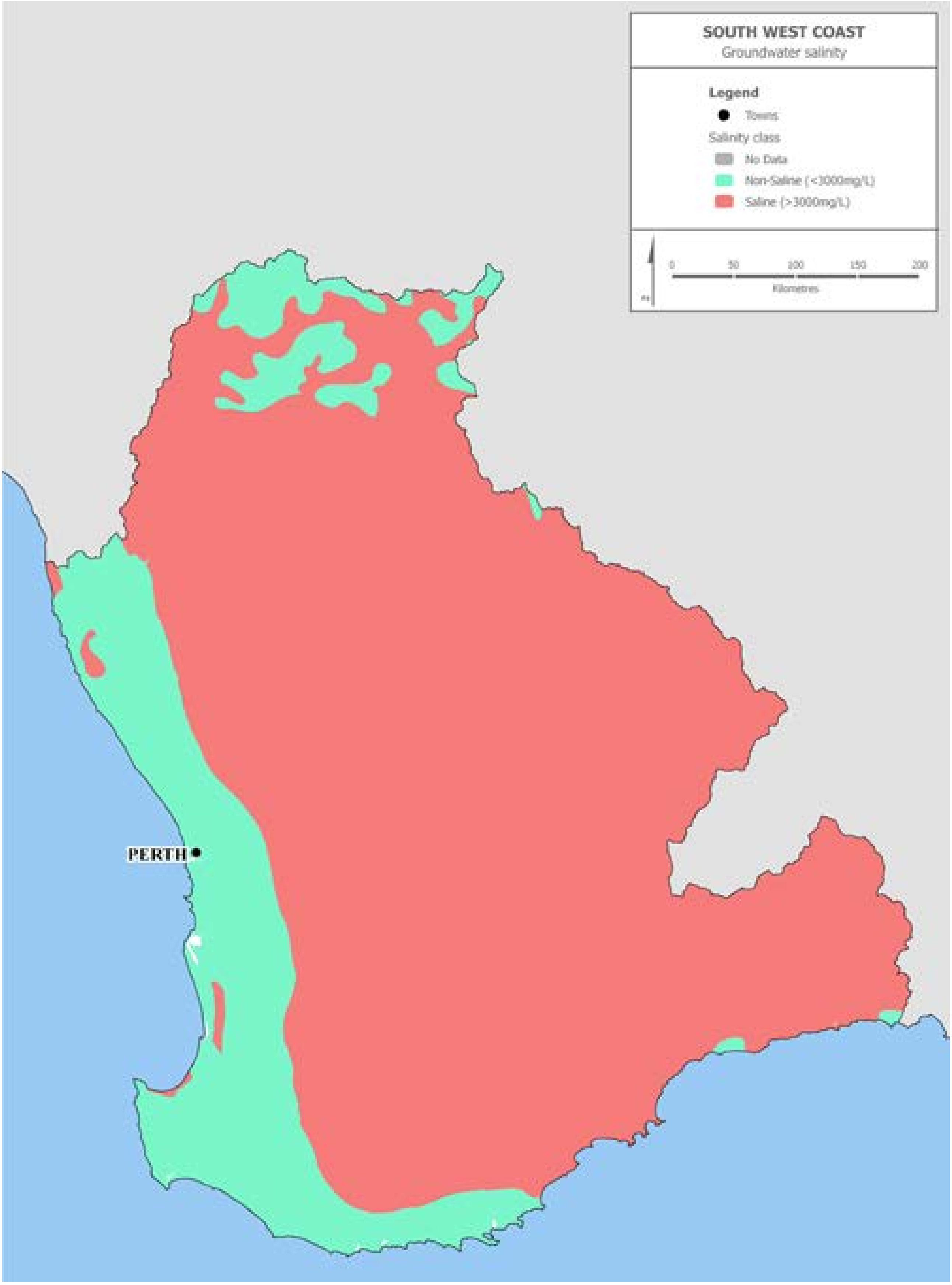


Figure 10-4. Watertable salinity classes within the South West Coast region (Bureau of Meteorology 2011e)

10.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 10-5 shows that the South West Coast region experienced relatively normal levels of monthly rainfall between July and September 2009. The remainder of the year was generally dominated by low monthly rainfall, particularly in the far southwest of the region. Exceptionally high rainfall was experienced over Perth and the surrounding areas in March 2010 with a very severe thunderstorm occurring on 22 March 2010, breaking an extensive dry spell of 122 days measured at Perth Airport (Bureau of Meteorology 2011d).

Evapotranspiration through 2009–10 was generally constrained to relatively low levels, largely as a consequence of ongoing dry conditions across much of the region. Higher than normal rainfall in November 2009 and increases in water availability temporarily led to slightly higher than normal levels of evapotranspiration.

Figure 10-5 shows that landscape water yield was consistently low during 2009–10. Modelled landscape water yield for the region is historically low compared to rainfall, with the months of June to October (late winter/ early spring) exhibiting the greatest water yield response to the higher rainfall winter. Ongoing dry conditions across the South West Coast region, particularly since around 2000–01, have led to consistently low levels of monthly and annual landscape water yield.

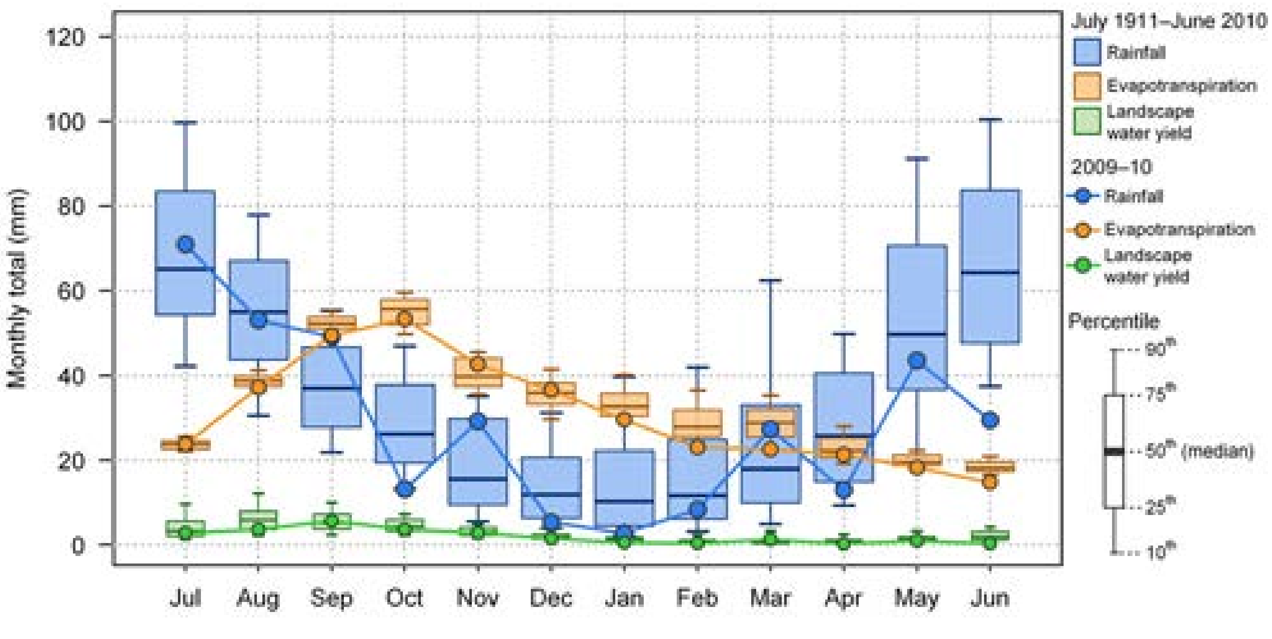


Figure 10-5. Monthly landscape water flows for the South West Coast region in 2009–10 compared with the long-term record (July 1911 to June 2010)

10.4.1 Rainfall

Rainfall for the South West Coast region for 2009–10 was estimated to be 346 mm, which is 21 per cent below the region's long-term (July 1911 to June 2010) average of 439 mm. Figure 10-6 (a) shows that the highest annual rainfall for 2009–10 occurred in the coastal zone in the far southwest of the region decreasing away from the coast to the northeast. Rainfall deciles for 2009–10, shown in Figure 10-6 (b), indicate annual rainfall was below average across almost all of the region and very much below average across much of the southwest and in the northeast.

Figure 10-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 340 mm (2000–01) to 562 mm (1998–99). The annual average for the period was 431 mm. The graph highlights the low annual rainfall experienced in 2009–10, which was the third lowest annual total in the 30-year period (lower annual rainfall occurred in 2000–01 and 2006–07).

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 10-7 (b). The graph reflects the seasonal pattern of rainfall in the region with wetter winters and lower summer rainfall. Towards the end of the 30-year period a slight shift in seasonal rainfall patterns is indicated, with a noticeable reduction in winter period rainfall averages around 1999–2000 coinciding with a slight increase in summer rainfall.

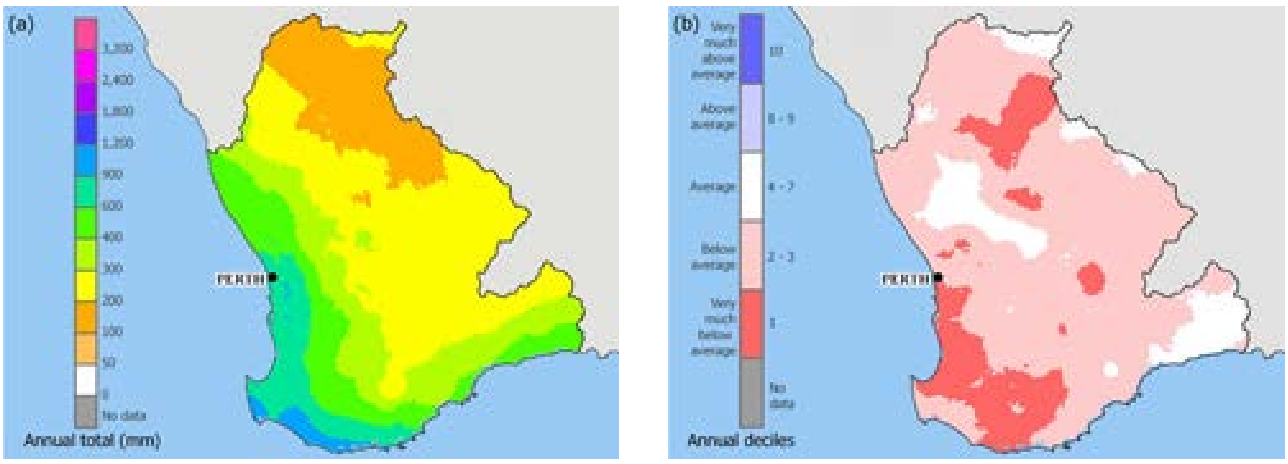


Figure 10-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South West Coast region

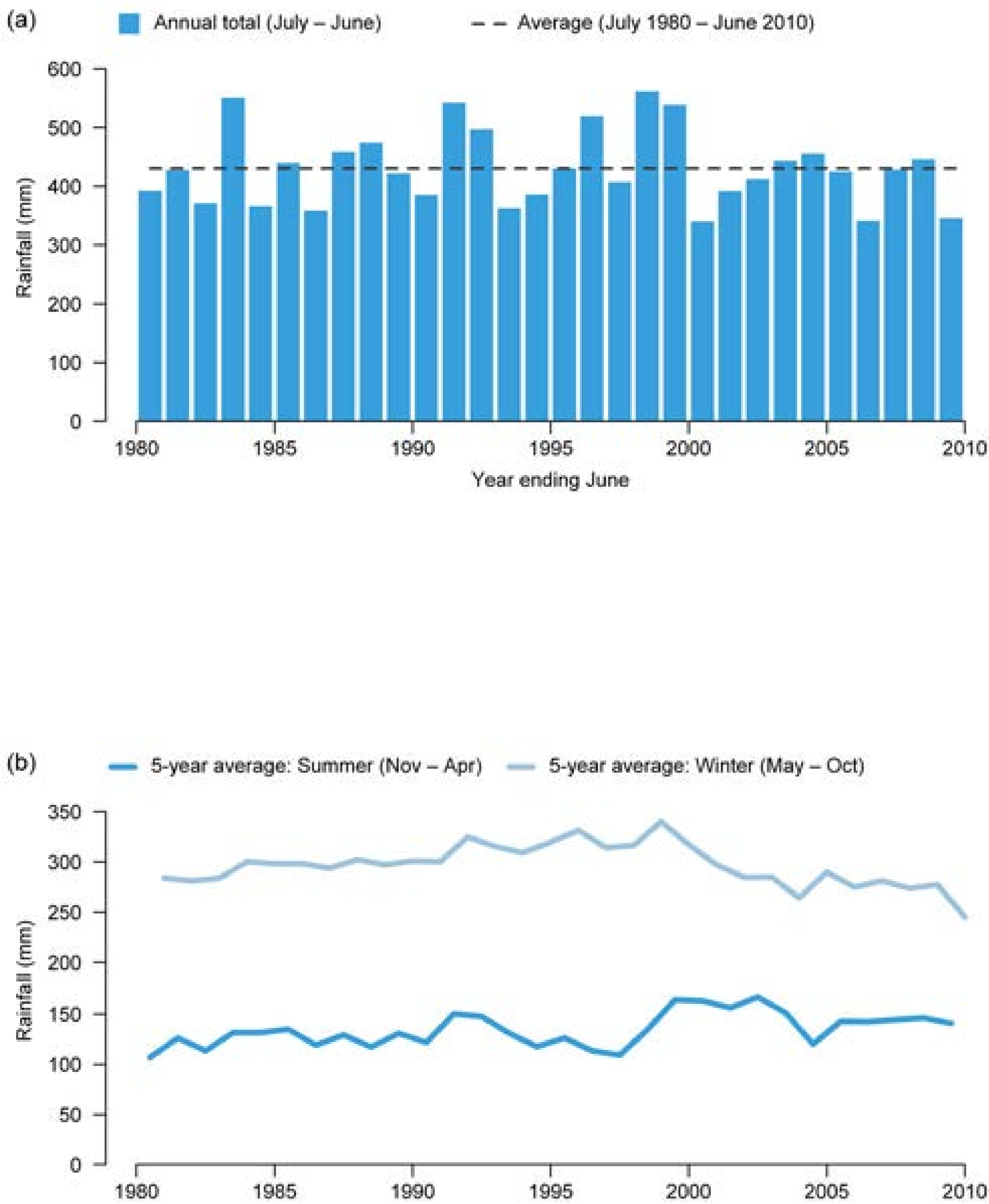


Figure 10-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the South West Coast region

10.4.1 Rainfall (continued)

Figure 10-8 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The summer period analysis indicates decreasing trends in summer rainfall across western coastal areas, whereas the southern coastal zone and the east of the region show slight increasing trends. The analysis of winter rainfall shows downward trends across almost the entire region. The strongest decreases in winter rainfall are observed on the west coast to the south of Perth. The magnitudes of the reductions in rainfall over the 30-year period identified in the southwest of the region, for the summer and winter periods, are high relative to seasonal average rainfall in these areas.

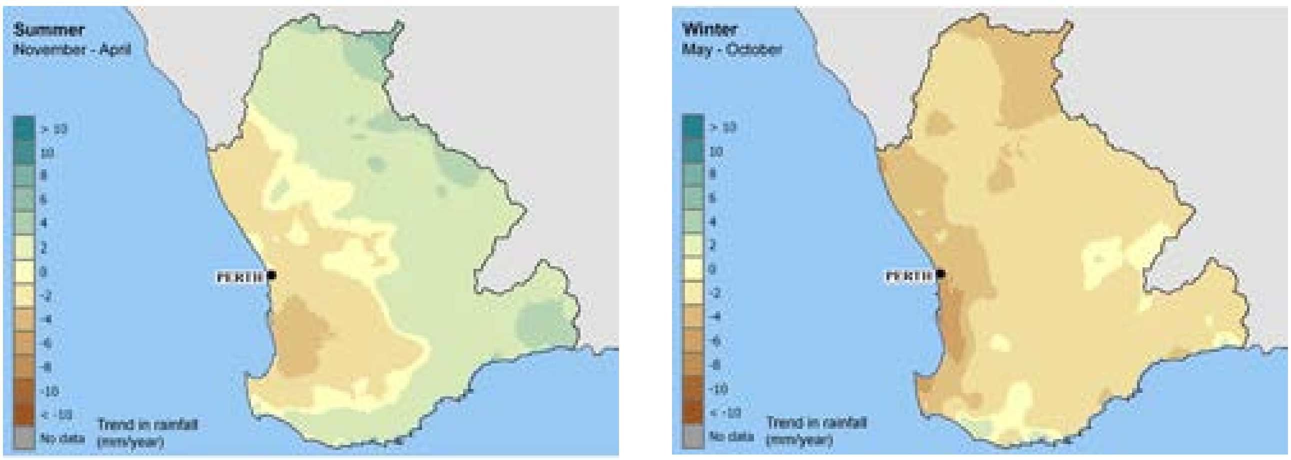


Figure 10-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the South West Coast region. The statistical significance of these trends is often very low

10.4.2 Evapotranspiration

Evapotranspiration for the South West Coast region for 2009–10 was estimated to be 373 mm, which is six per cent below the region's long-term (July 1911 to June 2010) average of 399 mm. Figure 10-9 (a) shows that the evapotranspiration for 2009–10 was estimated to be highest in the southwest of the region and is closely linked to the regional distribution of annual rainfall (Figure 10-6 [a]).

Evapotranspiration deciles for 2009–10, shown in Figure 10-9 (b), indicate evapotranspiration for the year was below average over much of the region. Very much below average values are identified in areas of the south and northwest. Annual evapotranspiration was above average for very limited areas in the far south and southwest of the region.

Figure 10-10 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 348 mm (1990–91) to 476 mm (1999–2000). Average annual evapotranspiration for the period was 398 mm.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 10-10 (b). Evapotranspiration for the region is approximately evenly distributed between the summer and winter periods. Over the 30 years, there appears to be very little variation in seasonal evapotranspiration.

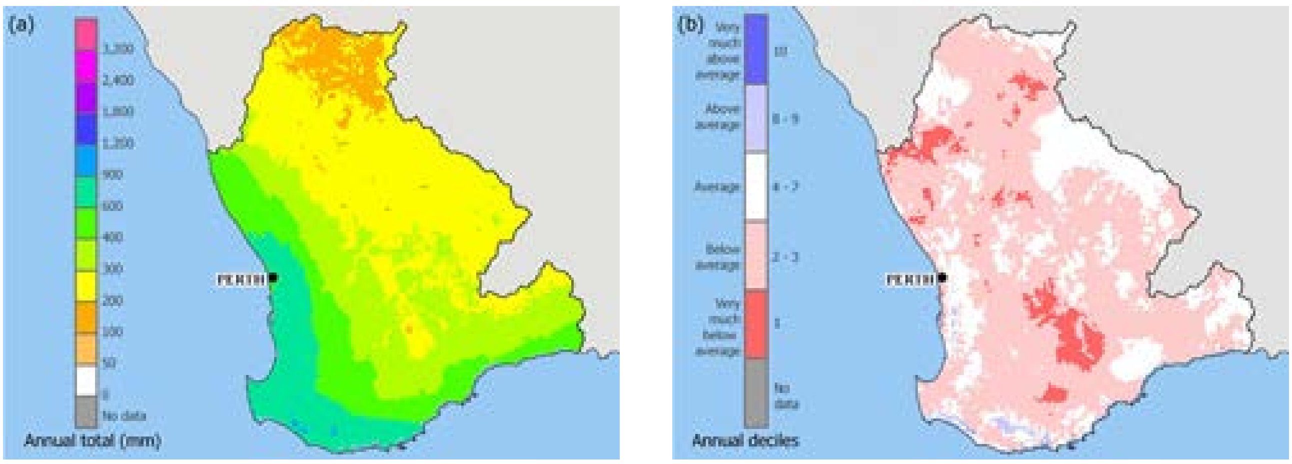
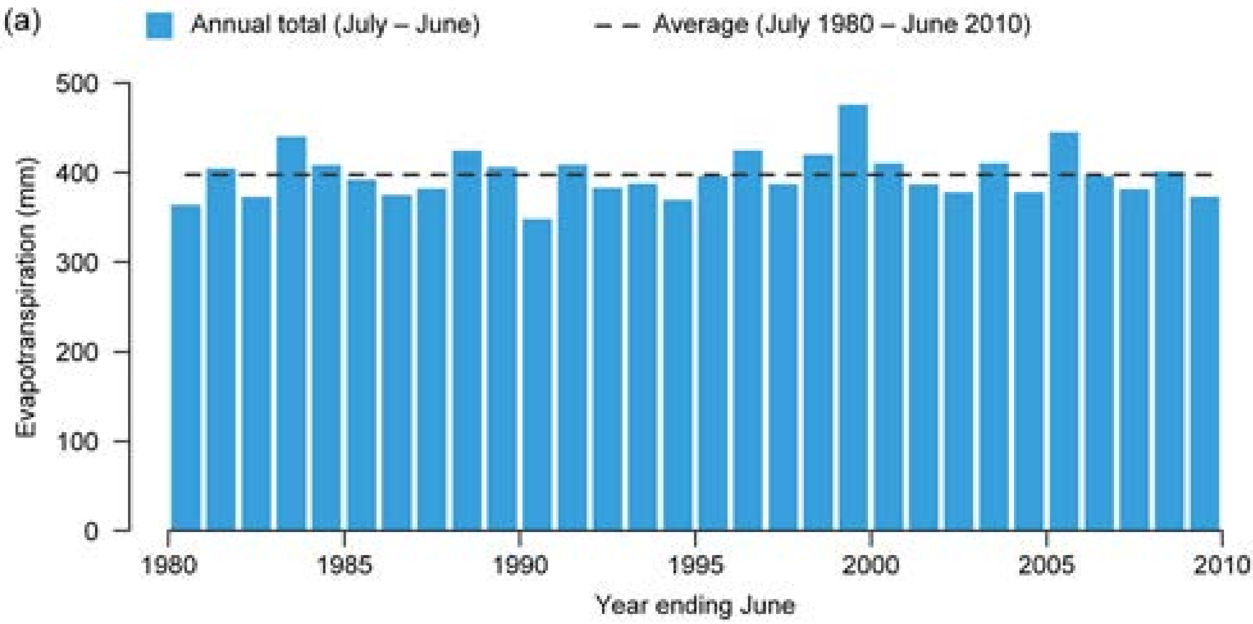


Figure 10-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South West Coast region



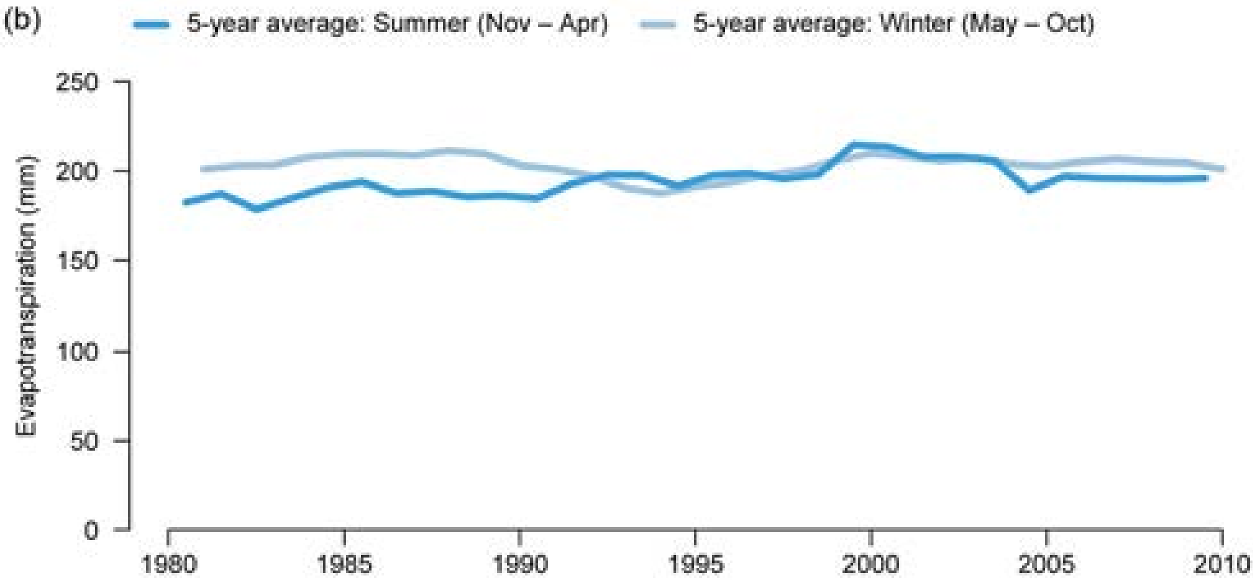


Figure 10-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the South West Coast region

10.4.2 Evapotranspiration (continued)

Figure 10-11 provides a spatial representation of trends in summer (November–April) and winter (May–October) evapotranspiration throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis indicates decreasing trends in evapotranspiration across the western side of the region and slightly increasing trends across the east and far south. The equivalent analysis of winter period shows no clear trends in evapotranspiration across much of the region. Slight decreasing trends are observed in the north and central-west of the region.

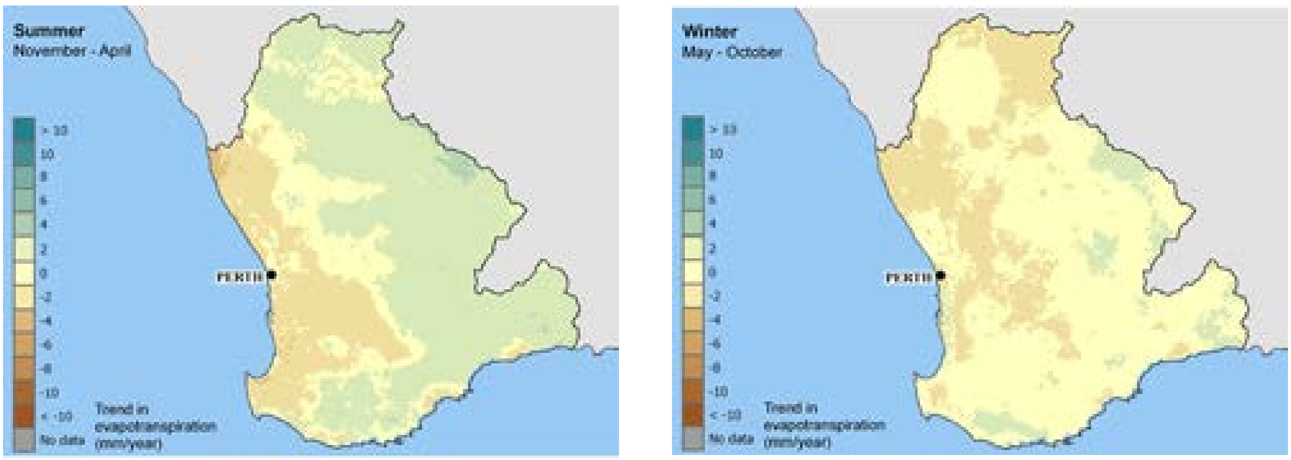


Figure 10-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the South West Coast region. The statistical significance of these trends is often very low

10.4.3 Landscape water yield

Landscape water yield for the South West Coast region for 2009–10 was estimated to be 24 mm, which is 34 per cent below the region's long-term (July 1911 to June 2010) average of 37 mm. Figure 10-12 (a) shows that landscape water yield for 2009–10 was very low (below 50 mm) across the majority of the region with the highest values observed in the far southwest of the region. Landscape water yield deciles for 2009–10, shown in Figure 10-12 (b), indicate that landscape water yield was at a below average or very much below average level across almost the entire region. Very limited areas of above average values were identified in the far north, south and east of the region.

Figure 10-13 (a) shows annual landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 14 mm (2006–07) to 71 mm (1999–2000). The annual average for this period was 32 mm. The data show that, with the exception of 2005–06, annual landscape water yield was noticeably lower than the 30-year average since 2001–02. The data reflect relatively high levels of landscape water yield during the wetter years of the 1990s compared to the drier years of the 1980s and 2000s.

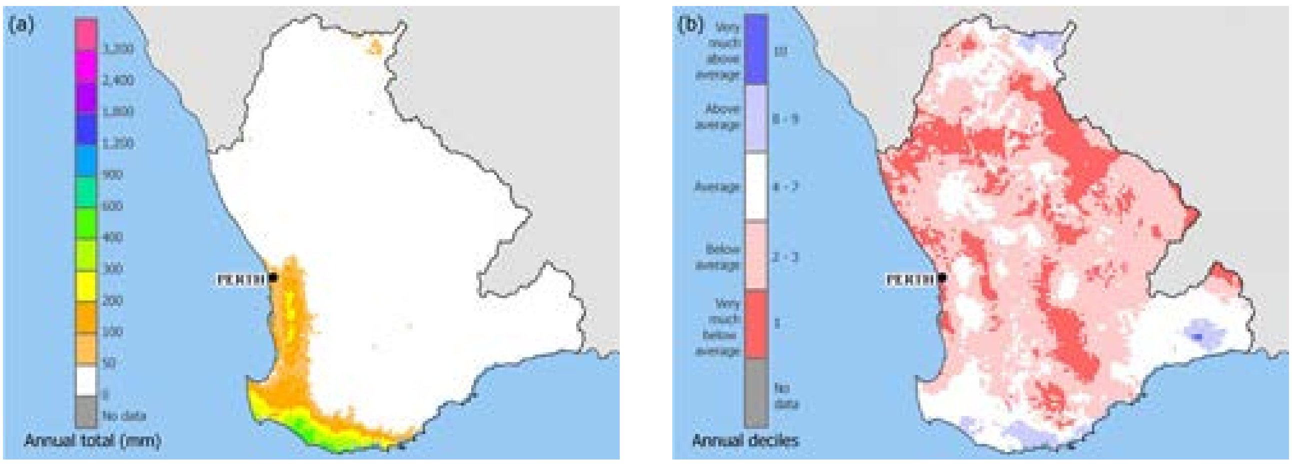
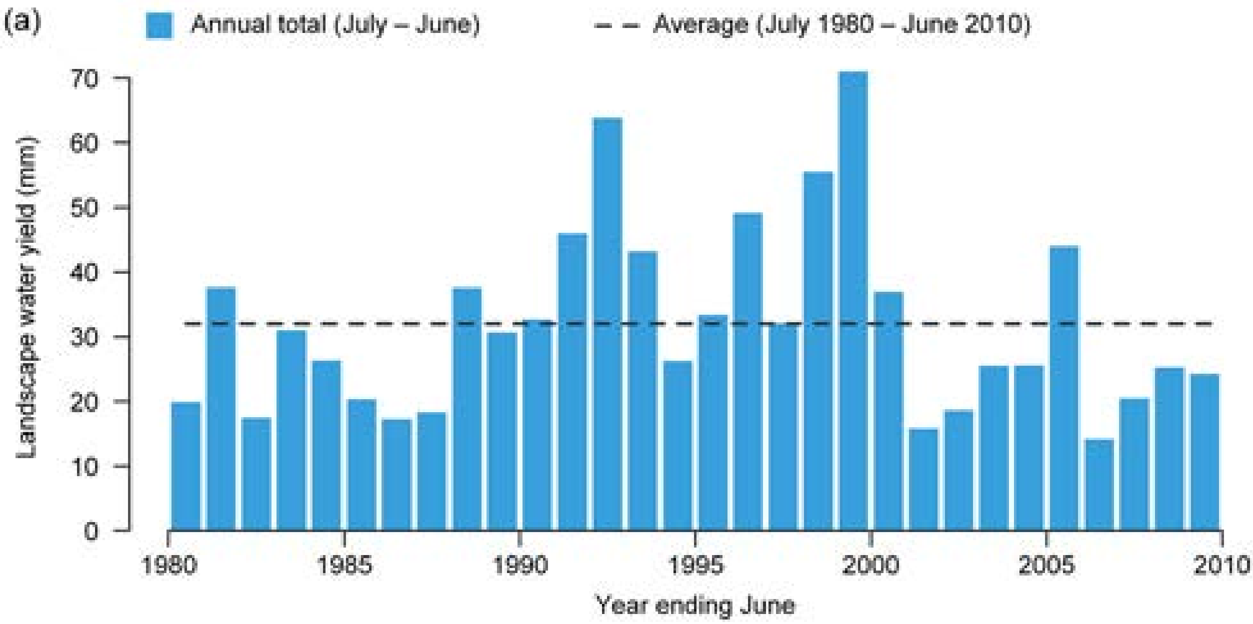


Figure 10-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the South West Coast region



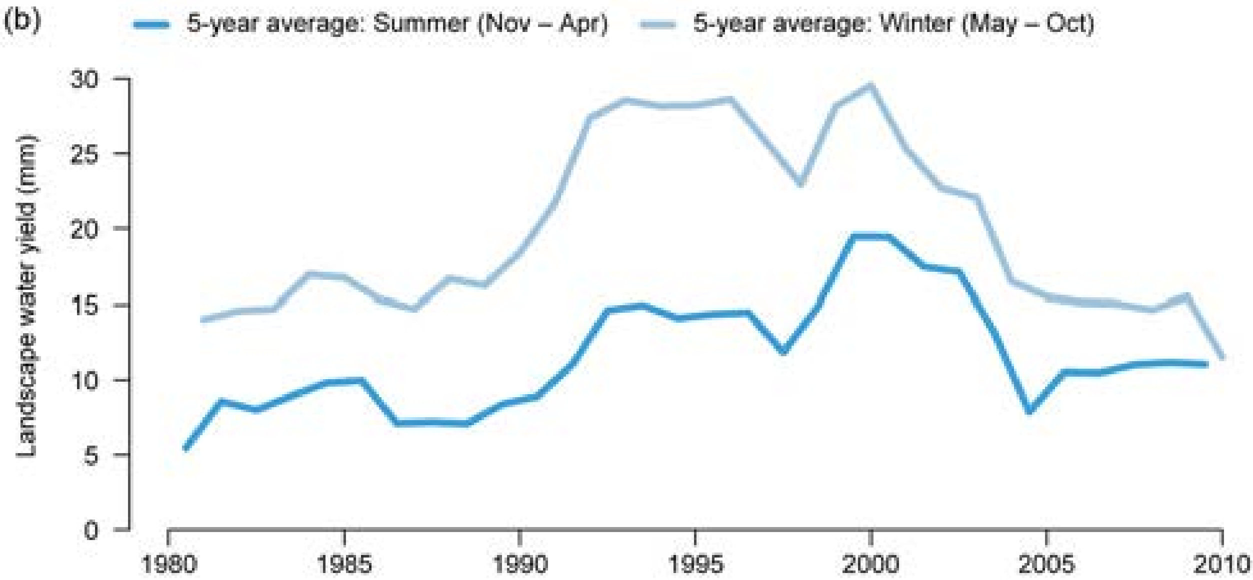


Figure 10-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the South West Coast region

10.4.3 Landscape water yield (continued)

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 10-13 (b). Landscape water yield is consistently higher for the winter period than for the summer and both seasons tended to increase during the 1990s. Over the past ten years, there was a noticeable decrease in winter period averages.

Figure 10-14 provides a spatial representation of trends in summer (November–April) and winter (May–October) landscape water yield throughout the region between November 1980 and October 2010. The linear regression slope calculated at each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period analysis identifies slight downward trends in landscape water yield across the southwest and slight increases in the north, northeast and far south of the region. The winter period analysis indicates strong decreasing trends across south-western coastal areas, particularly to the south of Perth across the inflow catchments to the surface water storages that form part of the region's Integrated Water Supply System. These large reductions in winter period landscape water yield over the 30 years are high relative to the winter average in these areas.

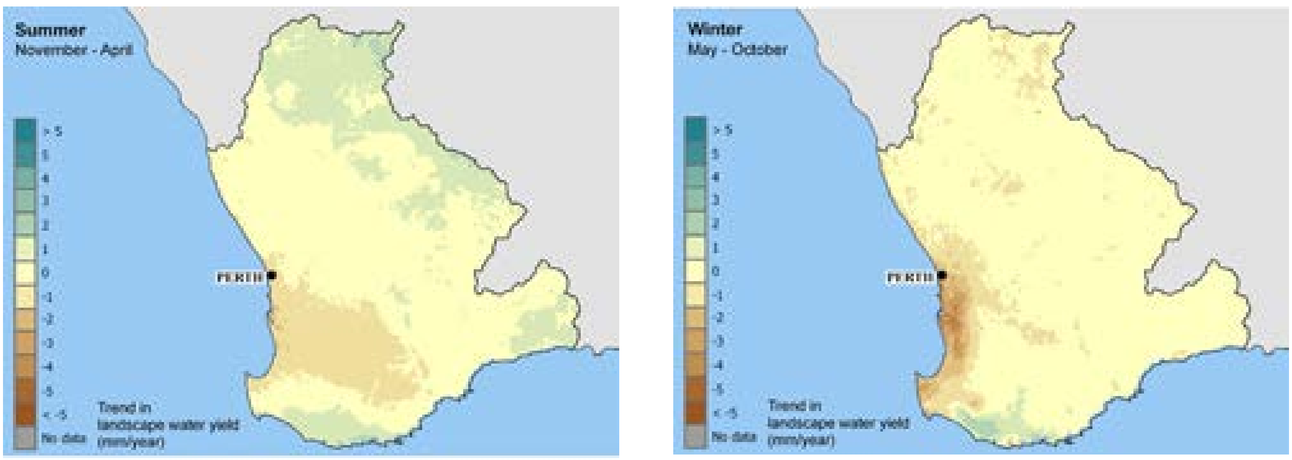


Figure 10-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the South West Coast region. The statistical significance of these trends is often very low

Figure 10-15. Stream gauges selected for analysis in the South West Coast region

10.5 Rivers, wetlands and groundwater

The 35 reliable stream gauges with relatively long historical records across 16 river basins, mainly located in the more humid southwest of the region, were selected for examination of regional streamflow in this report (see Figure 10-15). Streamflow at these gauges in 2009–10 was analysed in relation to historical flow patterns.

The groundwater management units within the region are presented in Figure 10-16. 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 indicative of the volume and quality of groundwater resources available – large units typically have low volume and low quality.

10.5.1 Streamflow and flood report

Figure 10-17 presents an analysis of river flows over 2009–10 relative to the past 30 years at 35 monitoring sites throughout the region. Gauges are selected according to the criteria outlined in the Technical supplement. Annual river flows for the 2009–10 reporting year are presented in terms of decile ranges derived from annual flow volumes for the previous 30 years at each site.

With regard to total annual discharge in 2009–10, Figure 10-17 shows that observed streamflow presents a slightly different pattern to the modelled 2009–10 landscape water yield decile rankings in respect to the past 30 years (Figure 10-18). In general, many basins contain areas of both above average and below average modelled landscape water yield. The averaging out of this pattern into a streamflow total at a downstream point in the basin

is resulting in a more complex comparison between measured run-off and modelled landscape water yields presented as a modelled grid.

Broadly, Figure 10-17 shows:

- above average streamflow for 2009–10 at the central-south of the region and at sites in the southwest, mainly in the Blackwood River basin
- average annual streamflow occurred at basins throughout the region
- some sites recorded below average annual total flows especially surrounding the Perth region.

At the time of writing, suitable data were not readily available from the Bureau's records for the presentation of a regional flood summary for 2009–10.

Figure 10-16. Major groundwater management units in the South West Coast region (Bureau of Meteorology 2011e)

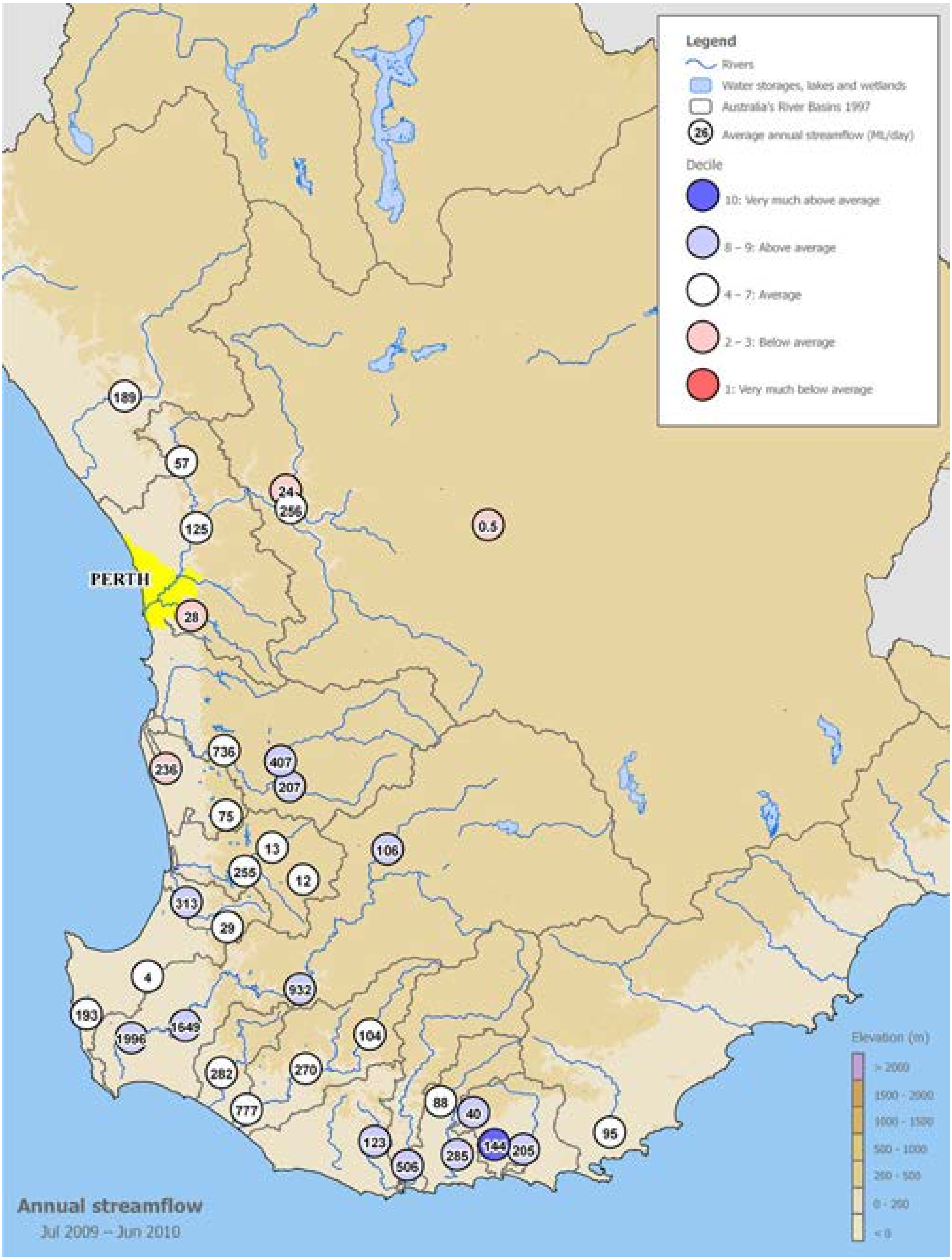


Figure 10-17 Annual streamflow volumes (ML/day) for selected gauges for 2009–10 and their decile rankings over the 1980 to 2010 period in the South West Coast region

10.5.2 Inflows to wetlands

The South West Coast region has a large number of important wetlands, most of which are groundwater dependent. These range from estuaries and coastal swamplands to freshwater springs and hyper-saline inland lakes of varying size, diversity and geomorphic origin (Department of Environment and Conservation 2011). However, at the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available for the analysis of the pattern of wetland river inflows for the region.

10.5.3 Groundwater status

Though the groundwater resources of this area are comparatively well developed, the groundwater status in the South West Coast region is not presented in this report. At the time of writing, suitable quality controlled and quality assured data from the Australian Water Information System (Bureau of Meteorology 2011a) were not available.

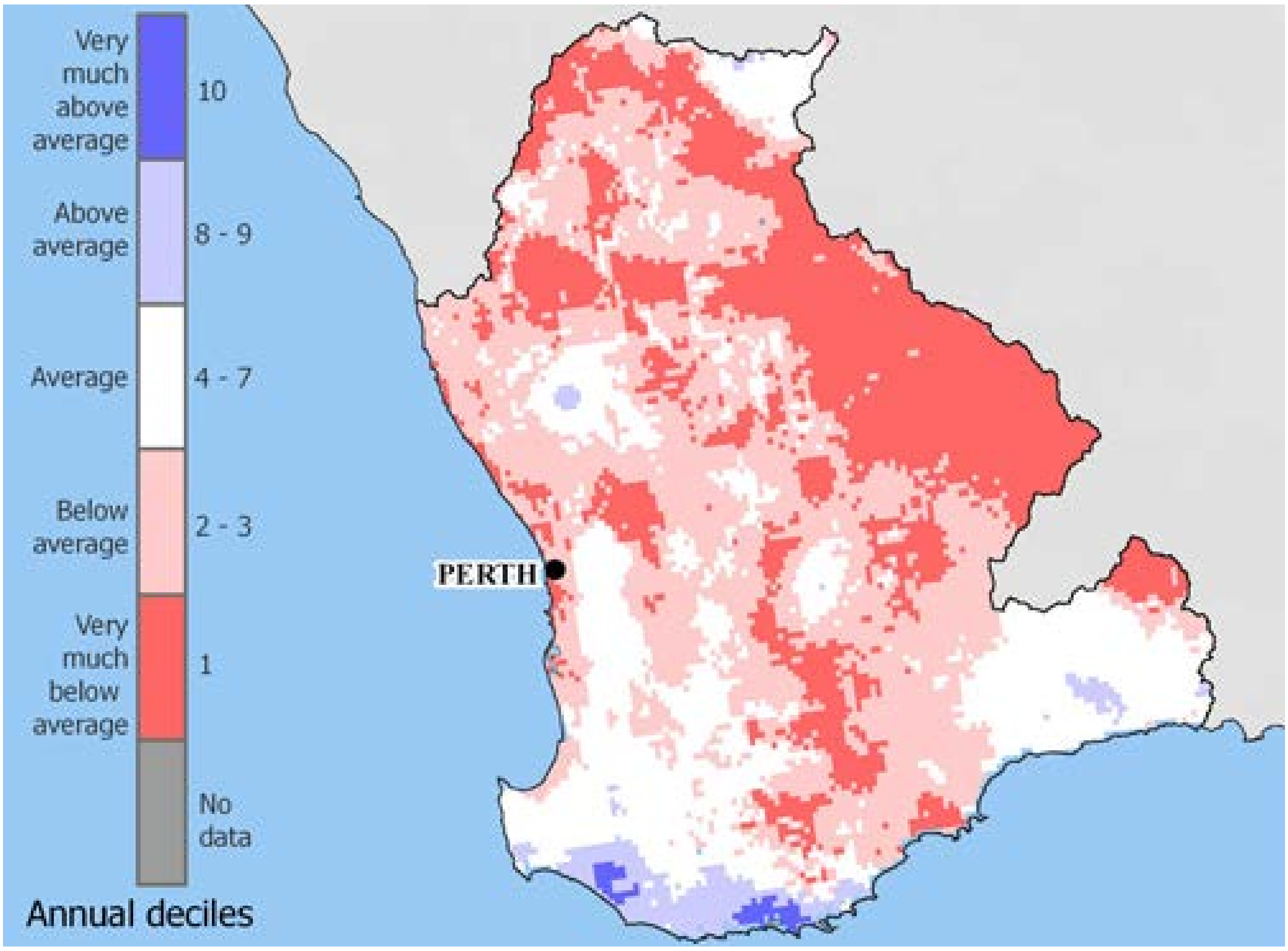


Figure 10-18. Map of modelled landscape water yield deciles for 2009–10 in comparison with the past 30 years for the South West Coast region

10.6 Water for cities and towns

10.6.1 Regional overview

There are four main cities and towns in the South West Coast region. Perth is the largest with a population of more than 1.6 million (Table 10-2; Figure 10-19). The urban area of Perth has expanded relatively rapidly in recent years due to a mineral resources boom in the State. Hundreds of new residential estates are being constructed, with many thousands of new homes established in the southern and northern ends of the Perth metropolitan area. The total urban area of Perth is about 1,600 km^2 which is around 7.6 per cent of the region's total area.

The demand for water for residential, irrigation and industrial use is increasing rapidly in and around Perth. The city consists of over 300 suburbs which are supplied with drinking water from 13 water storages, one desalination plant and groundwater from Gnangara and Jandakot mounds. Accessible volumes for three main water storages supplying Perth between 1990 and 2010 are shown in Figure 10-20.

Table 10-2. Cities and their water supply storages in the South West Coast region

City	Population*	River basin	Major supply storages
Perth	1,650,000	Swan Coastal	Canning, Serpentine and South Dandalup reservoirs
Mandurah	83,000	Murray River	No surface water storage
Bunbury	66,000	Preston River	No surface water storage
Albany	35,000	Kalgan River	No surface water storage

* Australian Bureau of Statistics (2010b)

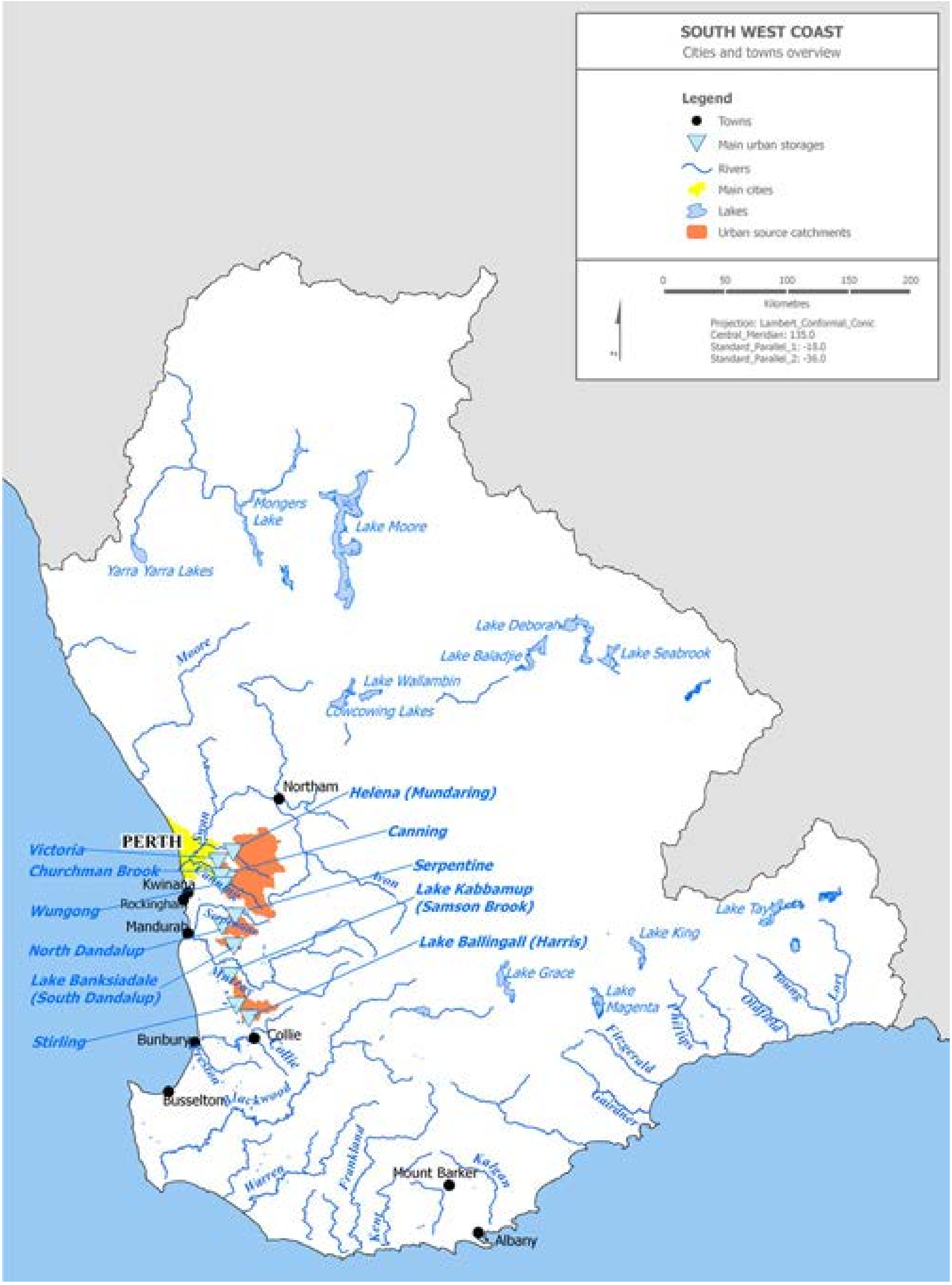


Figure 10-19. Urban areas and supply storages in the South West Coast region

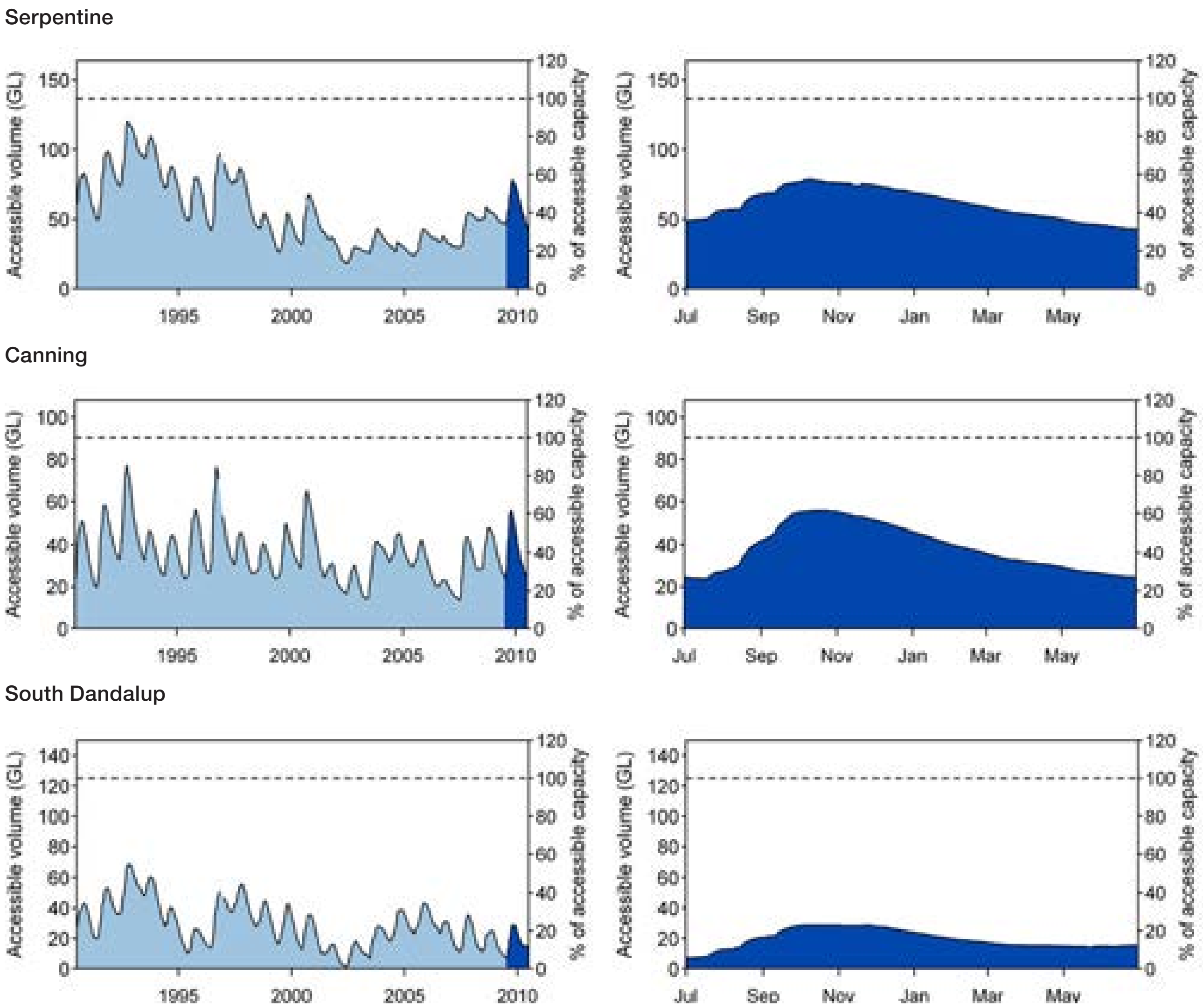


Figure 10-20. Variation in the amount of water held in storage over recent years (light blue) and over 2009–10 (dark blue) for cities in the South West Coast region. Gaps in the black line indicate unavailable data points

10.6.2 Perth water supply area

The Perth water supply area is located on the west coast of Western Australia (Figure 10-21). The boundary of this area is mostly defined by three surface water catchments: the Swan, Murray and Harvey river basins. The boundary extends from that defined by the surface water catchments in the north and south, and incorporates groundwater management areas and the Harvey Irrigation Area.

Geographically, the area is divided in two parts by the Darling Escarpment. The escarpment runs in a north-south direction and rises to more than 200 m above sea level. To the east is the Darling Range, which extends to the eastern boundary of the supply area. To the west of the escarpment are the coastal plains.

The Perth water supply area is home to waterways and wetlands of national significance. The Swan and Canning rivers and the Peel–Harvey estuarine system have strong environmental, cultural and recreational significance.

There are also important groundwater resources in the region, such as the Gnangara and Jandakot aquifers. Not only are these aquifers a source of public and self-supply, they also support numerous wetland ecosystems.

The area is served by the Integrated Water Supply System operated by the Water Corporation. This corporation supplies potable water to Perth and the surrounding urban areas as well as irrigation water to Harvey Water irrigation zones (Harvey, Waroona and Collie) located in the south. The total irrigable land area in these zones is approximately 300 km^2.

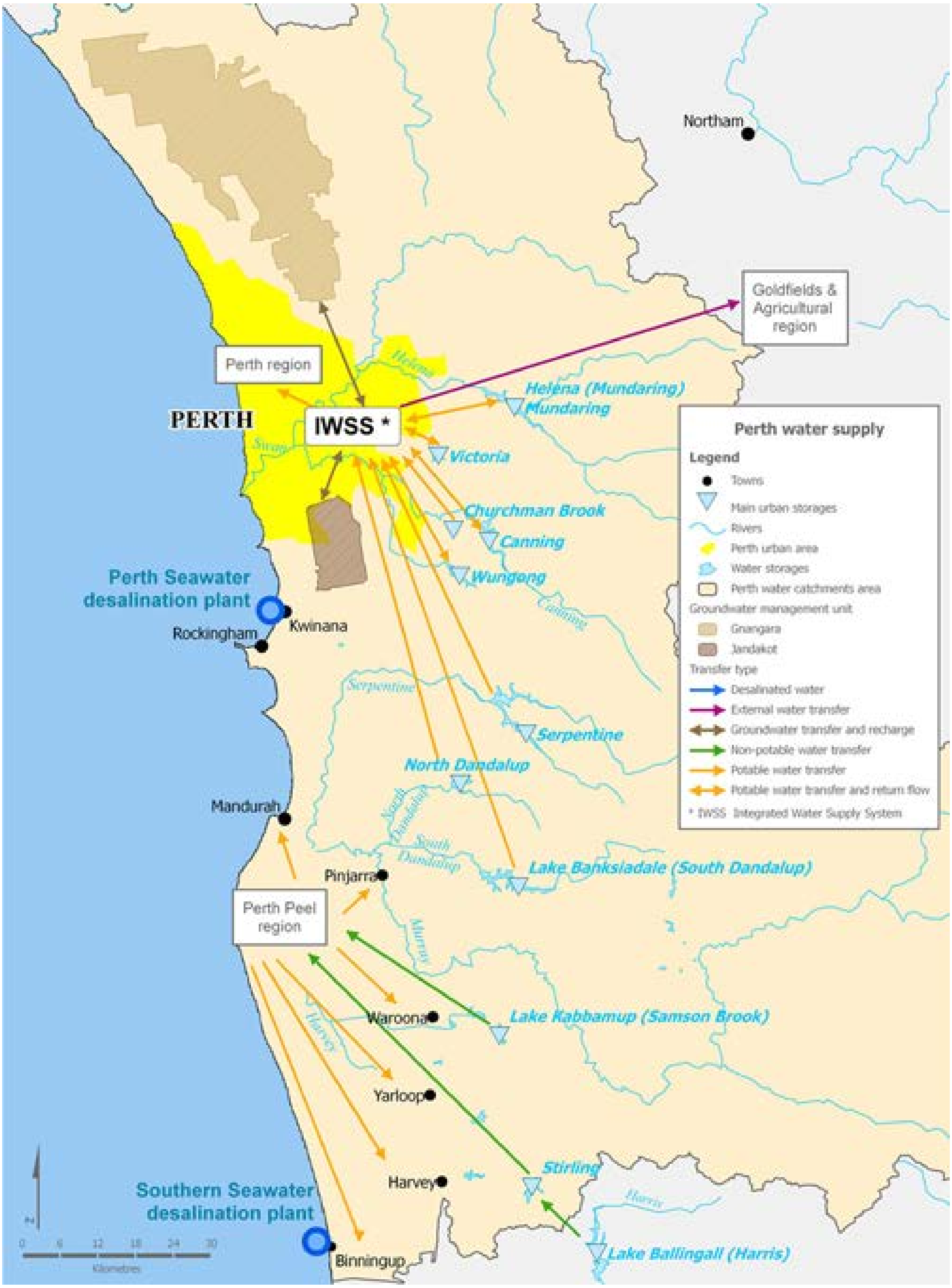


Figure 10-21. Water supply schematic for the Perth water supply area

10.6.2 Perth water supply area (continued)

The catchments of the Perth water supply area experienced a decline in rainfall over the past 30 years. During that time, wet season rainfall (May to October) is estimated to have declined by more than ten per cent. The result was a 50 per cent reduction in streamflow into public water storages and a substantial reduction in aquifer recharge (Government of Western Australia 2007; Vogwill et al. 2008). As a result, a number of major water initiatives are being pursued, including the Gnangara Sustainability Strategy, Perth–Peel Regional Water Plan and the construction of a second desalination plant (Water Corporation 2008).

The Gnangara Sustainability Strategy is an inter-agency initiative to ensure the sustainable use of water for drinking and commercial purposes and to protect the environment on the Gnangara watertable aquifer. The strategy was developed by the Department of Water in conjunction with the Department of Agriculture and Food, Department of Environment and Conservation, Department of Planning, Forest Products Commission, Water Corporation and CSIRO.

The Perth–Peel Regional Water Plan is being developed to set strategic directions for the sustainable management of water resources in the Perth water supply area. The Plan describes techniques that can be used to conserve and manage the water resources in the region such as: (1) reducing water demand by using water more effectively and efficiently; (2) facilitating the use of alternative sources of water supply; and (3) restoring and protecting waterway and wetland health (Froend et al. 2004).

Urban water infrastructures and management

The Water Corporation is the principal supplier of water, wastewater and drainage services to homes, businesses and farms in the Perth water supply area, as well as providing bulk water to farms for irrigation. It manages the Integrated Water Supply Scheme, which supplies water to 1.5 million of the 1.9 million people in the area. The scheme's service area takes in Perth and surrounding towns and, through the Goldfields Pipeline from Mundaring Weir, towns and farmlands in the Central Wheatbelt out to Kalgoorlie–Boulder. The scheme is supplied from multiple groundwater and surface water sources located over a wide geographic area.

Since 2006, sources of water to the Perth water supply area were supplemented with 45 GL of water annually from Kwinana Desalination Plant (Water Corporation 2011a). The Water Corporation is in the process of constructing a further seawater desalination plant near Bunbury to the south of Perth. It is due for completion in 2011 and will double the current supply of desalinated water to the area.

The water supply area has a high abstraction of groundwater for both domestic use and irrigation. The use of groundwater doubled in the 15 years prior to 2000 and, with growing requirements, the groundwater systems are subject to stress (Water Corporation 2008).

To manage groundwater abstraction, ecological water requirements and environmental water provisions are determined as part of water allocation processes. The environmental water provisions are the water regimes provided as a result of water allocation decision-making processes taking into account ecological, social and economic impacts. Environmental water provisions are determined by the Department of Water in accordance with the principles and processes set out in its Environmental Water Provision Policy (2000).

10.6.2 Perth water supply area (continued)

Surface storage levels and volumes in recent years

The combined accessible volume for three major storages in the Perth catchment area (Serpentine, Canning and South Dandalup) is 352 GL which is shown in Figure 10-22. These make up 50 per cent of the total capacity of all storages in the Perth catchment. South Dandalup Reservoir is the largest, with a capacity of 125 GL and it contributes approximately 18 per cent of the total storage capacity.

Figure 10-22 (top) shows the combined accessible volumes of the three major storages from 1990 to 2010. The combined storage volume was highest in 1992. Since then, the volume declined due to well below average inflows into the storages. The accessible storage fell from 265 GL in 1992 to below 40 GL in 2002. The combined accessible storage volume increased steadily since 2002 but remains well below the levels of the early 1990s.

Figure 10-22 (bottom) shows the combined volumes in the three major storages from July 2009 to June 2010. With winter inflows, the accessible storage volume increased from about 80 GL in July 2009 to about 160 GL in October 2009. From November 2009, the accessible storage was slowly drawn down to about 85 GL by the end of June 2010.

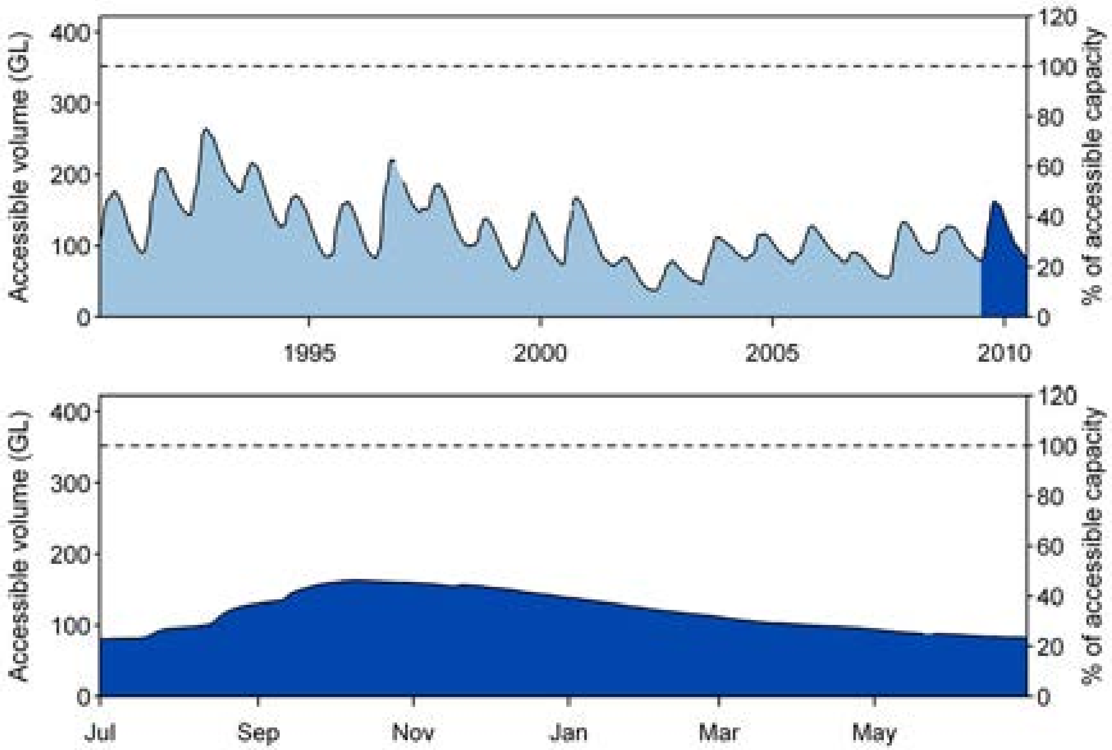


Figure 10-22. Combined surface water storage volumes for Serpentine, Canning and South Dandalup reservoir since 1990 (top) and during 2009–10 (bottom). Gaps in the black line indicate unavailable data points

10.6.2 Perth water supply area (continued)

Water restrictions in recent years

Figure 10-23 shows the stage of restrictions with the percentage of combined accessible storage of the three major storages. The stages are defined in the Water Agencies (Water Use) By-Laws 2010 under the Western Australian *Water Agencies (Powers) Act 1984*. It can be seen that Stage 1 restrictions were introduced when the combined accessible storage reached about 25 per cent of capacity in 1996. When the accessible storage fell below 20 per cent, the water restriction stage was increased to Stage 4 in 2001. Since 2002, the accessible capacity in these three storages dropped below 30 per cent every summer and, as a result, the water restriction stage increased from 4 to 5.

Sources and supply of urban water in recent years

At present, groundwater is the main source of water supplied to the Perth water supply area. Figure 10-24 (National Water Commission 2011a) illustrates that, on average, more than 50 per cent of the bulk water sourced by the Water Corporation is groundwater. The use of desalination water in the Perth region was started in 2006 and its contribution ranged from 18 to 33 GL between 2005–06 and 2009–10. The contribution of recycled water ranged from 4 to 6 GL over the same period.

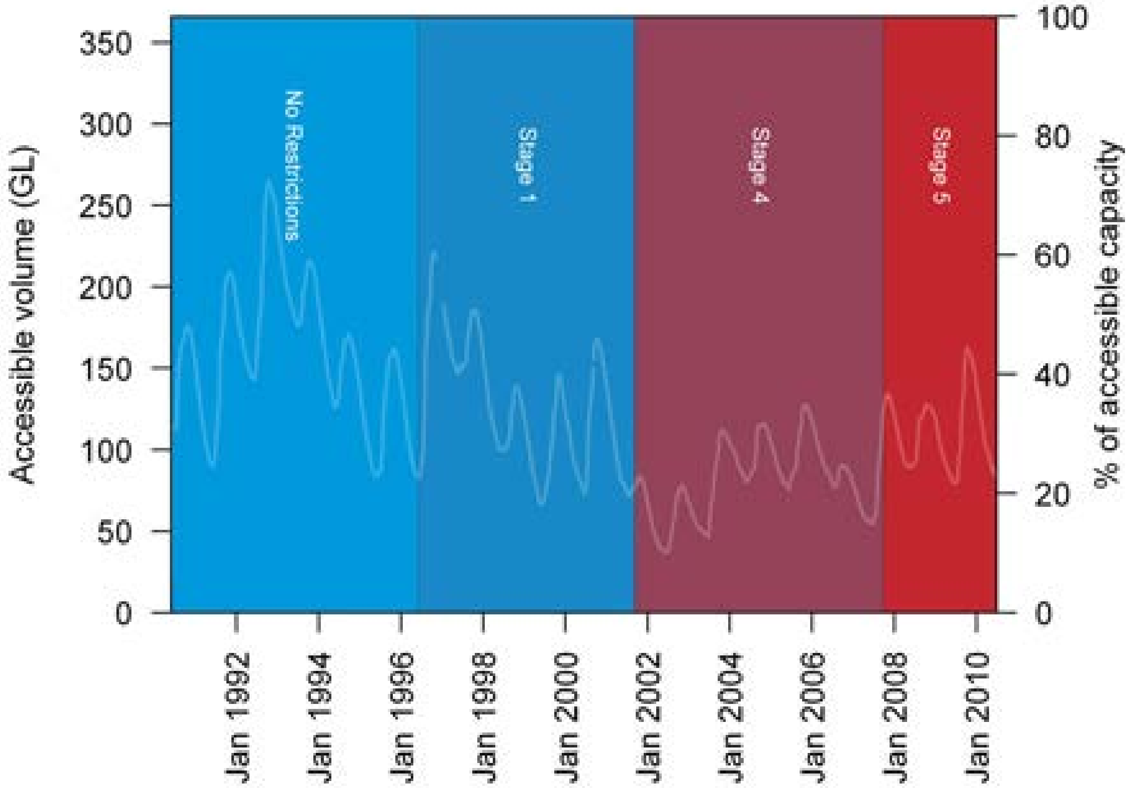


Figure 10-23. Urban water restriction levels for Perth since 1990 shown against the combined accessible water volume of Serpentine, Canning and South Dandalup reservoirs

10.6.2 Perth water supply area (continued)

It is clear from Figure 10-24 that total water sourced for the Perth water supply area grew from 260 GL in 2005–06 to 281 GL in 2009–10. This increase of 21 GL is due to a rapid rise in the population associated with the mining boom in Western Australia (Statistics Perth 2007). A second desalination plant is being built outside Binningup and will be managed by the Water Corporation and a Spanish-led consortium, Southern Sea Water Alliance. The maximum capacity of the plant will be 137 GL. It is expected to be completed by the end of 2011.

About 5 GL of water has been sourced from recycling each year since 2005–06. This water was supplied to consumers for a range of activities including the irrigation of agriculture, vineyards and market gardens.

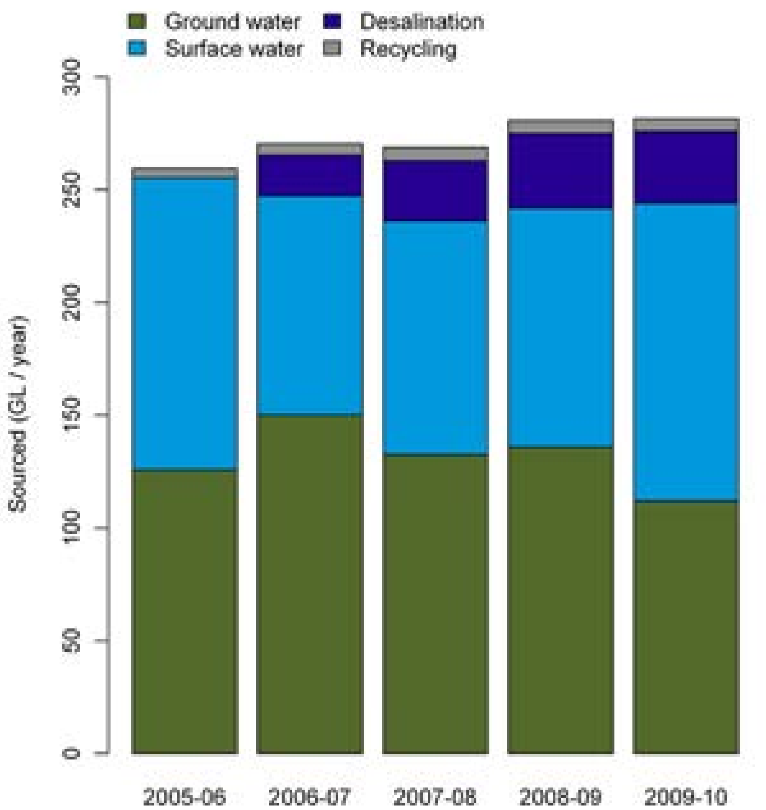


Figure 10-24. Total urban water sourced for Perth from 2005–06 to 2009–10

10.6.2 Perth water supply area (continued)

Figure 10-25 (National Water Commission 2011a) shows total volume of water delivered to residential, commercial, municipal and industrial consumers in the Perth water supply area between 2004–05 and 2009–10. The total water supplied grew by 40 GL over this period from 225 to 265 GL. About 70 per cent of the water supplied each year was used for residential purposes. Commercial, municipal and industrial water use comprised around 20 per cent of the water supplied with other water uses accounting for the remainder.

Using population numbers and total water supplied data from National Performance Reports, the per capita water use is estimated to be 417 litres/day in 2005–06 and 397 litres/day in 2009–10. This represents a per capita water saving of around 20 litres/day that can be attributed to water restrictions and increased public awareness of the need to conserve water.

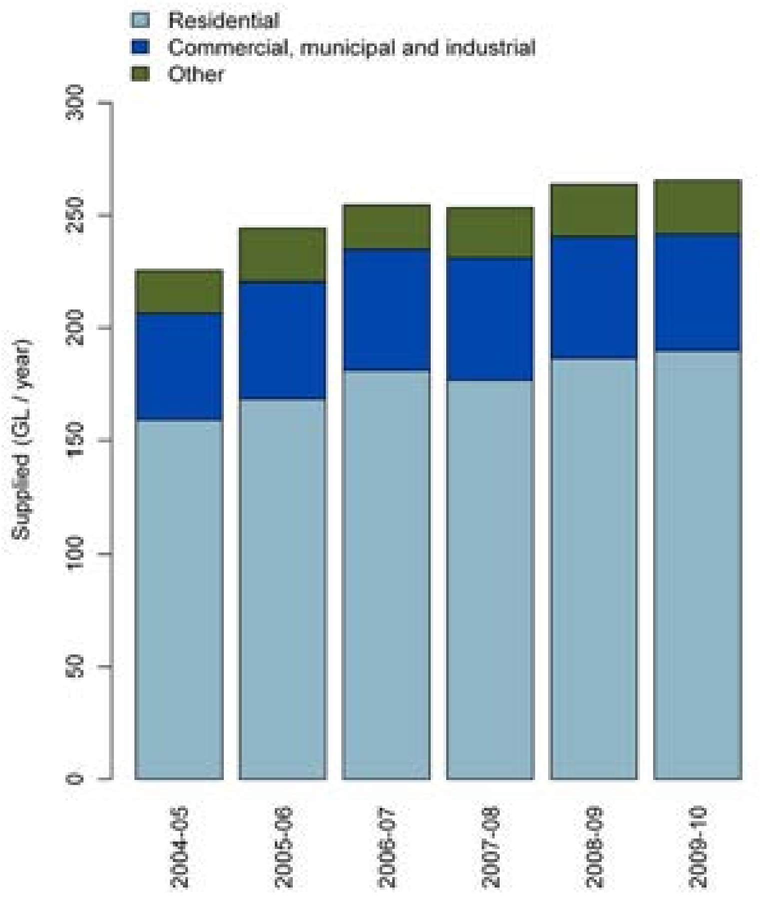


Figure 10-25. Total urban water supplied to Perth from 2004–05 to 2009–10

10.7 Water for agriculture

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). Irrigated agriculture is carried out in the metropolitan and south-western parts of the region.

10.7.1 Soil moisture

Decile ranges of upper soil moisture content in dryland agricultural areas of the region for summer 2009–10 (November to April) and winter 2010 (May to October) are shown in Figure 10-26. Much of the central pastoral areas had average to below average soil moisture conditions during the summer of 2009–10. Northern and southern areas had below average to very below average soil moisture conditions.

During the winter of 2010 (May to October), soil moisture conditions in dryland agricultural areas in the region deteriorated. Upper soil moisture was estimated to be very much below average for the winter period over the majority of the region due to continued low monthly rainfall across the region. Soil moisture conditions were at an average level in the agricultural areas in the far northeast and far southeast of the region.

10.7.2 Irrigation areas

The main irrigation scheme providing water to irrigation areas in the metropolitan and south-western parts of the region is the Harvey Water Irrigation Area (see Figure 10-27). This is one of the three main irrigation schemes in the State and provides more than 60 percent of water allocations in Western Australia (Government of Western Australia 2011). Irrigation in the Harvey Water Irrigation Area is mostly for pasture, followed by vegetables and horticulture.

Comparison of annual irrigation water use between 2005–06 and 2009–10 across the South West Coast region is shown in Figure 10-28 and Figure 10-29 by natural resource management region. Data were sourced from the Australian Bureau of Statistics reports on *Water Use of Australian Farms* (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011).

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

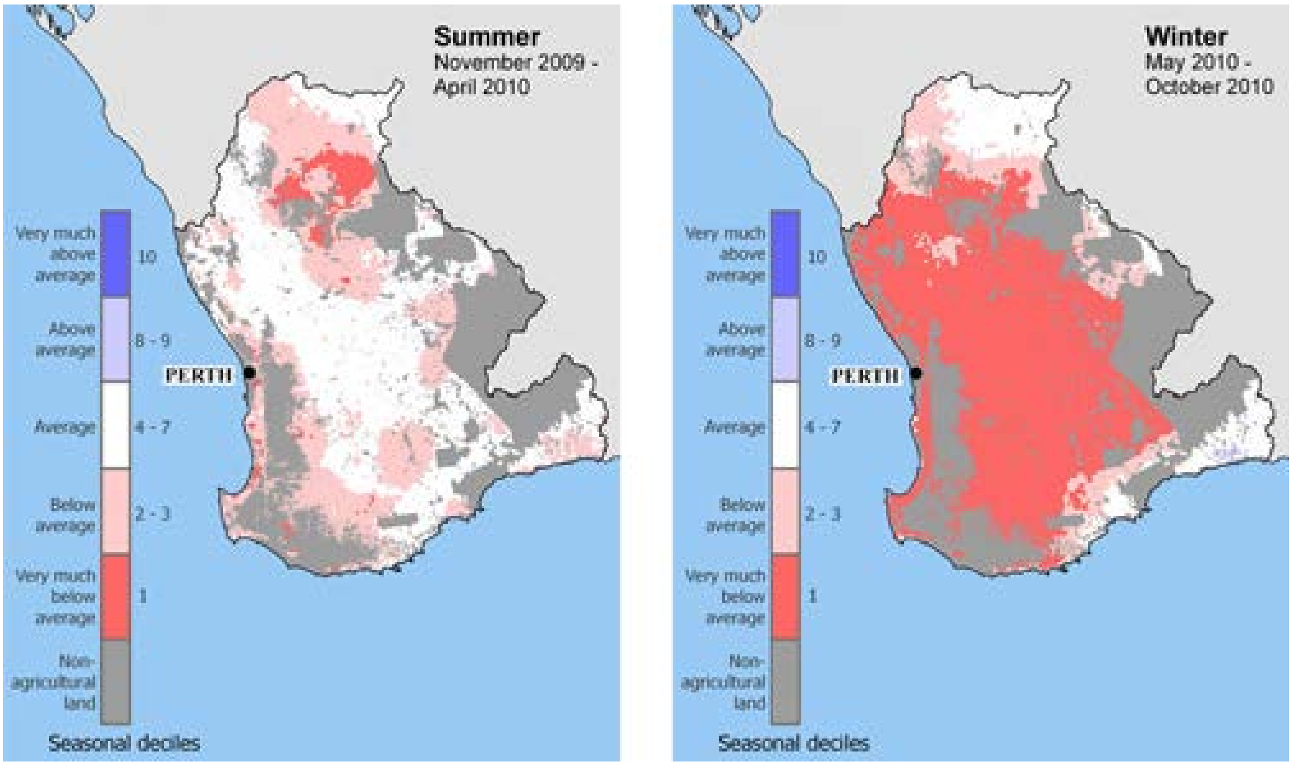


Figure 10-26. Deciles rankings over the 1911–2010 period for modelled soil moisture in the winter (May–October) and summer (November–April) of 2009–10 for the South West Coast region

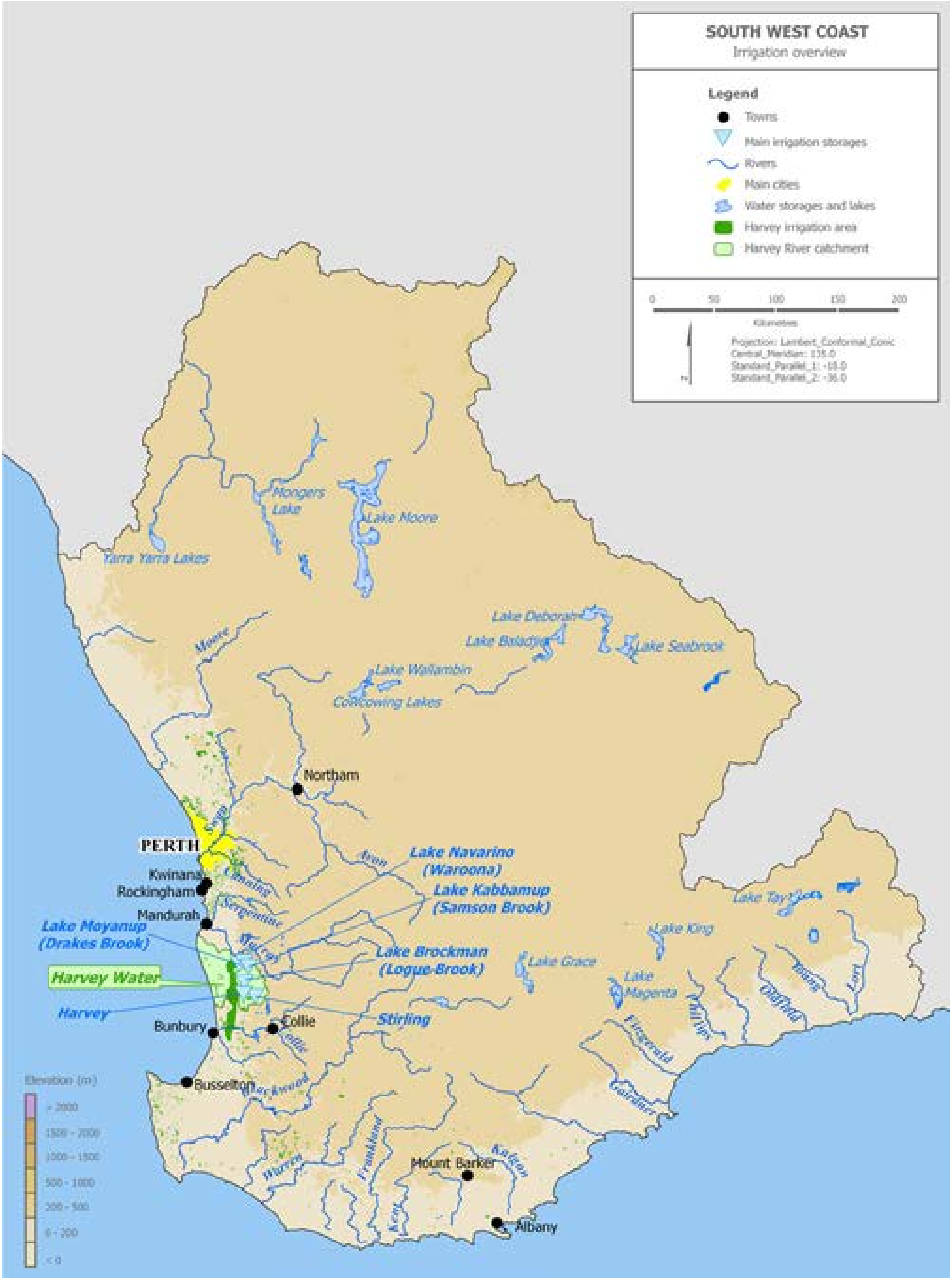


Figure 10-27. Context map of irrigation areas and infrastructure in the South West Coast region

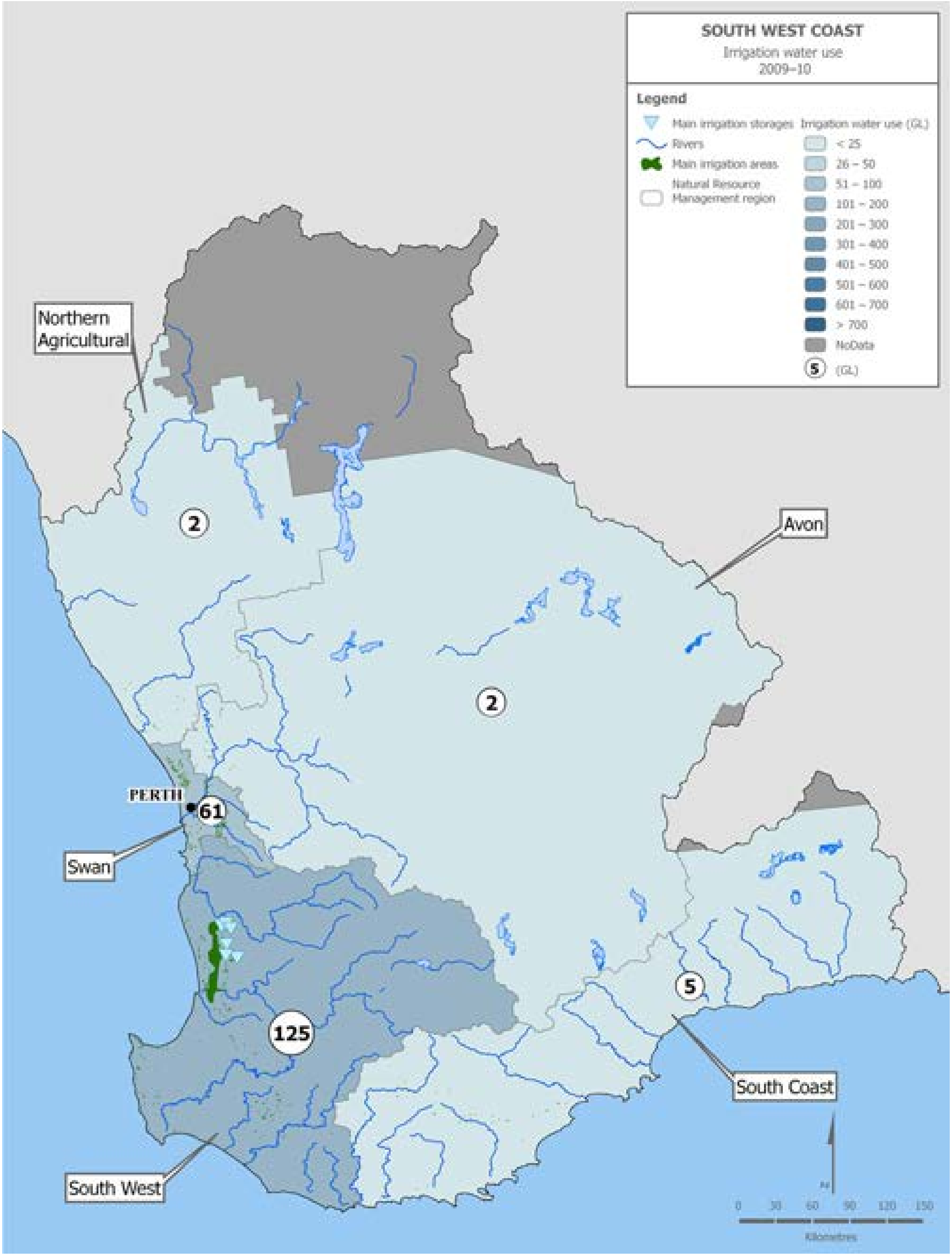


Figure 10-28. Annual irrigation water use per natural resource management region for 2009–10 (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

10.7.2 Irrigation areas (continued)

Harvey Water Irrigation Area

The Harvey Water Irrigation Area is located to the west of the Darling Scarp on the Swan Coastal Plain. It is within the Peel–Harvey catchment that overlaps Harvey River, Collie River and Preston river basins covering an area of 3,072 km^2. The coastal portion of the catchment, where the irrigation area is located, is about 190,000 ha and consists of a series of alluvial (water-borne) deposits in the east and a series of aeolian (wind-borne) deposits or dune systems in the west.

The Harvey Water Irrigation Area covers an area of 1,120 km^2 (Figure 10-30). The majority of land is used for dairy farming and beef production. Currently around 10,000 ha of land is under permanent irrigation for dairy farming, beef grazing and horticulture, with a total irrigable area of approximately 30,000 ha (Harvey Water 2011). This area is Western Australia's prime irrigated dairy area, supplying Perth and the southwest with more than 40 per cent of its milk.

Harvey Water is responsible for the water delivery infrastructure and is licensed to draw an annual volume of 136 GL from seven water storages which are the irrigation area supply sources. These storages are: Drakes Brook (Lake Moyanup), Harvey, Logue Brook (Lake Brockman), Samson Brook (Lake Kabbamup), Stirling, Waroona (Lake Navarino) and Wellington. Water is supplied by gravity flow from storages to farms along a network of open concrete lined and earthen channels and pipes.

Figure 10-31 shows that total water use in the Harvey Water Irrigation Area has declined since the late 1990s but has been relatively steady since around 2004–05. Total volume for the seven water storages in the irrigation area between 1990 and 2010 are shown in Figure 10-32. Inflows to the storages and water availability and supply to the irrigation area each year appear highly reliable, although the total storage volume was drawn down to unusually low levels (approximately 20 per cent of capacity) during the 2002–03 drought. The data indicate winter inflows during 2009 were at least average, with the total storage volume peaking above 300 GL in October 2009.

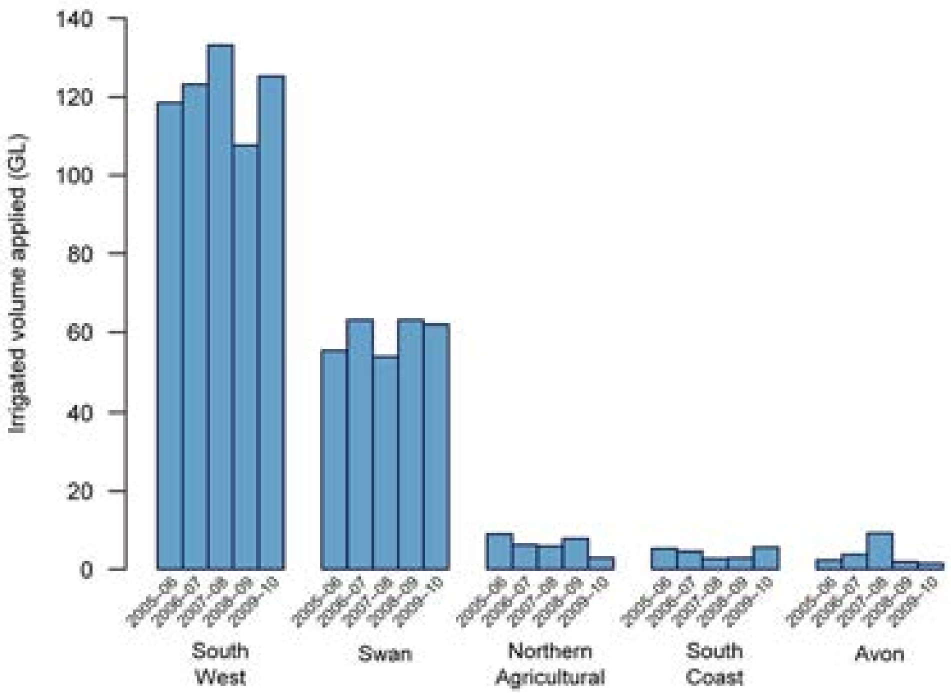


Figure 10-29. Total annual irrigation water use for 2005–06 to 2009–10 for natural resource management regions in the South West Coast region (Australian Bureau of Statistics 2007; 2008; 2009; 2010a; 2011)

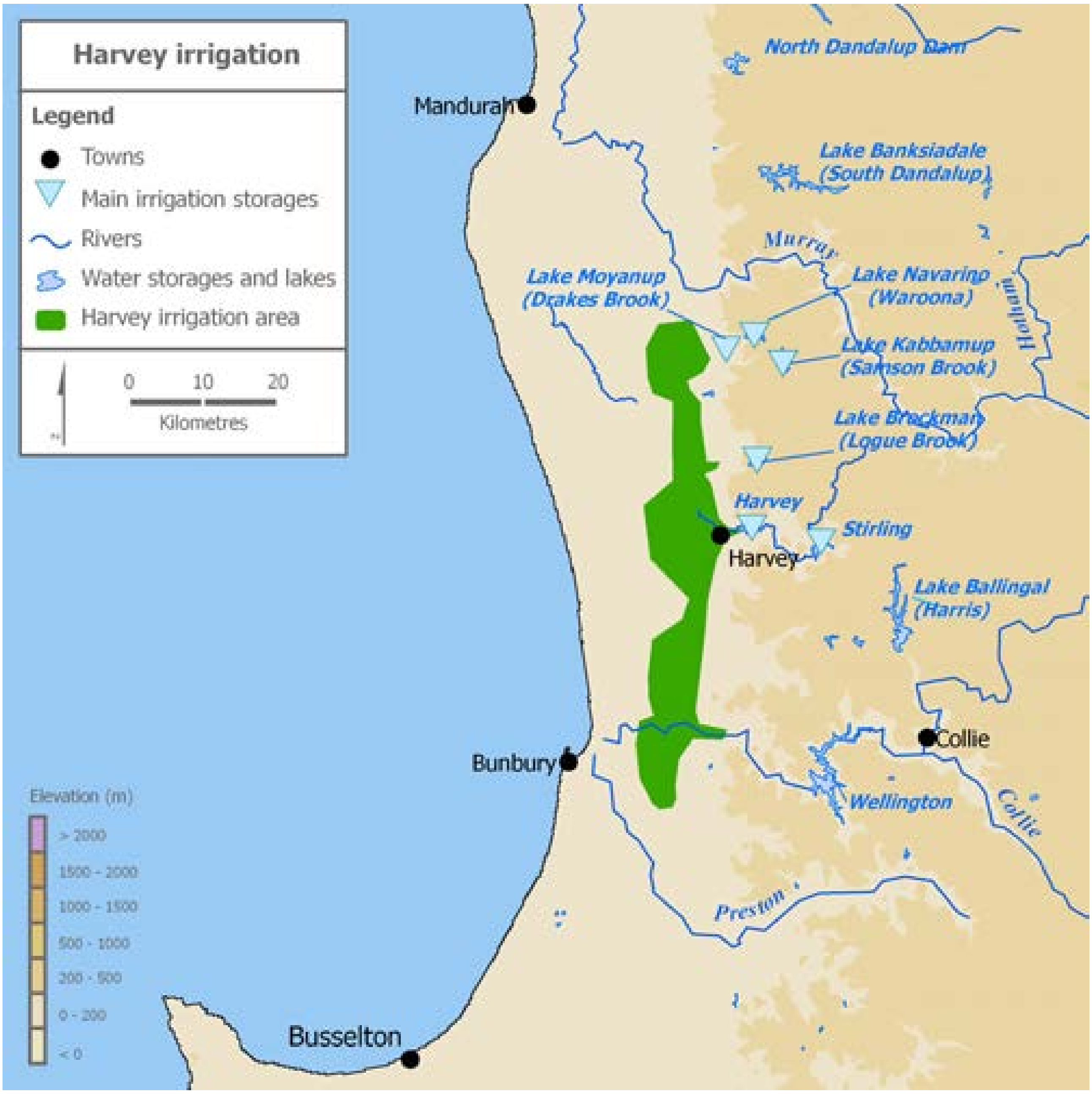


Figure 10-30. Location of the Harvey Water Irrigation Area

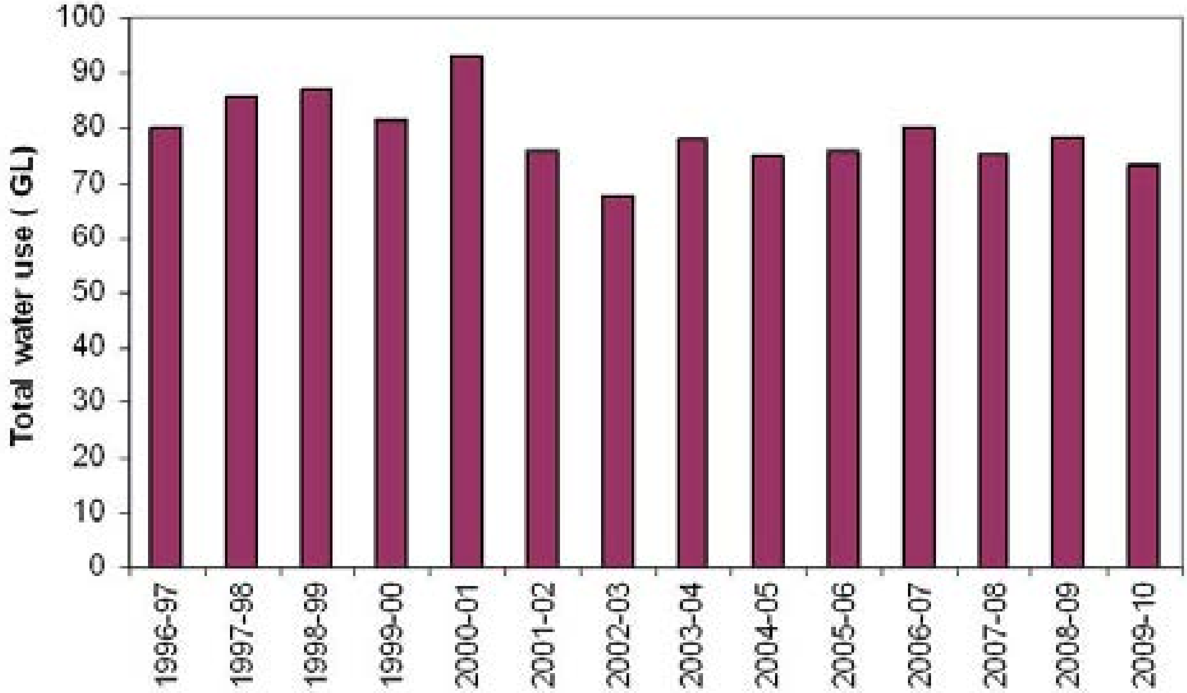


Figure 10-31. Changes in total water use over time in the Harvey Water Irrigation Area

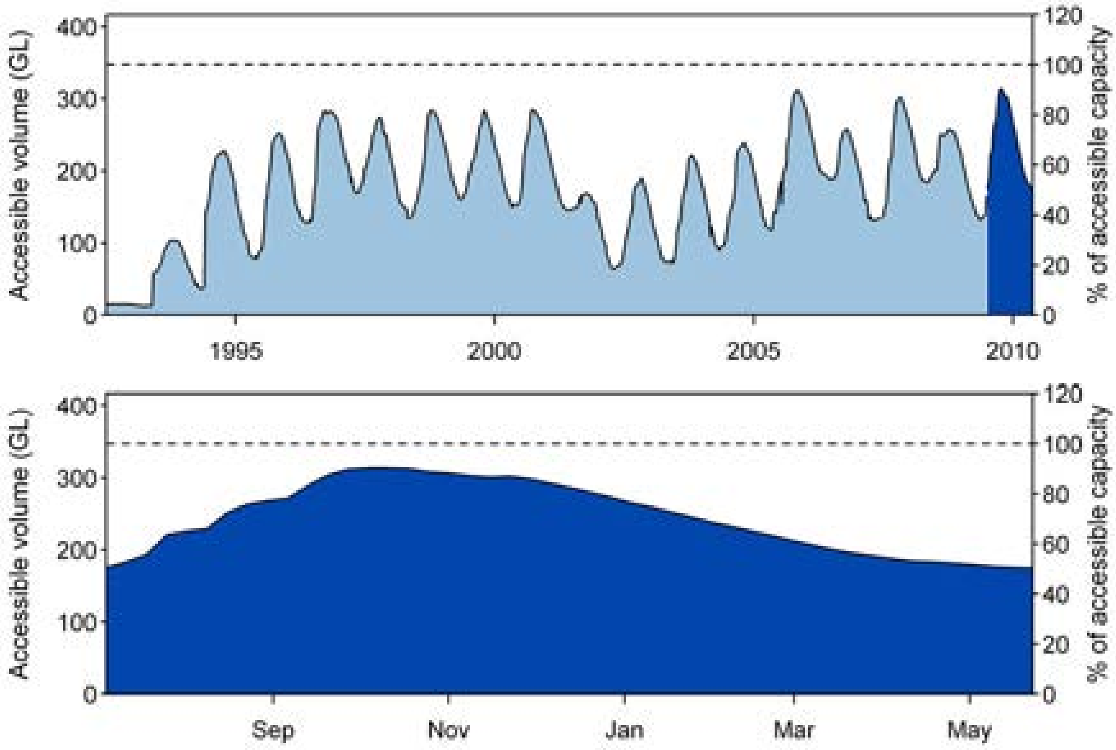


Figure 10-32. Combined water storage volumes available at the seven storages supplying the Harvey Water Irrigation Area since 1993 (top) and during 2009–10 (bottom)

11. Pilbara–Gascoyne

11. Pilbara–Gascoyne

11.1 Introduction

This chapter examines water resources in the Pilbara–Gascoyne region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level.

Details for selected rivers, wetlands, groundwater, urban areas and agriculture are not addressed. At the time of writing, suitable quality controlled and assured information was not identified in the Australian Water Resources Information System (Bureau of Meteorology 2011a).

The chapter begins with an overview of key data and information on water flows in the region in recent times followed by a description of the region.

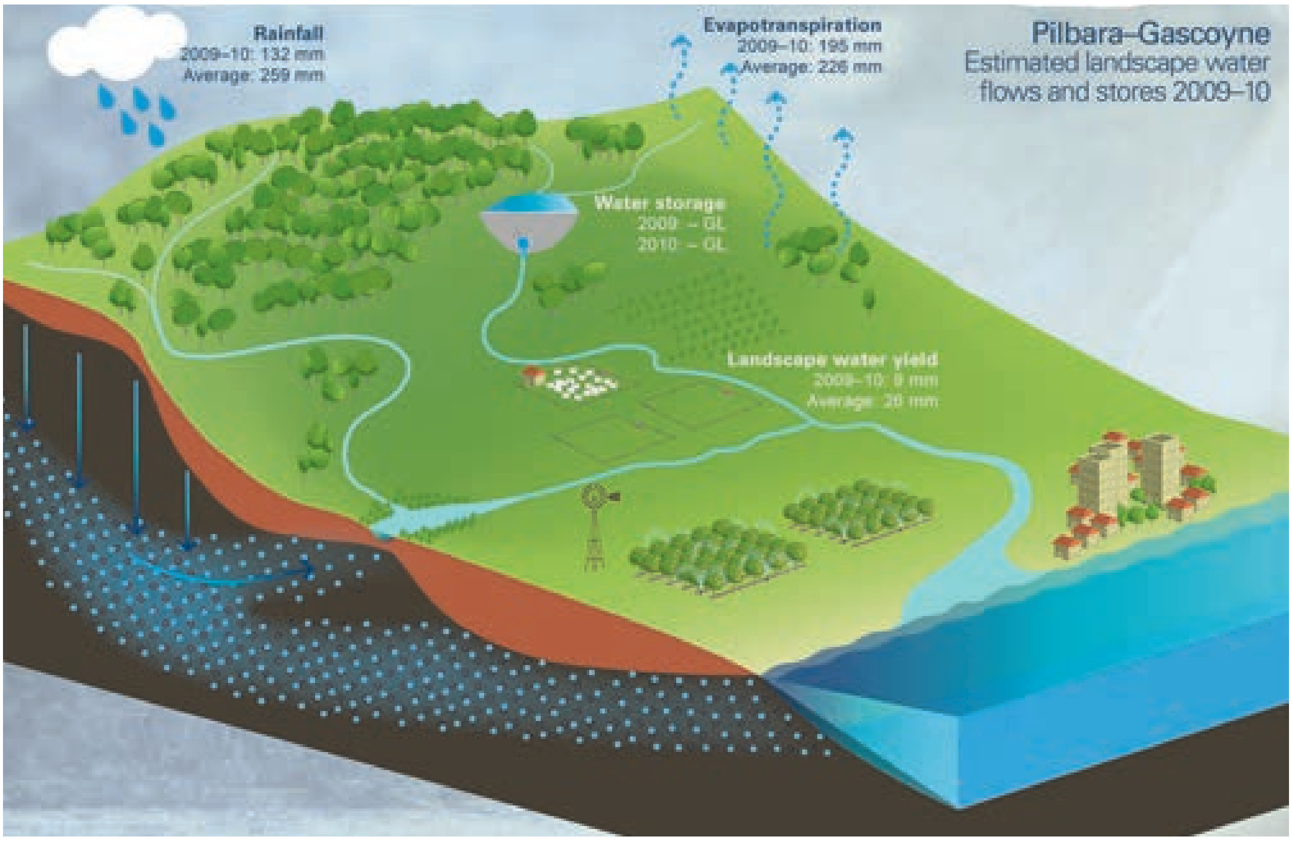


Figure 11-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) for the Pilbara–Gascoyne region

11.2 Key data and information

Figure 11-1 presents the 2009–10 annual landscape water flows in the Pilbara–Gascoyne region (no information is available for major storages in the region). Total annual rainfall for the Pilbara–Gascoyne region was the lowest in Australia for 2009–10 and the limited water availability also constrained evapotranspiration totals to below average levels (see Table 11-1). These dry conditions resulted in very low regional landscape water yield[1] for the year.

Table 11-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 11-1. Key information on water flows in the Pilbara–Gascoyne region[2]

Landscape water balance	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	132 mm	-49%	5	601 mm (1998–99)	132 mm (2009–10)
Evapotranspiration	195 mm	-14%	19	340 mm (1998–99)	176 mm (1990–91)
Landscape water yield	9 mm	-66%	12	149 mm (1999–2000)	9 mm (2009–10)

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

11.3 Description of region

The Pilbara–Gascoyne region is the central western corner of Western Australia. It covers a long coastal section and a dry inland section bordered by the western plateau. The region covers about 478,000 km^2 of land area. River basin areas vary in size from 18,000 km^2 to 91,000 km^2.

The region has an arid subtropical climate, with a temperate Mediterranean climate predominantly occurring in the south. Rainfall is generally low and variable. Irregular monsoonal rain occurs in the north.

The area encompasses two major plateaus: the Pilbara plateau in the north and the Gascoyne plateau in the southeast. The western part of the region includes coastal and inland dunes and alluvial floodplains, with some low relief in the southwest. Seasonal or persistent aridity has resulted in low vegetation cover and intermittent river systems.

The generally flat landscapes ensure high rainfall infiltration rates. Rivers are sparse and drain internally or towards the Indian Ocean. Greenough and Murchison rivers in the southern basin generate substantial amounts of flow at high rainfall periods.

The region does not contain any Ramsar wetland sites. Surface water storages are generally lacking and irrigated agriculture is only practised in the southern coastal part of the region, at a local scale.

The region has a population of approximately 75,000. The main city is Geraldton with a population of 27,000. Other main towns are Karratha, Port Hedland (including South Hedland) and Carnarvon.

Most population centres in the region are supplied by groundwater with the occasional small storages filled by both surface and groundwater. Water supply in the region is provided by the Water Corporation of Western Australia, the same agency supplying water to the South West Coast region, including Perth. Mainly local groundwater sources are used, placing increasing pressure on groundwater resources. As a consequence, the Water Corporation is working towards securing future water resources for the region, including plans for the construction of a seawater desalination plant near Karratha.

The mix of land use in the region is illustrated in Figure 11-2. Most of the region is in a relatively natural state, much of which is used for grazing. Dryland agriculture accounts for approximately three per cent of the land use in the area. Irrigation is limited and intensive land uses such as urban areas account for 0.03 per cent of the area.

The region's watertable aquifers are given in Figure 11-3 (extracted from the Bureau of Meteorology's Interim Groundwater Geodatabase). The hydrogeology of the region is dominated by the large area of outcropping Palaeozoic fractured basement rock of low permeability. The groundwater systems in this rock typically offer restricted low volume groundwater resources. Major groundwater management units within the region include Gascoyne, East Murchison and Pilbara.

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

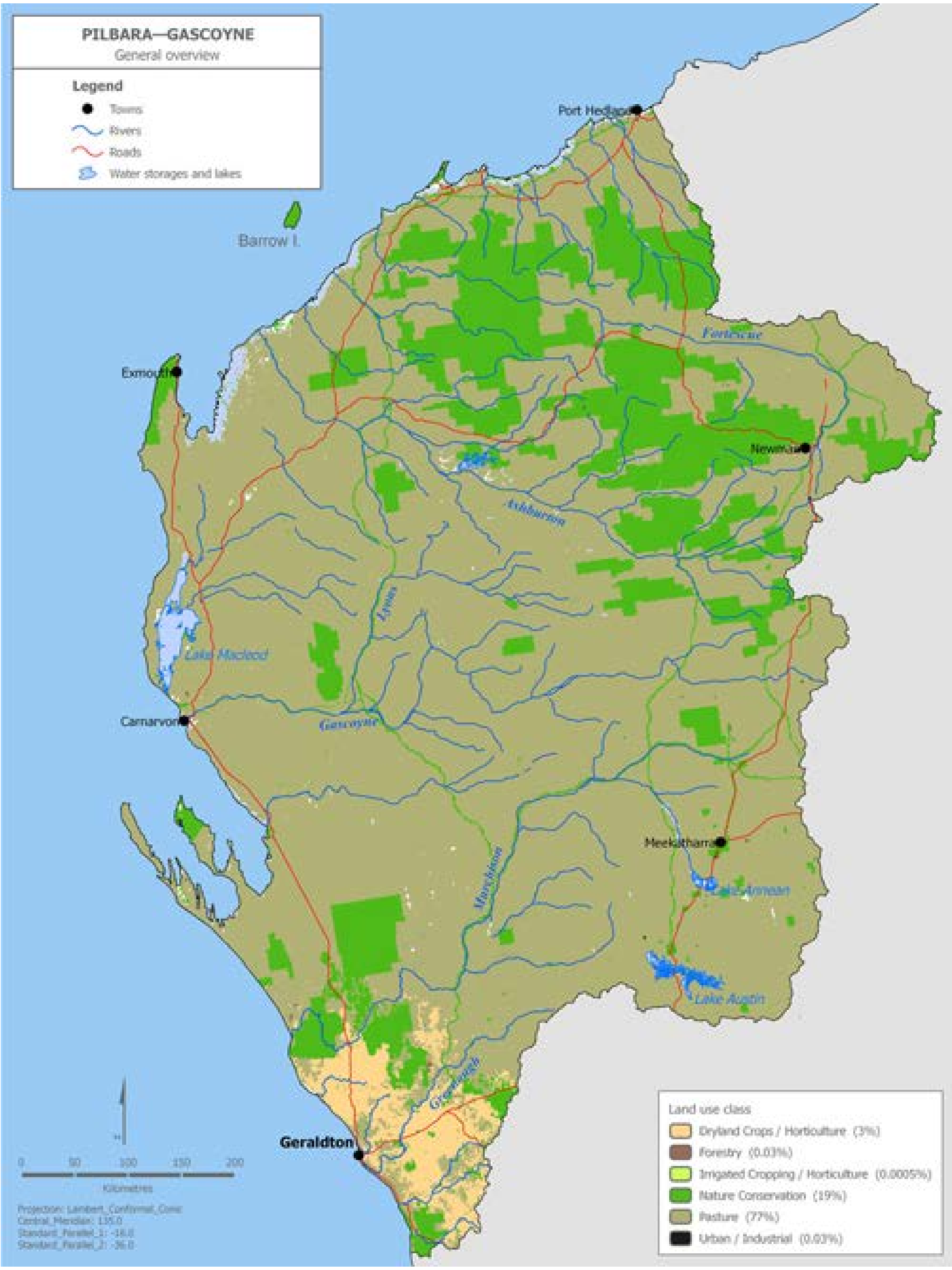


Figure 11-2. Key landscape and hydrological features of the Pilbara–Gascoyne region (land use classes based on Bureau of Rural Sciences 2006)

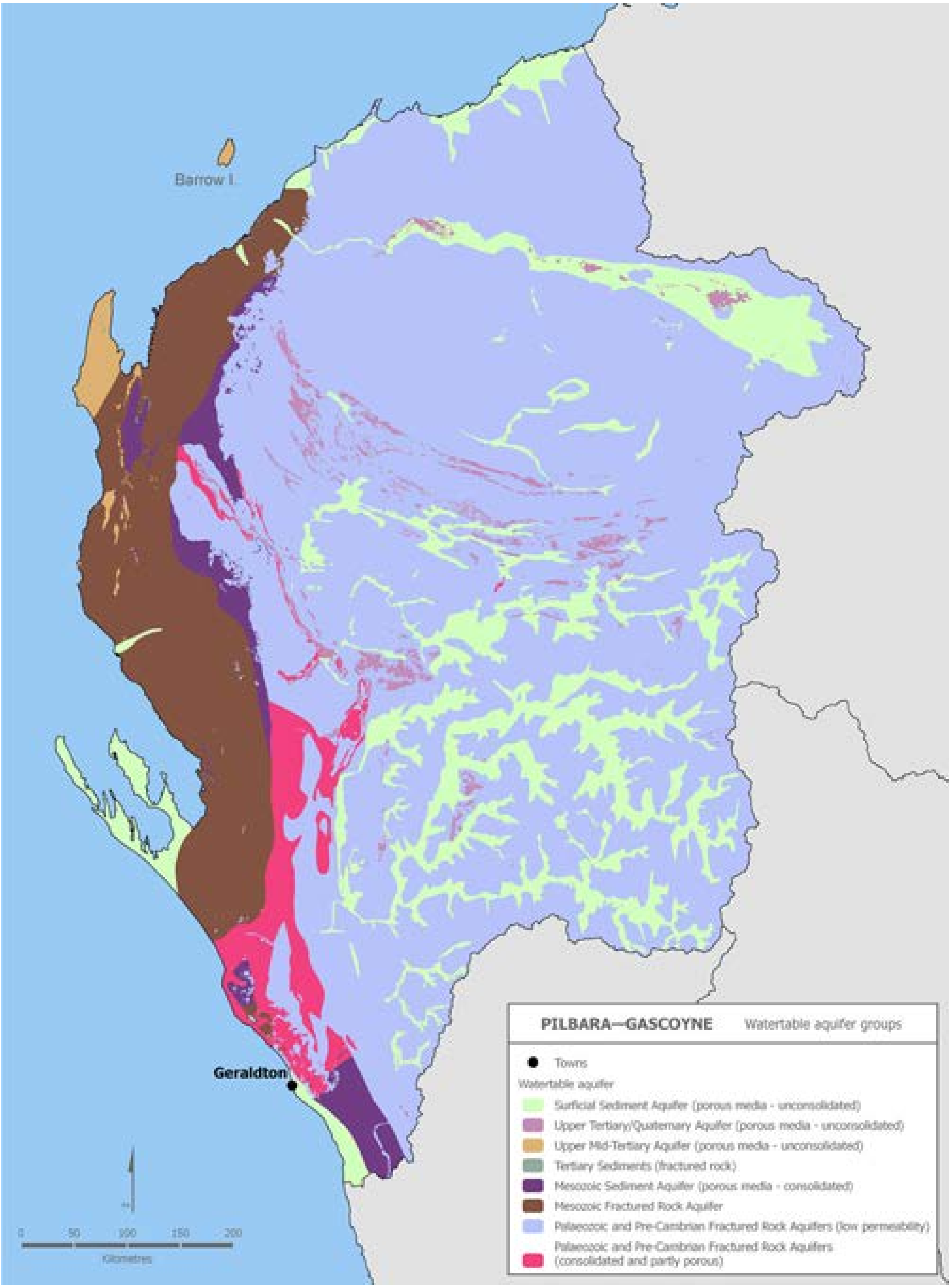


Figure 11-3. Watertable aquifer groups in the Pilbara–Gascoyne region (Bureau of Meteorology 2011e)

11.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 11-4 shows that for 2009–10, the Pilbara–Gascoyne region experienced low monthly rainfall throughout the year, particularly relative to the historically higher rainfall months from January to June. The region has a dominantly arid climate characterised by low rainfall throughout the year. Even in this context, 2009–10 was exceptionally dry, representing the fifth lowest annual total in the long-term record (July 1911 to June 2010) and the lowest total in the past 30 years (see Figure 11-6 [a]). November 2009 was the only month to receive notably above average rainfall.

Monthly evapotranspiration was constrained to below the historic normal range through much of 2009–10 due to low monthly rainfall and limited water availability. Most months experienced higher evapotranspiration than rainfall. Above normal evapotranspiration was experienced in November and December 2009 following relatively high November rainfall.

Low monthly rainfall constrained regional landscape water yield to very low levels throughout 2009–10, generating almost no landscape water yield responses through the year. Total water yield for 2009–10 was the lowest annual total in the past 30 years (see Figure 11-12).

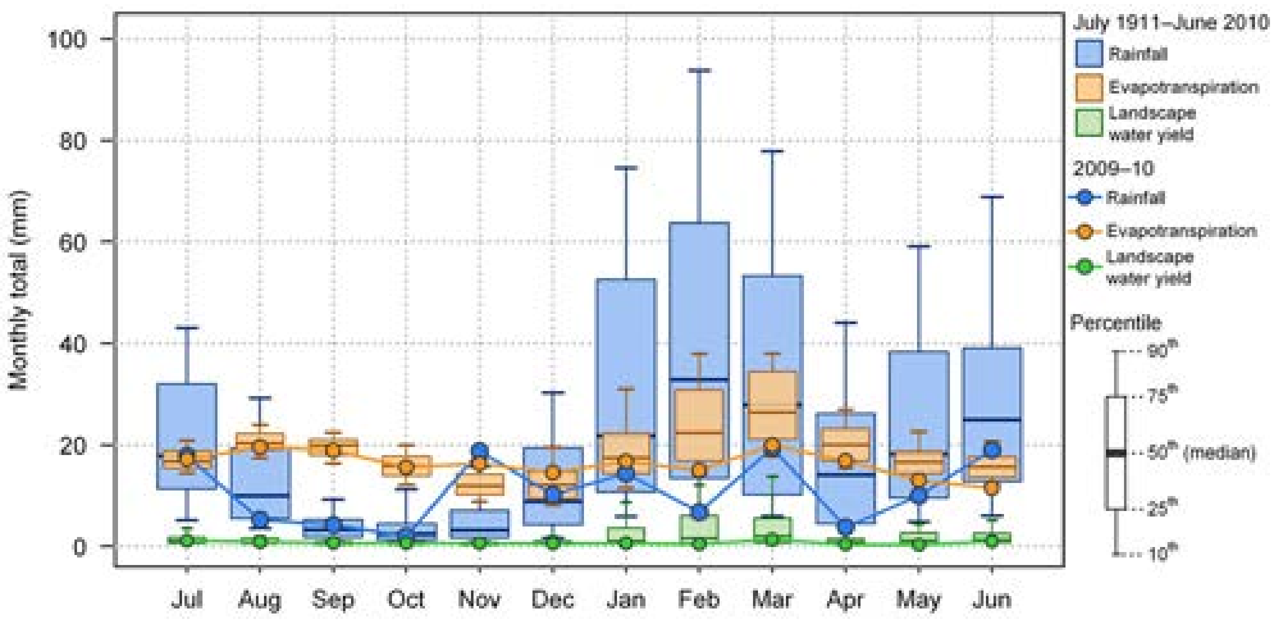


Figure 11-4. Monthly landscape water flows for Pilbara–Gascoyne region in 2009–10 compared with the long-term record (July 1911 to June 2010)

11.4.1 Rainfall

Rainfall for the Pilbara–Gascoyne region for 2009–10 was estimated to be 132 mm, which is 49 per cent below the region's long-term (July 1911 to June 2010) average of 259 mm. Figure 11-5 (a) shows that during 2009–10, the majority of the region received a relatively even distribution of low annual rainfall with the highest rainfall in the far south of the region. Rainfall deciles for 2009–10, shown in Figure 11-5 (b), indicate annual rainfall was below average and very much below average across the majority of the region.

Figure 11-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 132 mm (2009–10) to 601 mm (1998–99). The annual average for the period was 285 mm. The diagram clearly shows that 2009–10 experienced the lowest total rainfall in the past 30 years.

Regional rainfall shows a high level of interannual variability with a number of years, including 1998–99, 1999–2000 and 2005–06, experiencing extremely high annual totals relative to the 30-year average.

Summer (November–April) and winter (May–October) rainfall time-series are presented in Figure 11-6 (b) to provide an indication of patterns, trends and variability in seasonal rainfall components over the 30-year period. The graph indicates that for the first half of the 30-year period, annual rainfall was relatively evenly distributed through the year with slightly higher summer rainfall than during the winter period. High rainfall years experienced since the mid-1990s are reflected in noticeable increases in summer rainfall, whereas there was a reduction in the winter period averages through the 2000s.

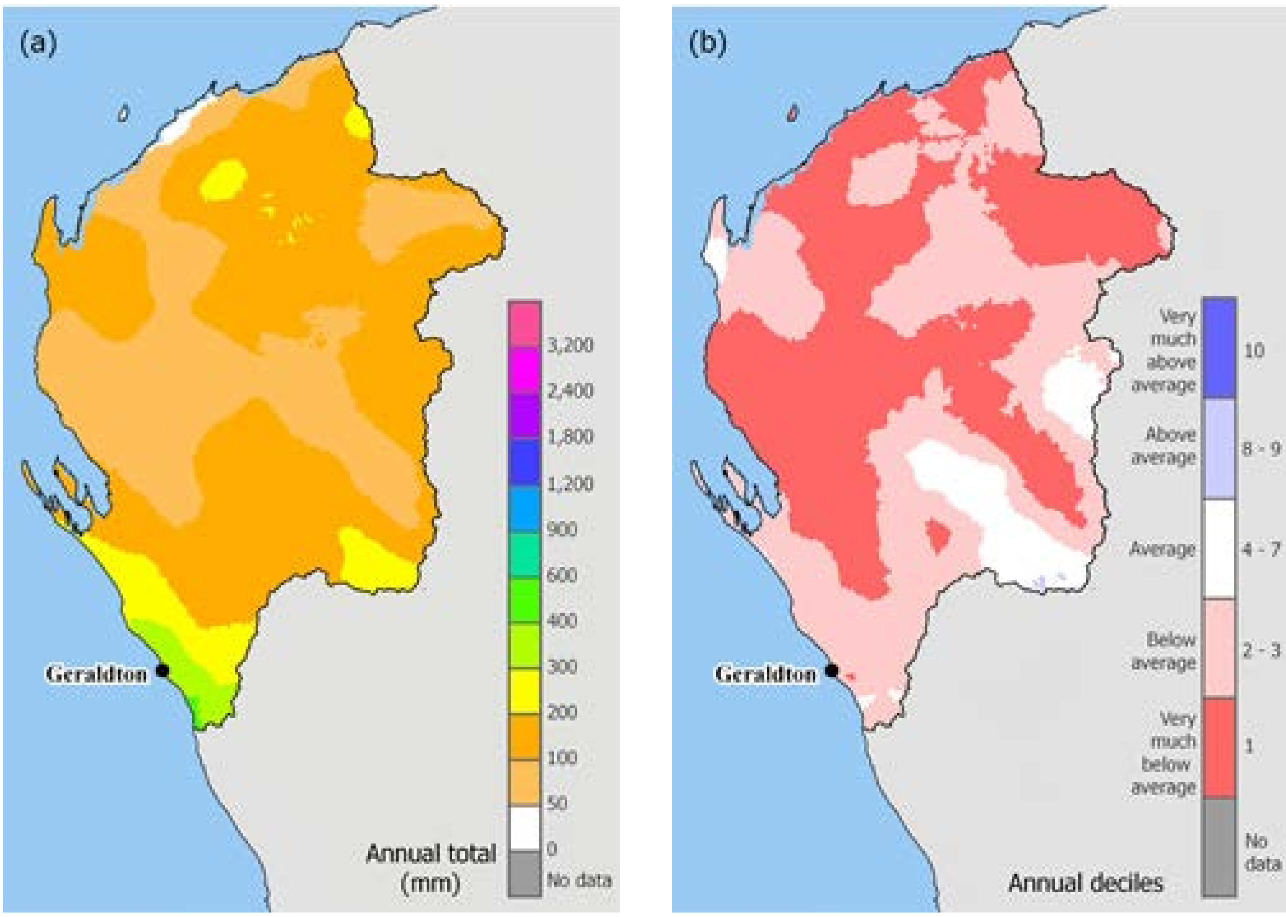


Figure 11-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Pilbara–Gascoyne region

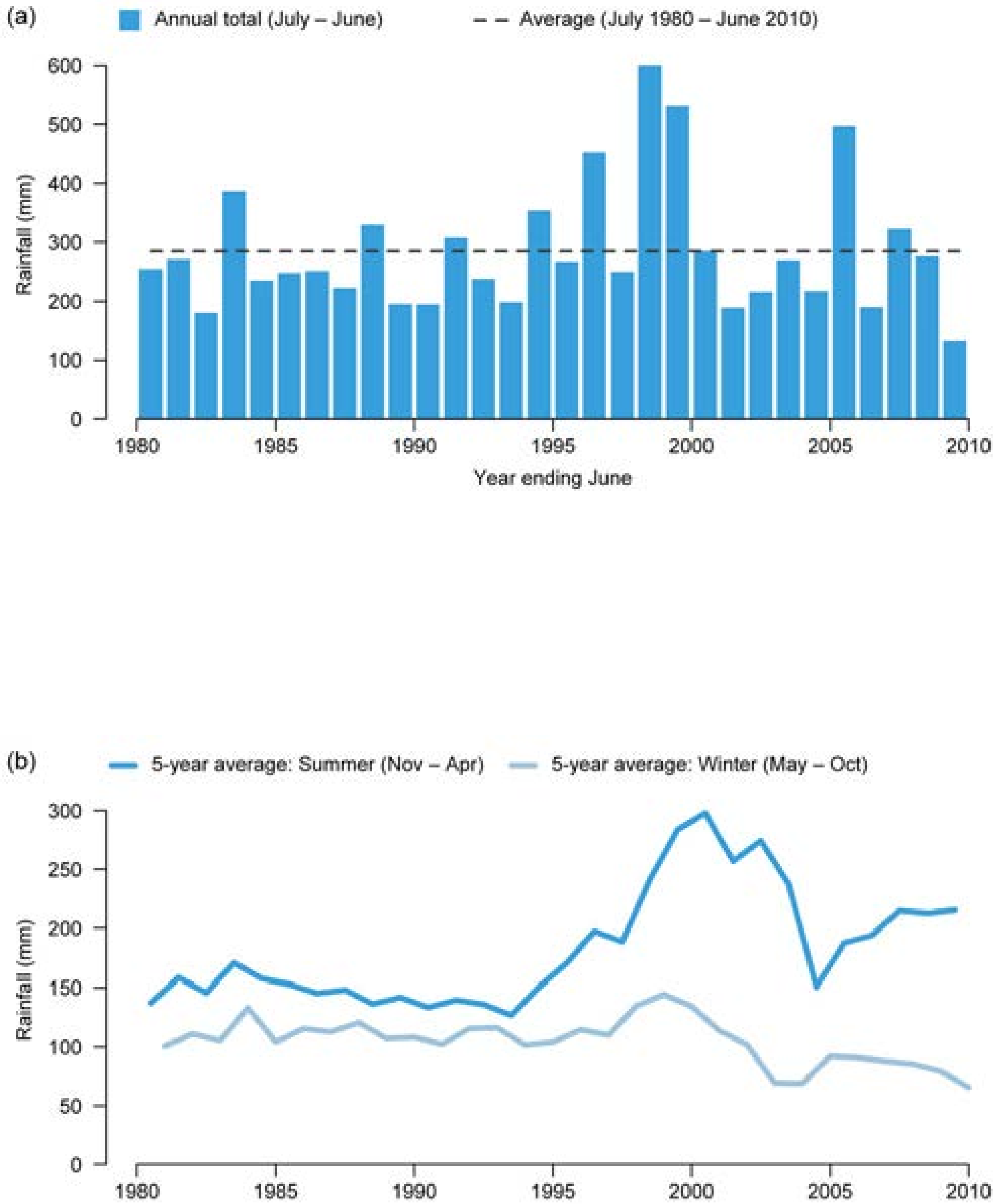
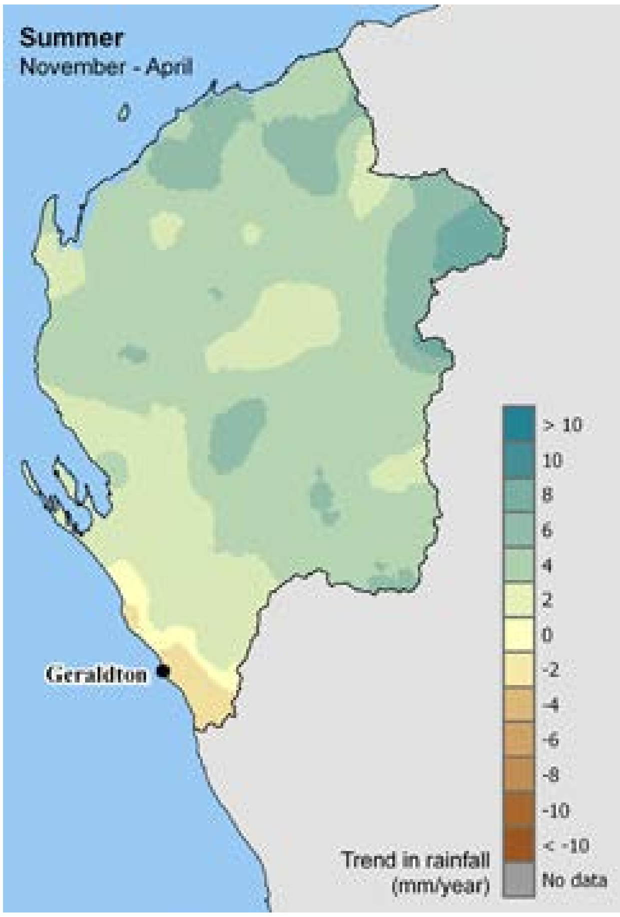


Figure 11-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Pilbara–Gascoyne region

11.4.1 Rainfall (continued)

Figure 11-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis indicates that over the past 30 years, there were contrasting changes between summer and winter rainfall. The summer period analysis shows generally positive trends in rainfall across much of the region with the largest increases to the far north and east of the region. Southern areas, around Geraldton, indicate very slight decreases in summer rainfall. The winter period analysis shows a general reduction in rainfall across almost the entire region, which is more noticeable to the south and through the centre of the region.



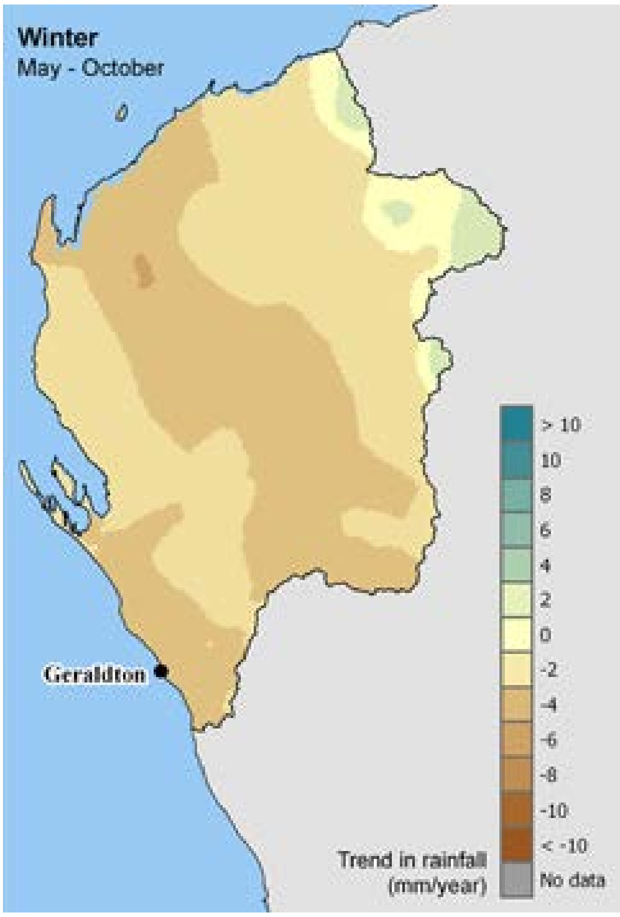


Figure 11-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Pilbara–Gascoyne region. The statistical significance of these trends is often very low

11.4.2 Evapotranspiration

Evapotranspiration for the Pilbara–Gascoyne region for 2009–10 was estimated to be 195 mm, which is 14 per cent below the region's long-term (July 1911 to June 2010) average of 226 mm. The distribution of annual evapotranspiration for 2009–10, shown in Figure 11-8 (a), is closely linked to the distribution of annual rainfall (see Figure 11-5). Highest annual totals are observed in areas receiving slightly higher rainfall to the far south and north. The majority of the region experienced low levels of annual evapotranspiration.

Evapotranspiration deciles for 2009–10, shown in Figure 11-8 (b), indicate that evapotranspiration for the year was below average and very much below average across much of the region due to limited water availability, particularly over the western half. The east of the region generally experienced average conditions.

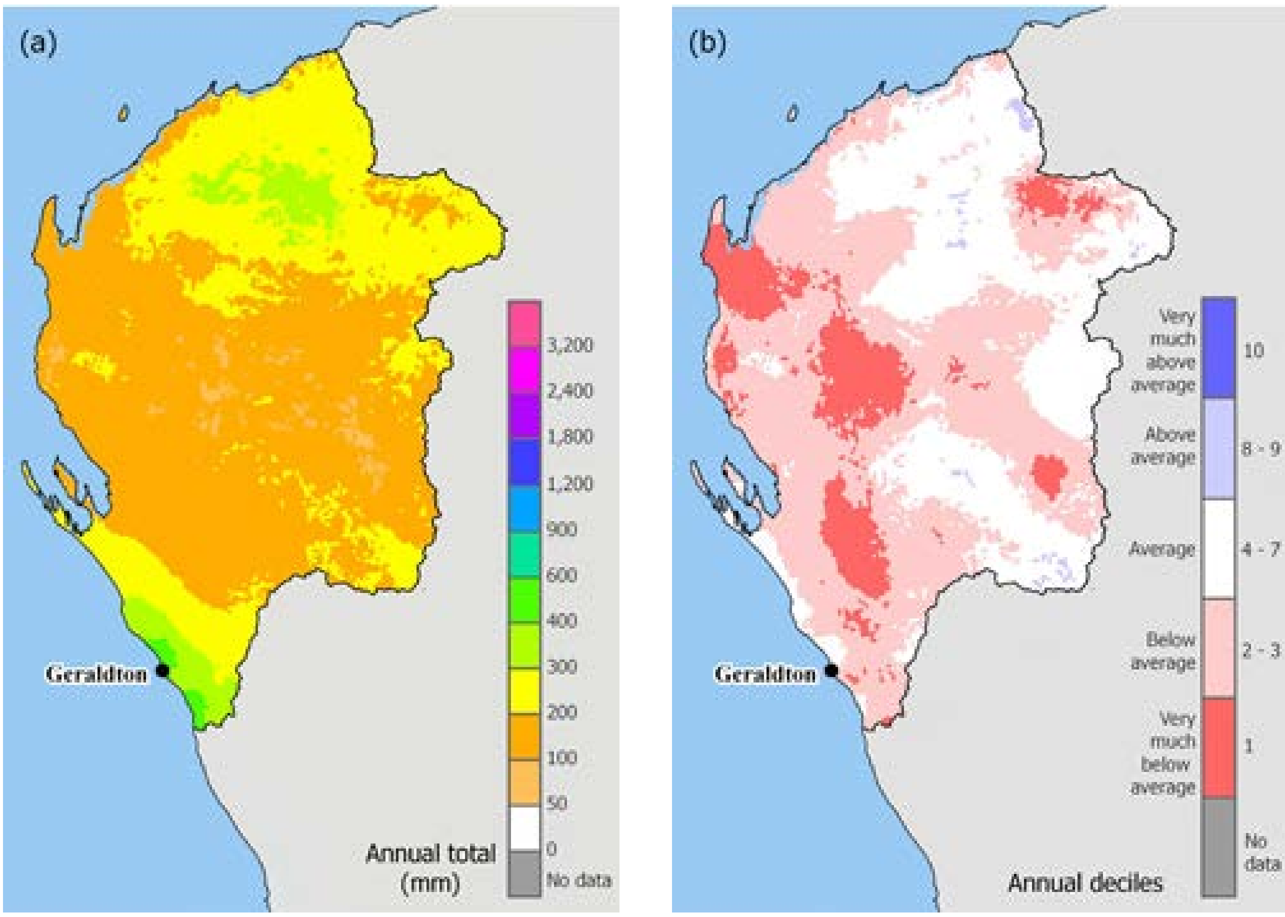


Figure 11-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Pilbara–Gascoyne region

11.4.2 Evapotranspiration (continued)

Figure 11-9 (a) shows annual evapotranspiration for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, evapotranspiration ranged from 176 mm (1990–91) to 340 mm (1998–99). The annual average for this period was 240 mm. The plot shows that evapotranspiration for 2009–10 was constrained below the 30-year average following two years of slightly above average annual evapotranspiration.

Summer (November–April) and winter (May–October) evapotranspiration time-series are presented in Figure 11-9 (b) to provide an indication of patterns, trends and variability in seasonal evapotranspiration over the 30-year period. Summer and winter period evapotranspiration is shown to be relatively equal throughout the first half of the 30-year period with the summer averages demonstrating increased variability through the second half of the period. These increases in the summer period averages and variability are closely linked to observed increases in summer rainfall averages (Figure 11-6 [b]). Winter period evapotranspiration remained relatively consistent over the 30-year period.

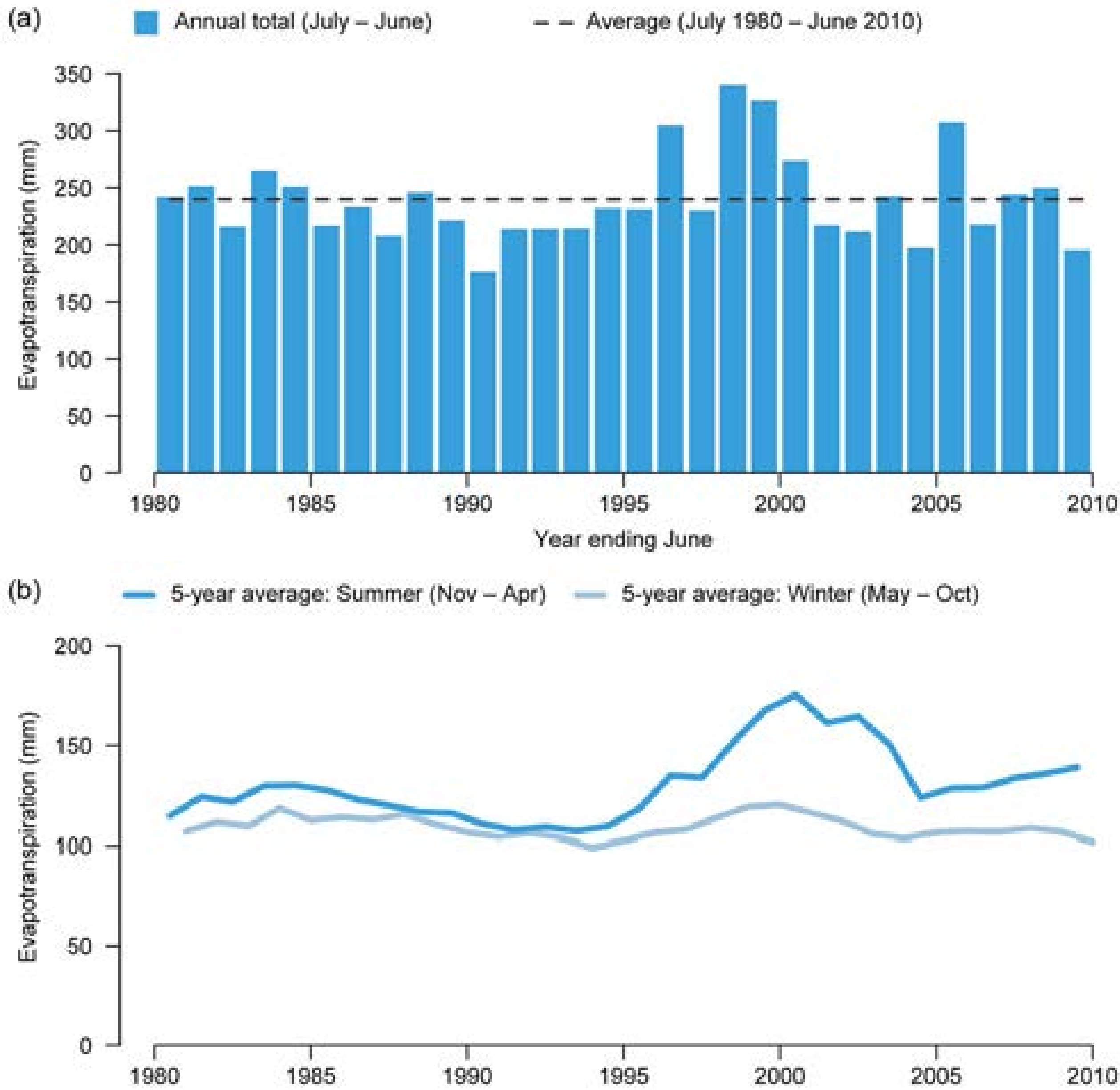


Figure 11-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Pilbara–Gascoyne region

11.4.2 Evapotranspiration (continued)

Figure 11-10 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The analysis indicates a slight increase in summer period evapotranspiration across almost the entire region. The winter period shows slight reductions in evapotranspiration across the majority of the region over the 30-year period with slight increases in limited areas to the northeast.

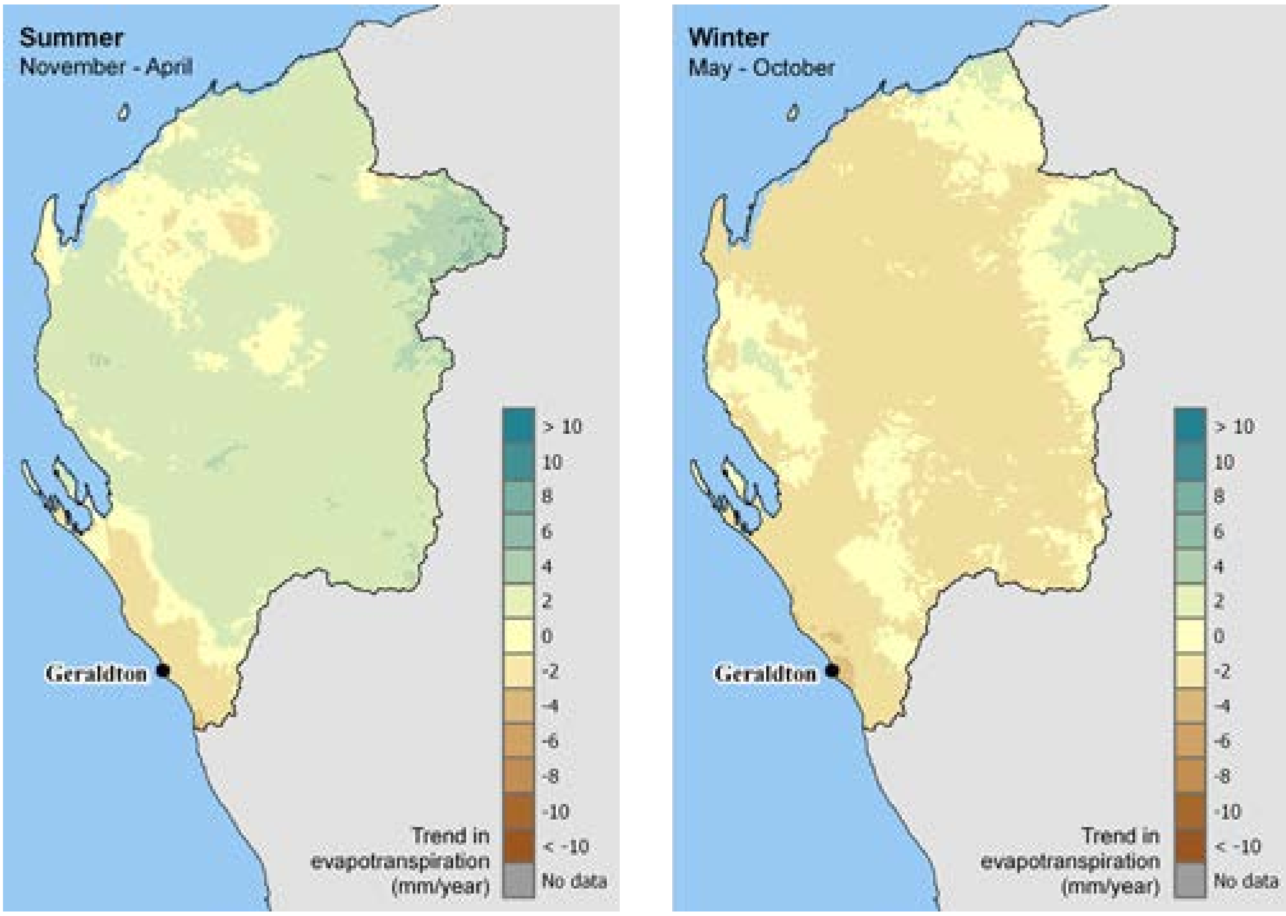


Figure 11-10. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration trends over 30 years (November 1980 to October 2010) for the Pilbara–Gascoyne region. The statistical significance of these trends is often very low.

11.4.3 Landscape water yield

Landscape water yield for the Pilbara–Gascoyne region for 2009–10 was estimated to be 9 mm, which is 66 per cent below the region's long-term (July 1911 to June 2010) average of 26 mm. Figure 11-11 (a) shows the landscape water yield for 2009–10 was very low (less than 50 mm) across almost the entire region.

Landscape water yield deciles for 2009–10, shown in Figure 11-11 (b), indicate below average or very much below average annual landscape water yields for across much of the region. Average and above average values are identified across very limited areas to the southeast and far northwest of the region.

Figure 11-12 (a) shows annual landscape water yield for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 9 mm (2009–10) to 149 mm (1999–2000). The annual average for this period was 37 mm. The data clearly show the extremely low annual total landscape water yield that was experienced in 2009–10, representing the lowest total in the 30 year period. The response of landscape water yield to high annual rainfall at the end of the 1990s is reflected in annual totals very much higher than the 30-year average.

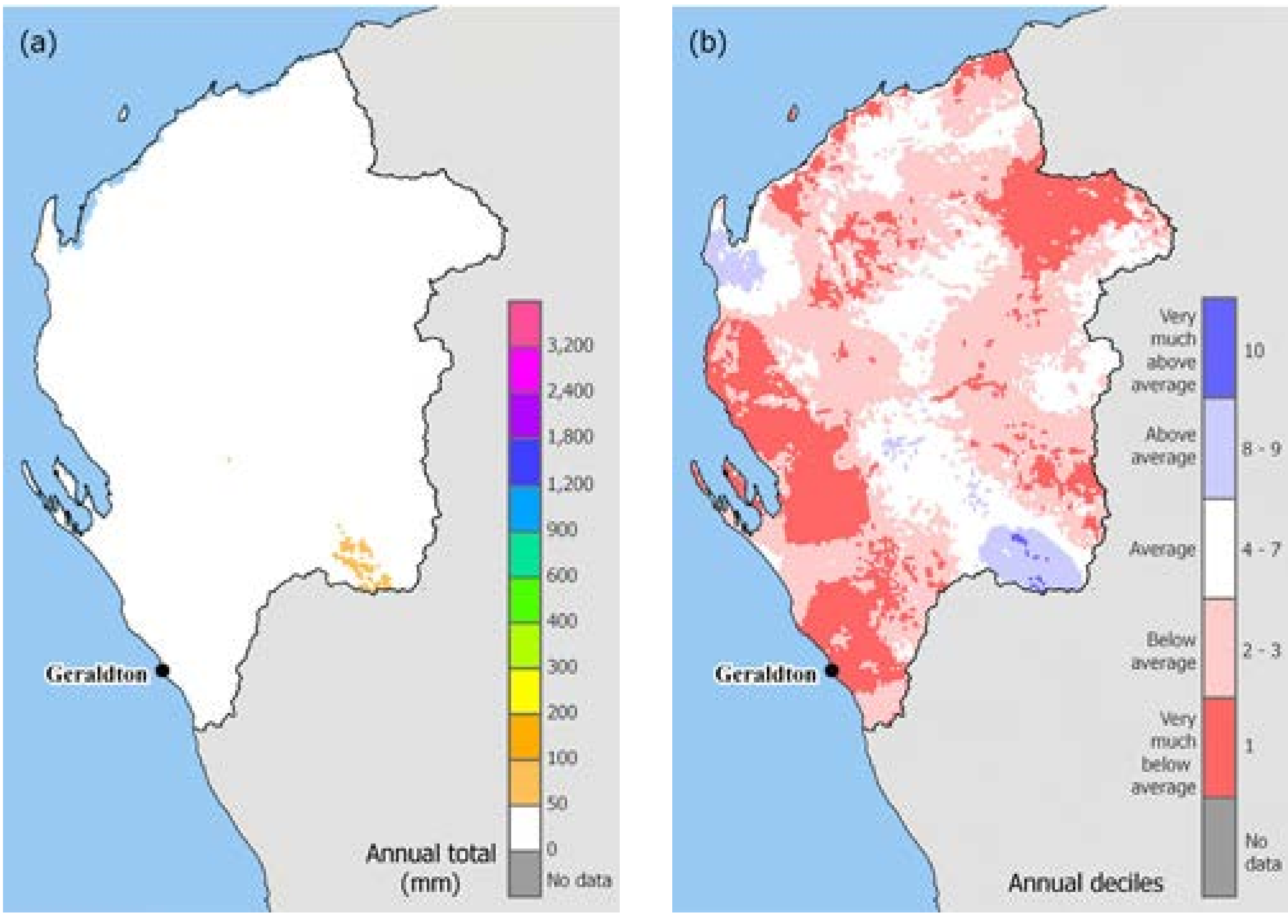


Figure 11-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Pilbara–Gascoyne region

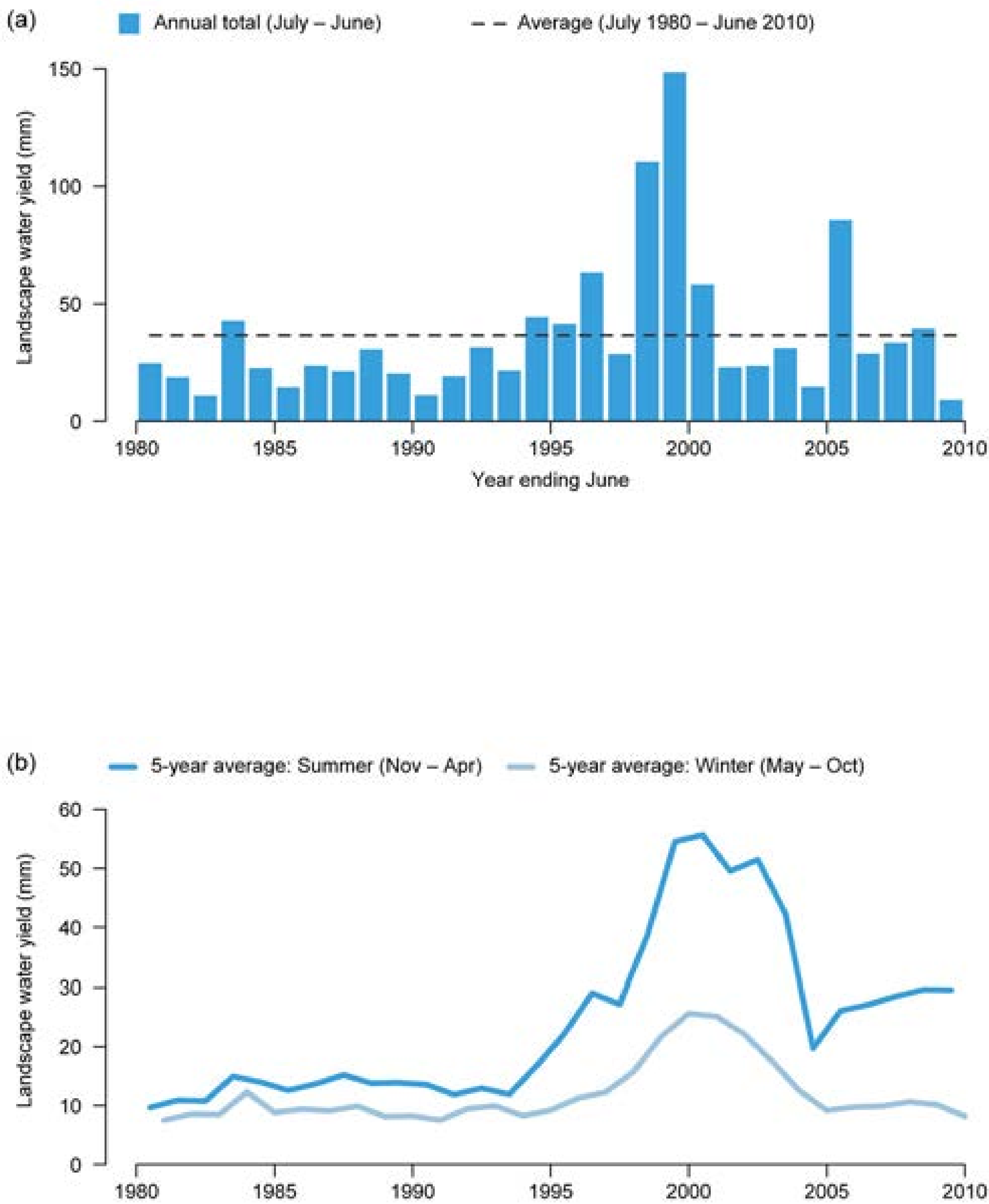


Figure 11-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Pilbara–Gascoyne region

11.4.3 Landscape water yield (continued)

Summer (November–April) and winter (May–October) landscape water yield time-series are presented in Figure 11-12 (b) to provide an indication of patterns, trends and variability in seasonal landscape water yield over the 30-year period. The data show a consistent seasonal pattern during the first half of the 30-year period with very little variability in the averages of both seasonal periods. The extremely high landscape water yield years at the end of the 1990s are reflected in increases in both the summer and winter season averages. The summer period shows greater increases compared to the winter period and remained relatively high through to the end of the period.

Figure 11-13 provides a spatial representation of trends in summer (November–April) and winter (May–October) landscape water yield throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period shows slight increases in landscape water yield across much of the region, with slightly stronger increases identified across northern areas. The greater increases in summer period landscape water yield are reflected in the five-year moving averages shown in Figure 11-12 (b). The winter period analysis does not show clearly defined trends for the region as a whole over the 30-year period. There is a small increasing trend in the northeast and a small decreasing trend in the central-north.

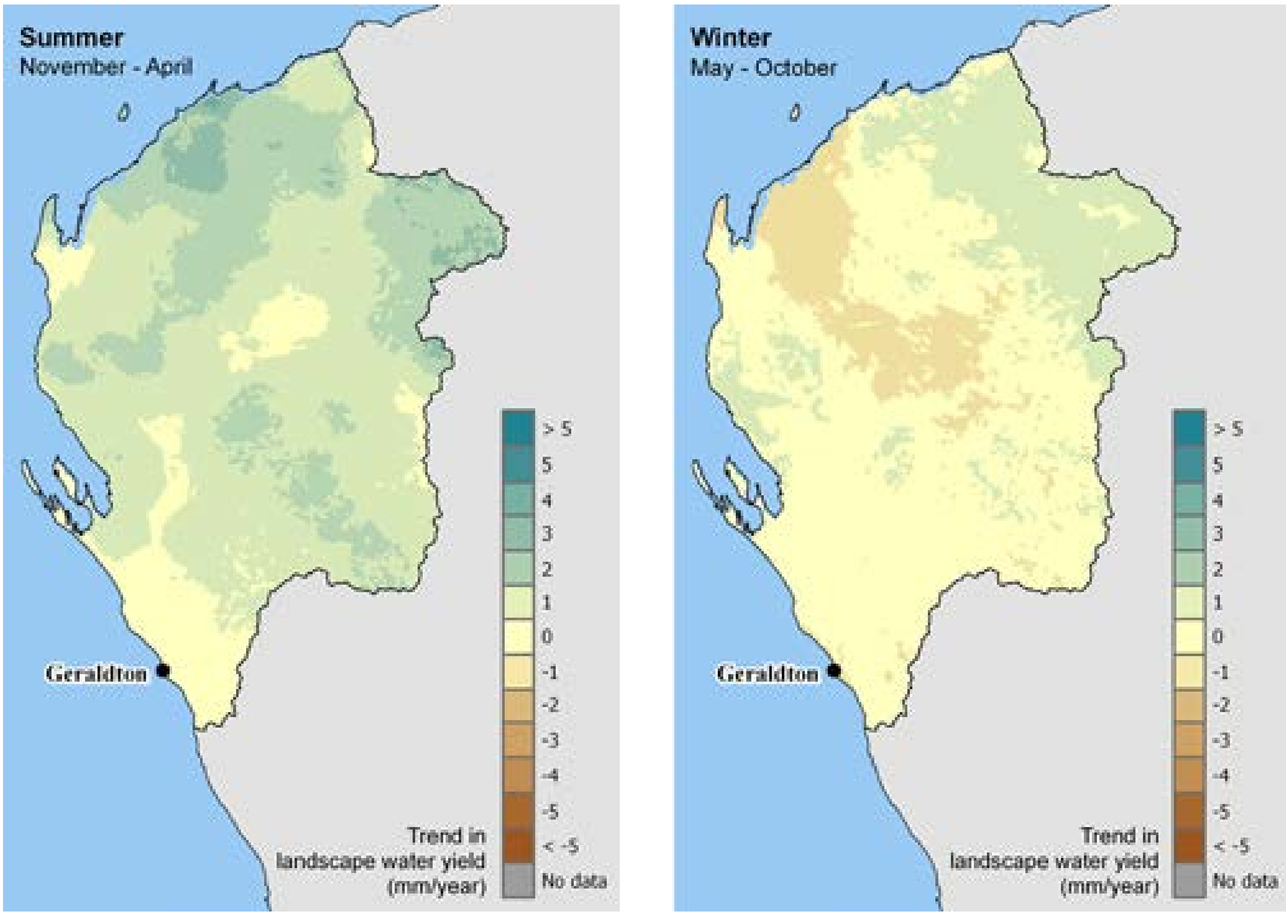


Figure 11-13. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Pilbara–Gascoyne region. The statistical significance of these trends is often very low

12. North Western Plateau

12. North Western Plateau

12.1 Introduction

This chapter examines water resources in the North Western Plateau region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level.

Details for selected rivers, wetlands, groundwater, urban areas and agriculture are not addressed. At the time of writing, suitable quality controlled and assured information was not identified in the Australian Water Resources Information System (Bureau of Meteorology 2011a).

The chapter begins with an overview of key data and information on water flows in the region in recent times followed by a description of the region.

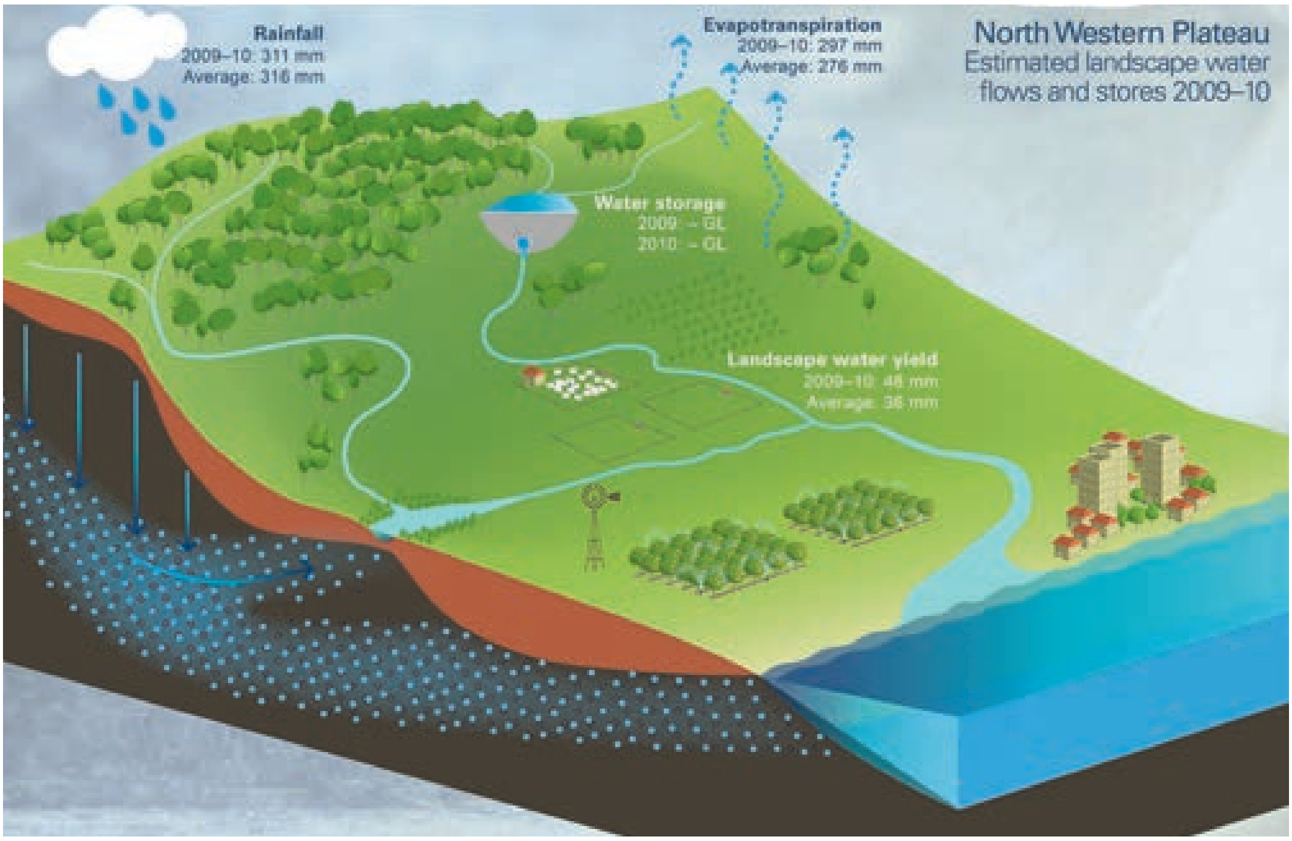


Figure 12-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) for the North Western Plateau region

12.2 Key data and information

Figure 12-1 presents the 2009–10 annual landscape water flows in the North Western Plateau region (no information is available for major storages in the region). Only the most western and northern parts of the region were assessed due to model data limitations in the central Plateau that prevent a comprehensive assessment of regional totals. Hence, the regional totals given in Figure 12-1 (and Table 12-1) should be treated with caution. Regional rainfall and evapotranspiration totals for 2009–10 were approximately average. Very high rainfall in December 2009 generated a significant response in modelled landscape water yield[1] totals, which contributed greatly to the above average annual total.

Table 12-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 12-1. Key information on water flows in the North Western Plateau region[2]

Landscape water balance	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	311 mm	-1%	52	782 mm (1999–2000)	177 mm (1989–90)
Evapotranspiration	297 mm	+7%	65	442 mm (1999–2000)	222 mm (1990–91)
Landscape water yield	48 mm	+35%	76	199 mm (1999–2000)	8 mm (1989–90)

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

12.3 Description of region

The North Western Plateau region is located in northwest Australia and includes major parts of the Great Sandy and Gibson deserts. The region covers 716,000 km^2 of land area and only has some limited surface water resources present in the northern part of the region. The climate is very arid with the northern part effected by erratic monsoonal rainfall in summer.

The coastline consists of tide-dominated strand plains and tidal creeks. Some dry lakes are scattered over the region, but aeolian landforms including dunes and sand plains dominate the landscape.

The region is home to the Eighty Mile Beach Ramsar coastal wetland site. Here, large tidal mudflats attract numerous migratory waders in spring. Other significant wetlands include springs in the hinterland that support unusual vegetation types.

Apart from some mining towns with variable populations and some small settlements along the Great Northern Highway, there are no significant population centres located in the region. Water supply is generally through rainwater collection and local groundwater bores. There are no reported major surface water storages or irrigated agriculture areas in the region.

The mix of land use in the region is illustrated in Figure 12-2. Most of the region is in a relatively natural state and 77 per cent is associated with nature conservation. Of the region, 22 per cent is used for grazing, along the western and northern boundaries. Irrigated agriculture and urban areas account for less than 0.01 per cent of the area.

The hydrogeology is dominated by the large area of outcropping fractured basement rock in the west and east of the region (Figure 12-3). The associated groundwater systems typically offer restricted low volume water resources. Other important hydrogeological groups are the Mesozoic sediment through the centre of the region and the surficial sediments in-filling paleovalleys in the East Murchison groundwater management unit — these groups are likely to offer more reliable groundwater resources. The major groundwater management units within the region include Canning–Kimberley, East Murchison, Goldfields and Pilbara.

The major watertable aquifers present in the region are given in Figure 12-3 (extracted from the Bureau of Meteorology's Interim Groundwater Geodatabase). Groundwater systems that provide more potential for extraction are labelled as:

- Mesozoic sediment aquifer (porous media – consolidated)
- Surficial sediment aquifer (porous media – unconsolidated).

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

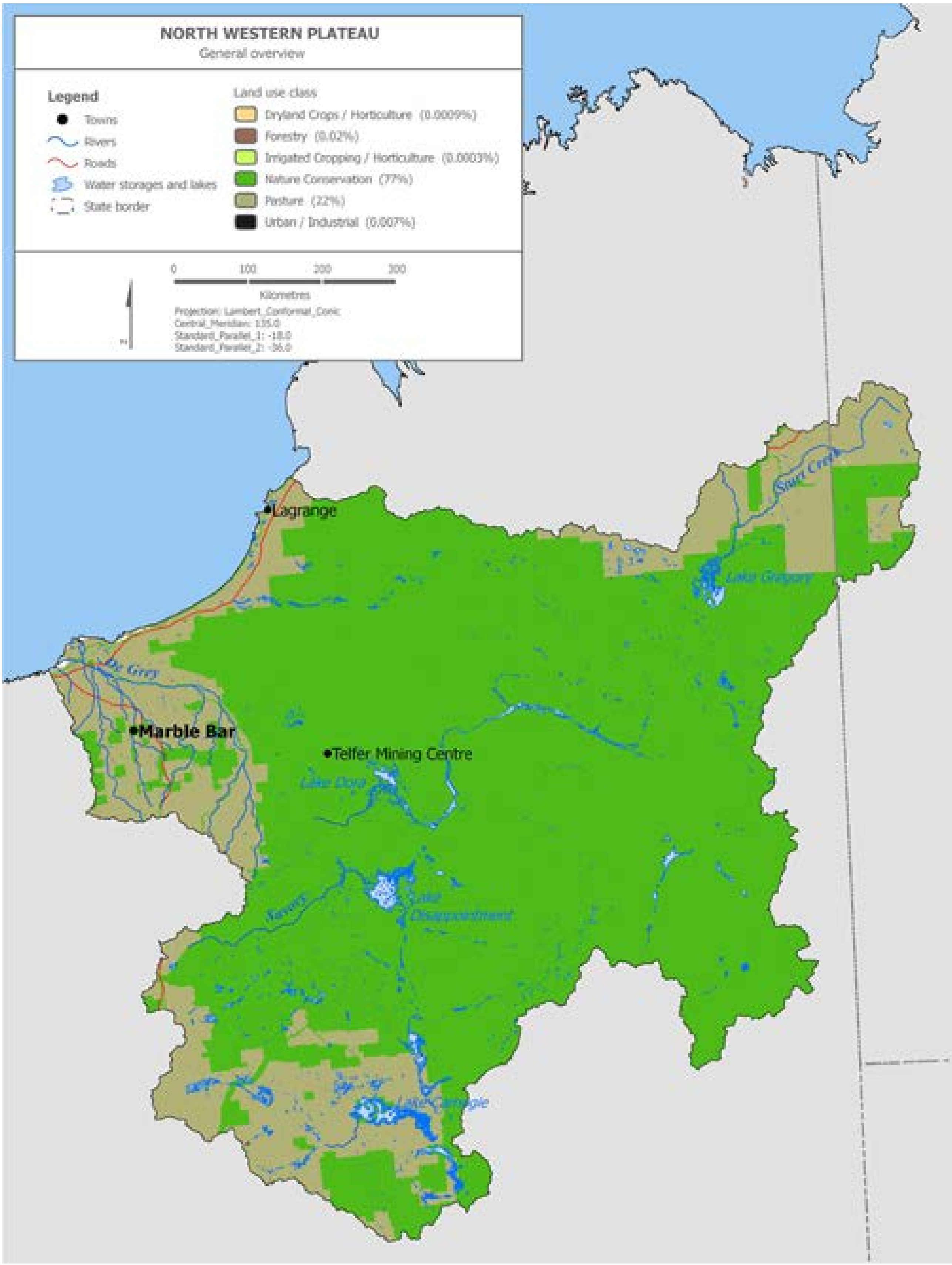


Figure 12-2. Key landscape and hydrological features of the North Western Plateau region (land use classes based on Bureau of Rural Sciences 2006)

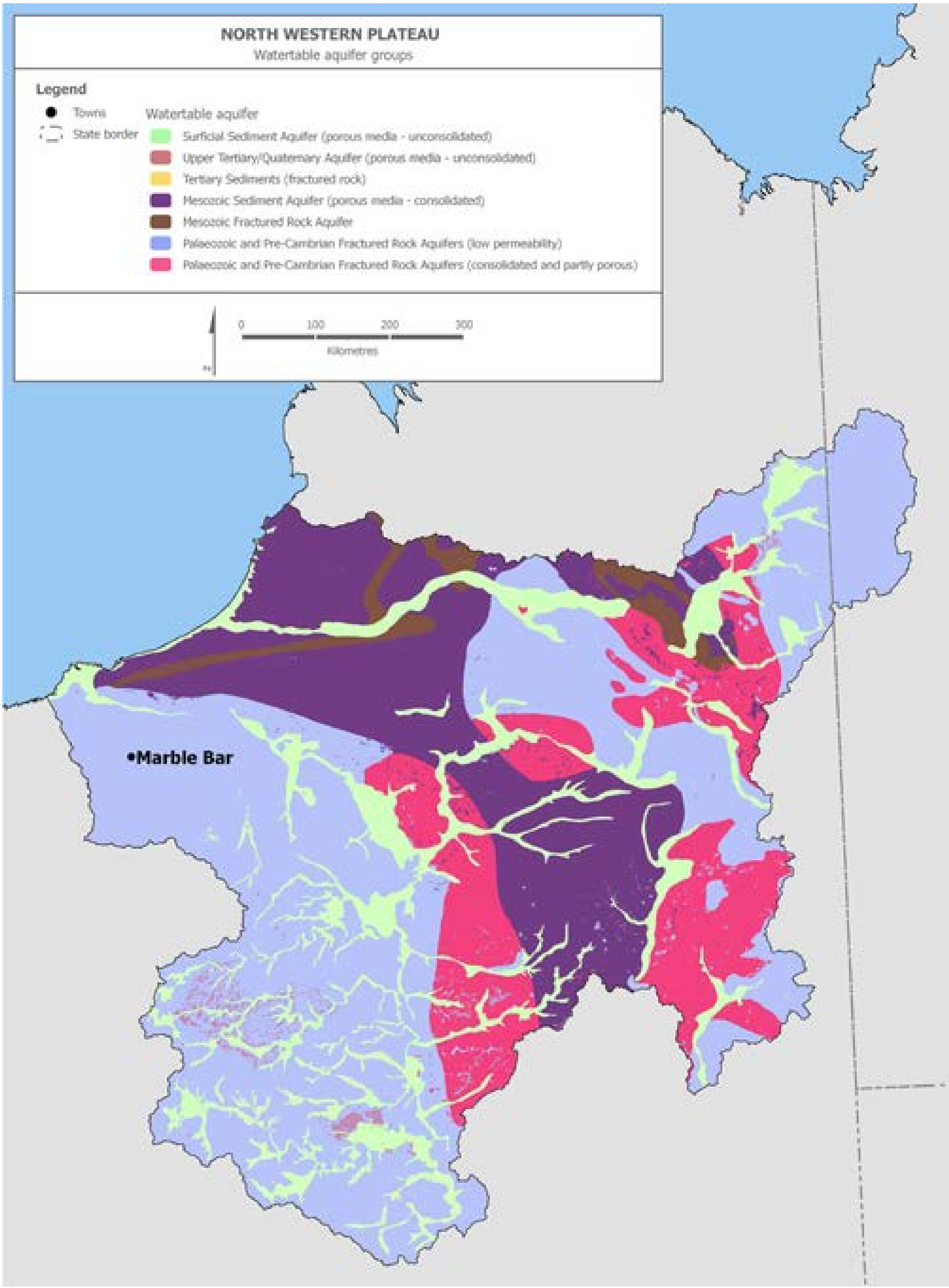


Figure 12-3. Watertable aquifer groups in the North Western Plateau region (Bureau of Meteorology 2011e)

12.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Large areas of the centre and east of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data for these areas. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 12-4 shows that historically the modelled area of the North Western Plateau region has a very seasonal distribution of rainfall. The more tropical north and northeast of the region experiences a marked wet summer and dry winter, whereas the southwest of the region is largely arid with low annual rainfall. During 2009–10, the low rainfall conditions at the beginning of the year gave way to a very high December 2009 rainfall total. Almost a third of the annual rainfall for 2009–10 fell in the month of December. The remainder of the summer through to the end of the year generally experienced normal or lower than normal monthly rainfall. April and especially May 2010 were wetter than normal.

Evapotranspiration in northern Australia is largely constrained by water availability rather than energy, i.e. solar radiation, and therefore exhibits a seasonal pattern closely linked to rainfall. During 2009–10, regional evapotranspiration was higher than normal for December 2009 and January 2010 following the very high levels of rainfall in December.

Modelled landscape water yield for the region shows clear responses to high monthly rainfall, when levels of rainfall significantly exceed evapotranspiration losses, although water yield is generally very low relative to rainfall through much of the year. The very high December 2009 rainfall generated the second highest December modelled landscape water yield in the long-term record (July 1911 to June 2010). The remainder of the year returned to low monthly totals.

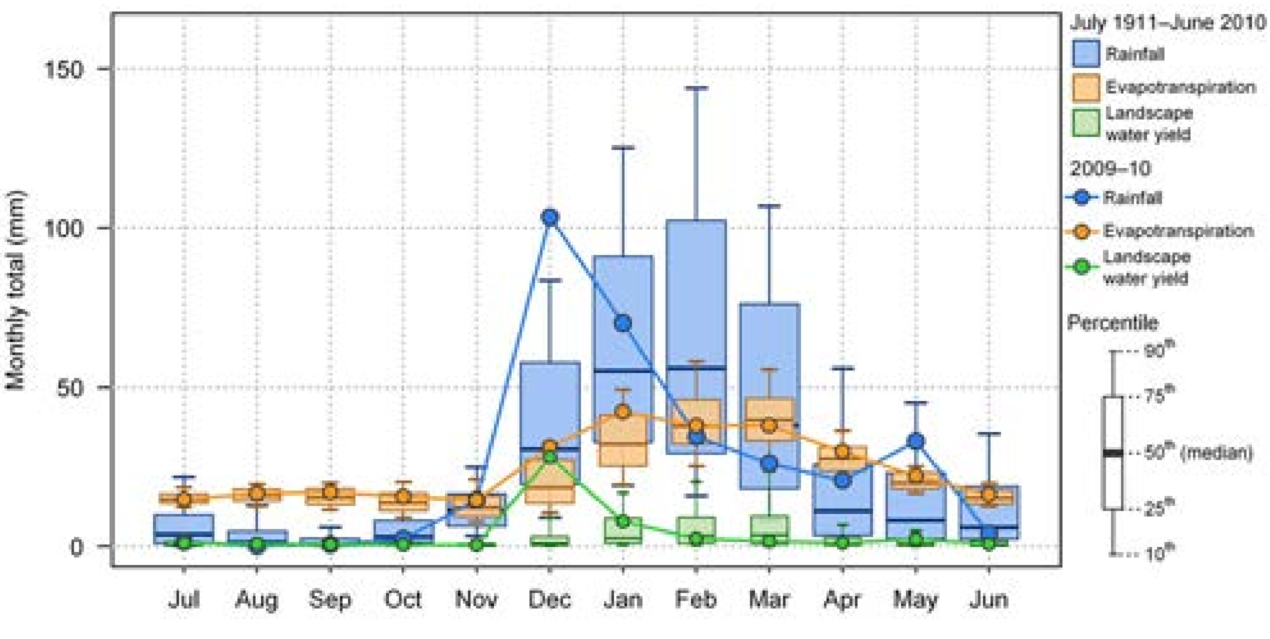


Figure 12-4. Monthly landscape water flows for the North Western Plateau region in 2009–10 compared with the long-term record (July 1911 to June 2010)

12.4.1 Rainfall

Rainfall for the North Western Plateau region for 2009–10 was estimated to be 311 mm, which is one per cent below the region's long-term (July 1911 to June 2010) average of 316 mm. Figure 12-5 (a) shows that during 2009–10, the highest rainfall occurred in the north and far northeast of the region with a decreasing annual rainfall gradient toward the drier inland areas in the southwest. Rainfall deciles for 2009–10, shown in Figure 12-5 (b), indicate rainfall was at an average or above average level across the north of the region. Below average and very much below average rainfall occurred in the west and southwest of the region.

Figure 12-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 177 mm (1989–90) to 782 mm (1999–2000). The annual average for the period was 394 mm. Annual rainfall for the past three years (2007–08 to 2009–10) was consistently below the 30-year average. An extended period of relatively low annual rainfall in the late 1980s to early 1990s was followed by a period of higher rainfall in the late 1990s and early/ mid-2000s.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 12-6 (b). The seasonal distribution of rainfall for the region is characterised by a wet summer and a dry winter season. Summer rainfall averages increased notably and varied over recent years whereas winter rainfall remained low.

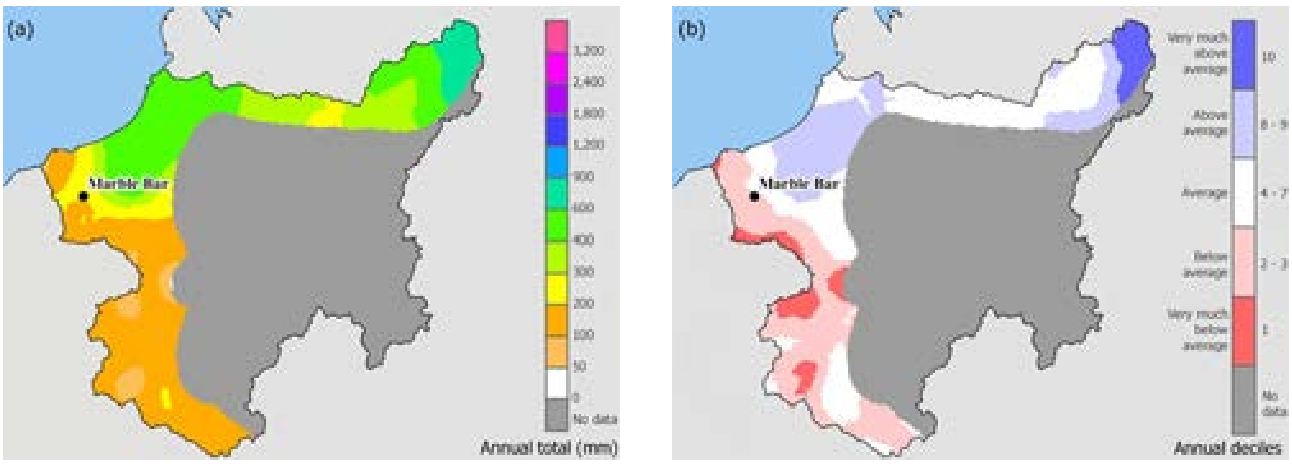
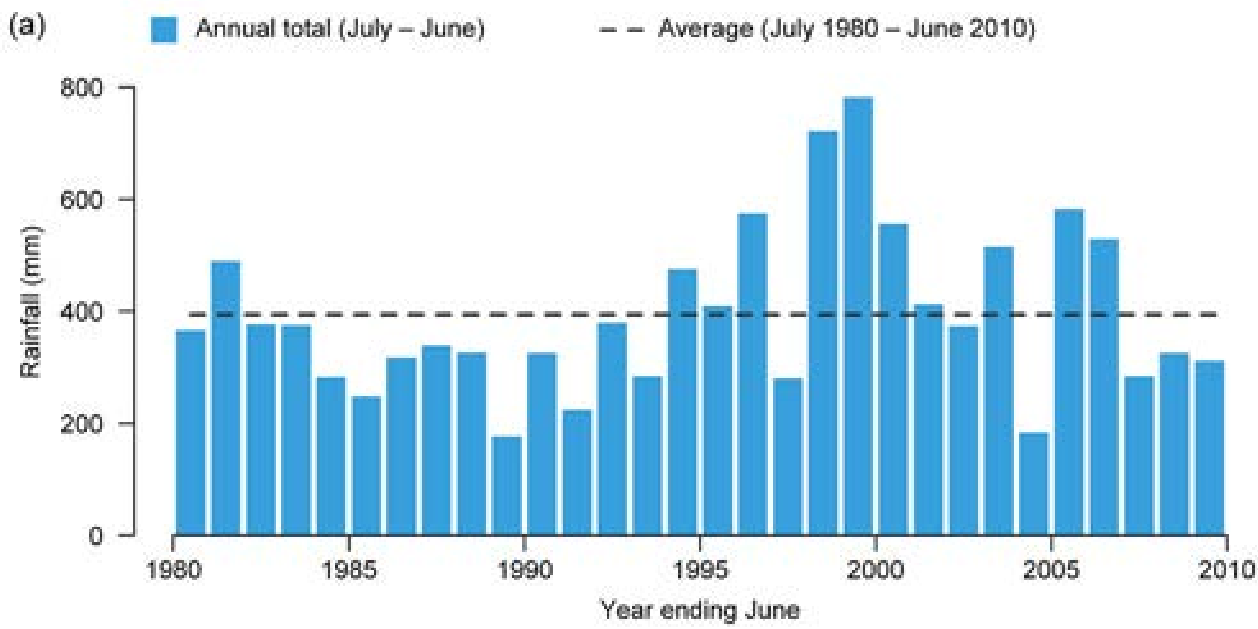


Figure 12-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North Western Plateau region



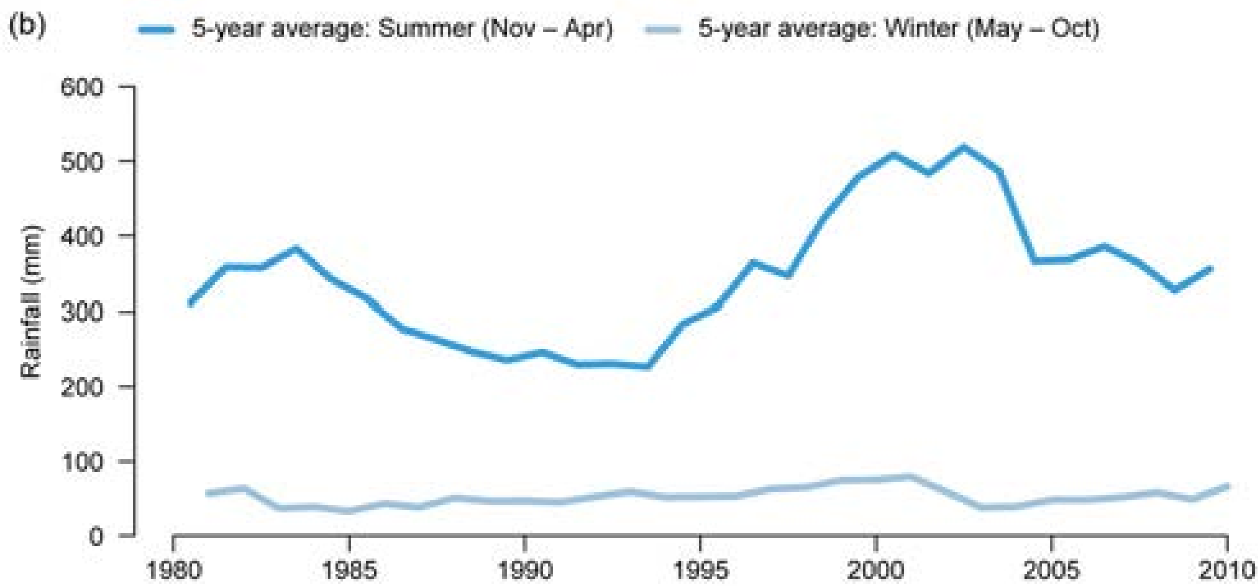


Figure 12-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the North Western Plateau region

12.4.1 Rainfall (continued)

Figure 12-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis of summer rainfall shows generally increasing rainfall across much of the region for which data are available, particularly across the west. Negative trends in summer rainfall are identified in the north and northwest of the region. The equivalent analysis of the winter period rainfall shows lower magnitude increases in seasonal rainfall across the region with the exception of some decreasing trends identified in the far south.

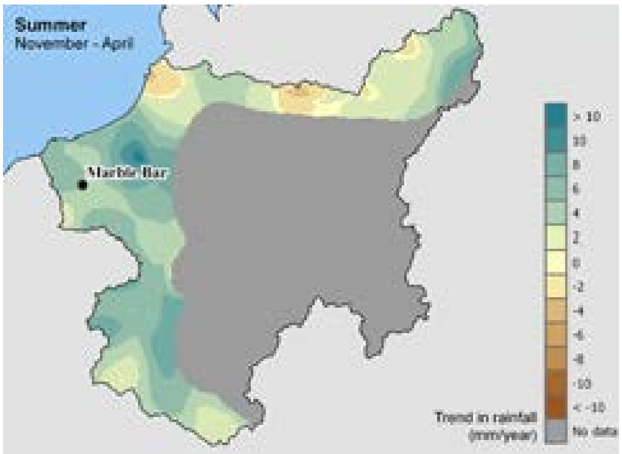


Figure 12-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the North Western Plateau region. The statistical significance of these trends is often very low

12.4.2 Evapotranspiration

Evapotranspiration for the North Western Plateau region for 2009–10 was estimated to be 297 mm, which is seven per cent above the region's long-term (July 1911 to June 2010) average of 276 mm. Figure 12-8 shows that evapotranspiration for 2009–10 was highest across the wetter north and northeast of the region and lowest in the drier far south of the region. The distribution of annual evapotranspiration across the region is very closely linked to the distribution of annual rainfall (Figure 12-5 [a]). Evapotranspiration deciles for 2009–10, shown in Figure 12-8 (b), indicate evapotranspiration was above average in the north and northwest of the region. Below average evapotranspiration is identified in the west and far south of the region.

Figure 12-9 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, evapotranspiration ranged from 222 mm (1990–91) to 442 mm (1999–2000). The annual average for this period was 318 mm. The relatively dry period in the late 1980s and early 1990s and the following wetter years in the late 1990s and early 2000s are clearly reflected in the annual evapotranspiration.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 12-9 (b). The data show that variability in annual evapotranspiration over the 30 years is much more apparent in the higher summer period averages.

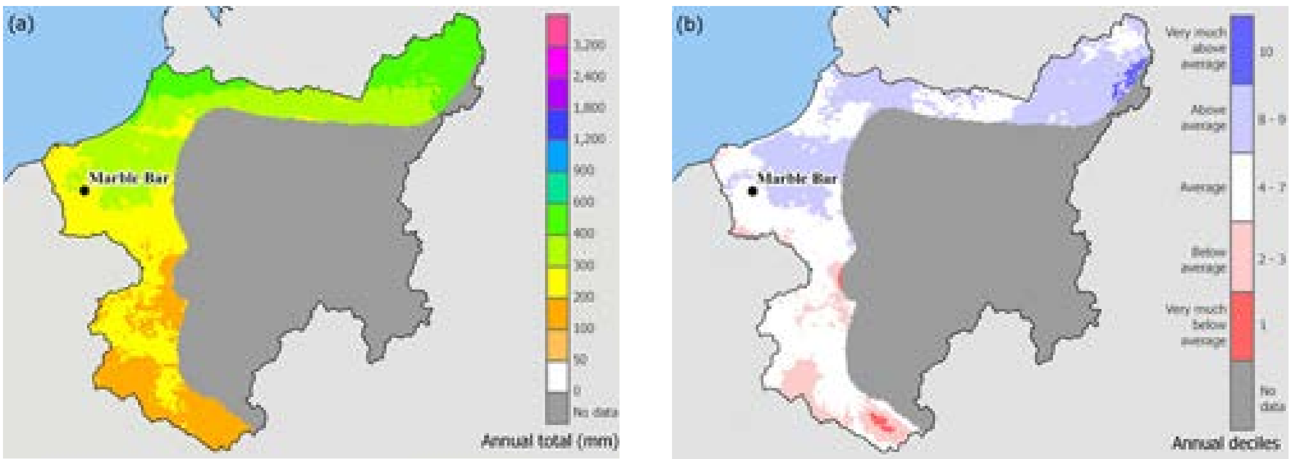
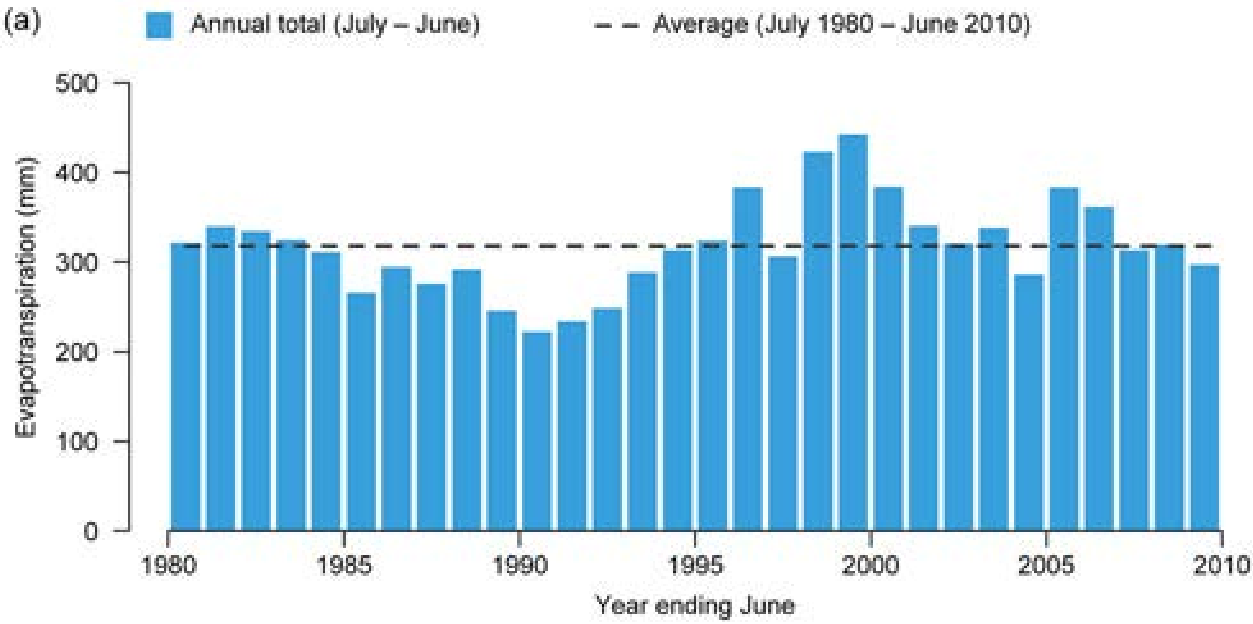


Figure 12-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North Western Plateau region



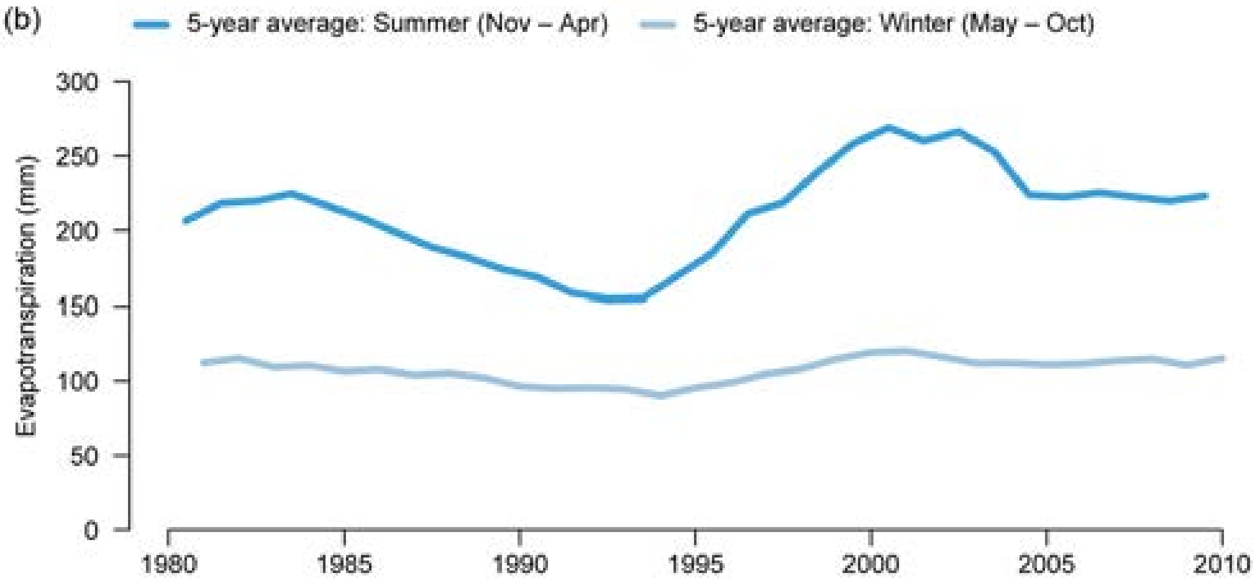


Figure 12-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the North Western Plateau region

12.4.2 Evapotranspiration (continued)

Figure 12-10 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

In general, the analysis indicates slight increases in evapotranspiration over much of the region in both the summer and winter periods. These increases are of a higher magnitude in the summer period. The winter period map shows slight reductions in evapotranspiration across some areas to the west and far southwest of the region.

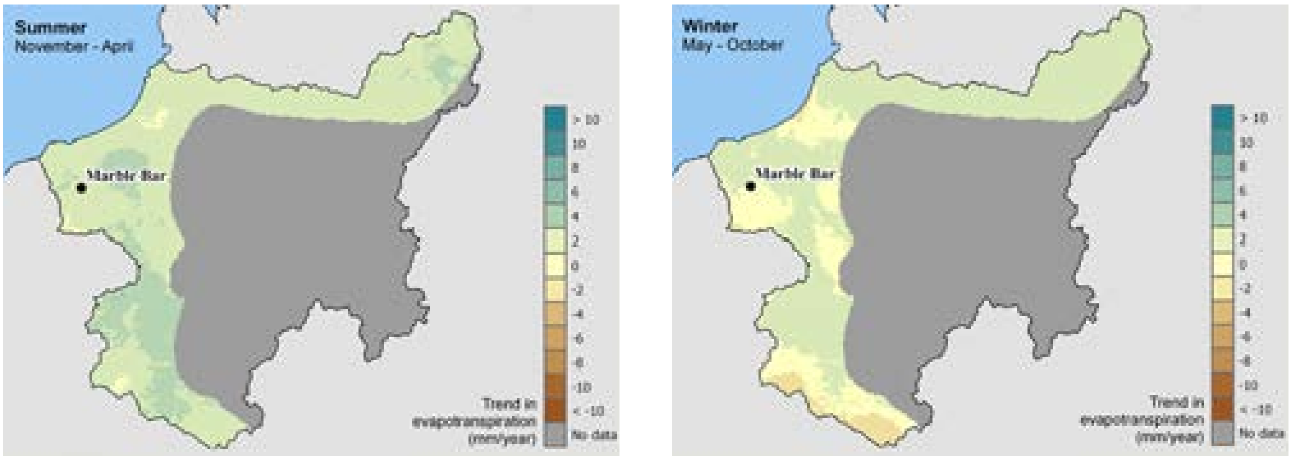


Figure 12-10. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the North Western Plateau region. The statistical significance of these trends is often very low

12.4.3 Landscape water yield

Landscape water yield for the North Western Plateau region for 2009–10 was 48 mm, which is 35 per cent above the region's long-term (July 1911 to June 2010) average of 36 mm. The pattern and distribution of landscape water yield for 2009–10, shown in Figure 12-11 (a), indicates that the highest water yield occurred across the wetter north and far northeast of the region. Landscape water yield deciles for 2009–10, shown in Figure 12-11 (b), demonstrate that the areas of highest annual landscape water yield in the northwest and far northeast of the region experienced above average conditions. The west and southwest of the region experienced below average and very much below average landscape water yield for 2009–10.

Figure 12-12 (a) shows annual landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, landscape water yield ranged from 8 mm (1989–90) to 199 mm (1999–2000). The annual average for this period was 64 mm. The influence of low annual rainfall on annual modelled landscape water yield between the mid-1980s and mid-1990s and the high rainfall years of the late 1990s and early 2000s are clearly reflected in the data.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 12-12 (b). Landscape water yield is higher for the summer period than for the winter. Variability in landscape water yield is clearly shown with both seasons experiencing increases between the lows of the early 1990s and peaks in the early 2000s.

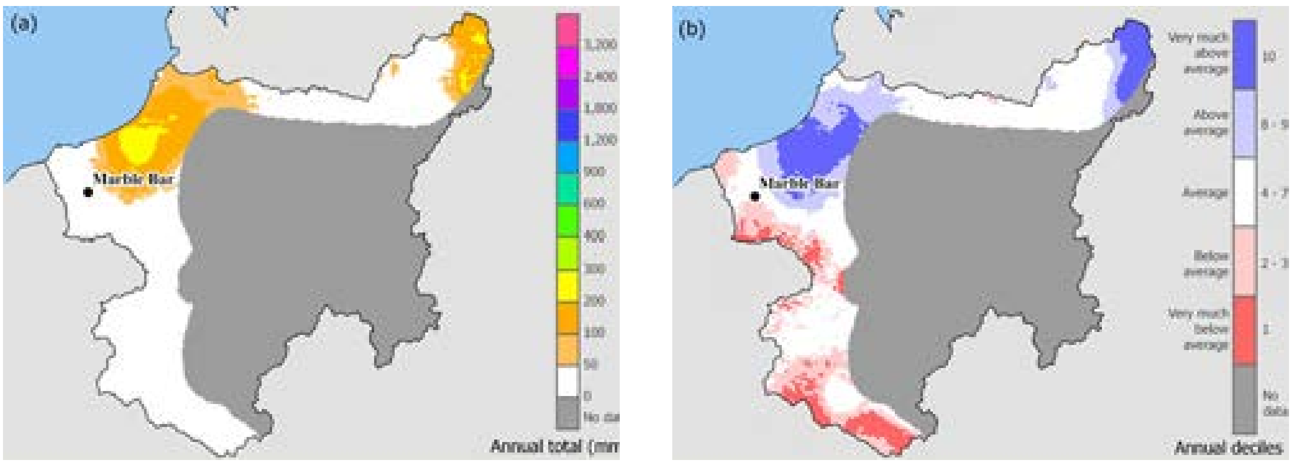
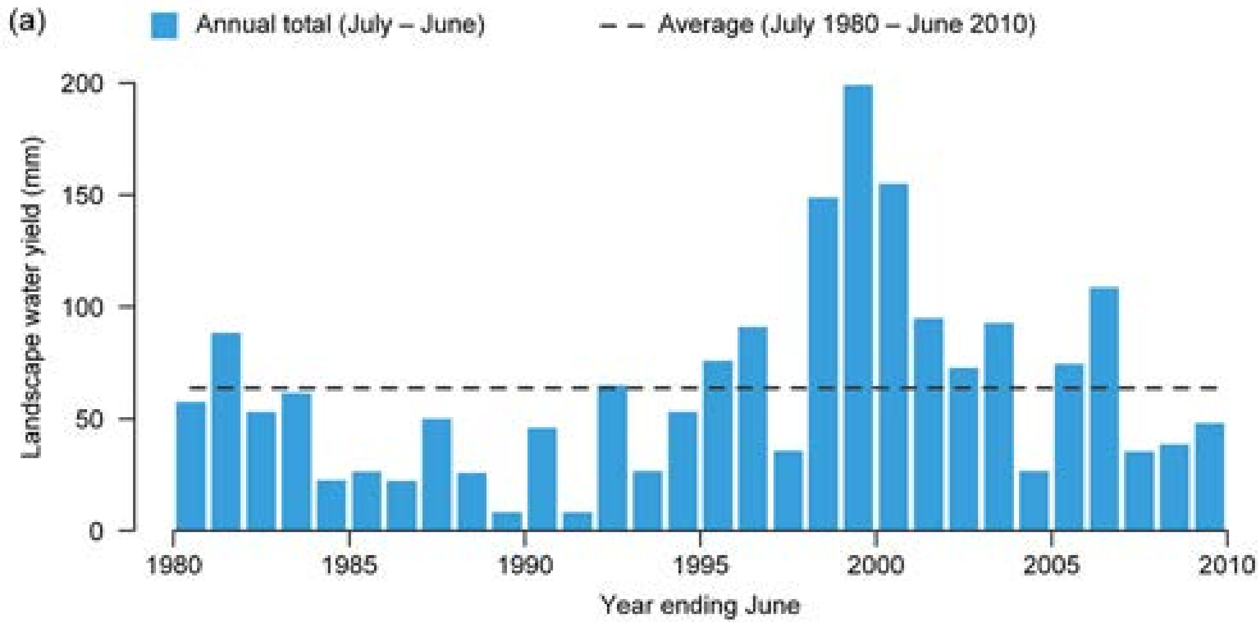


Figure 12-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the North Western Plateau region



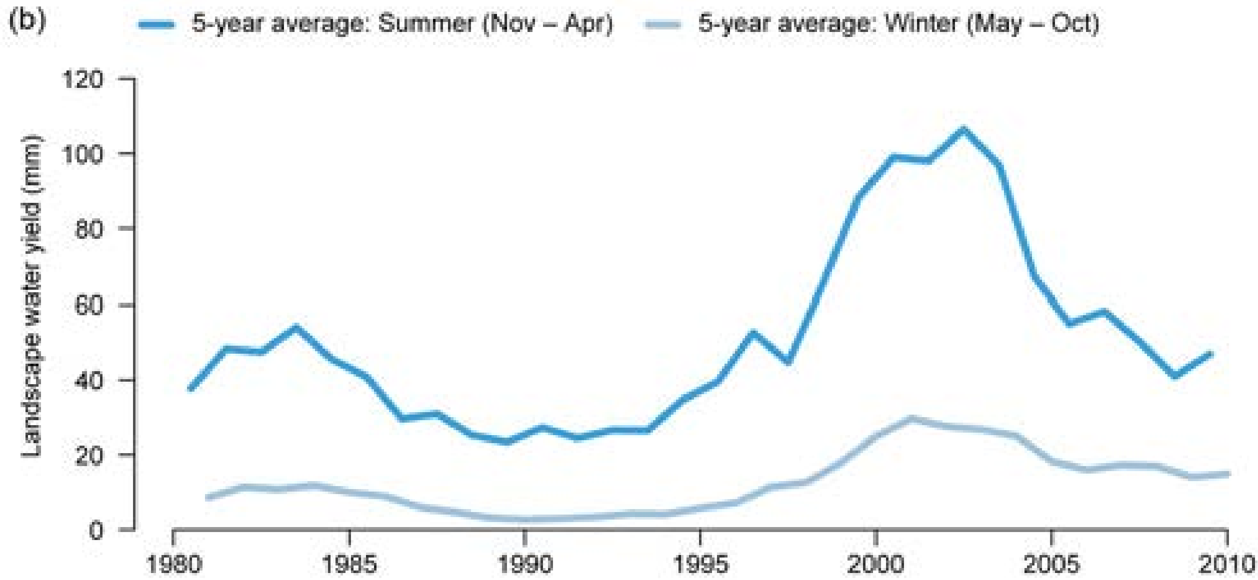


Figure 12-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the North Western Plateau region

12.4.3 Landscape water yield (continued)

Figure 12-13 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal water yield over the 30 years.

The summer period analysis shows decreasing trends across areas to the north of the region with the remainder of the region generally showing increases in seasonal landscape water yield. The winter period analysis shows a very slight positive trend across most of the region over the 30-year period.

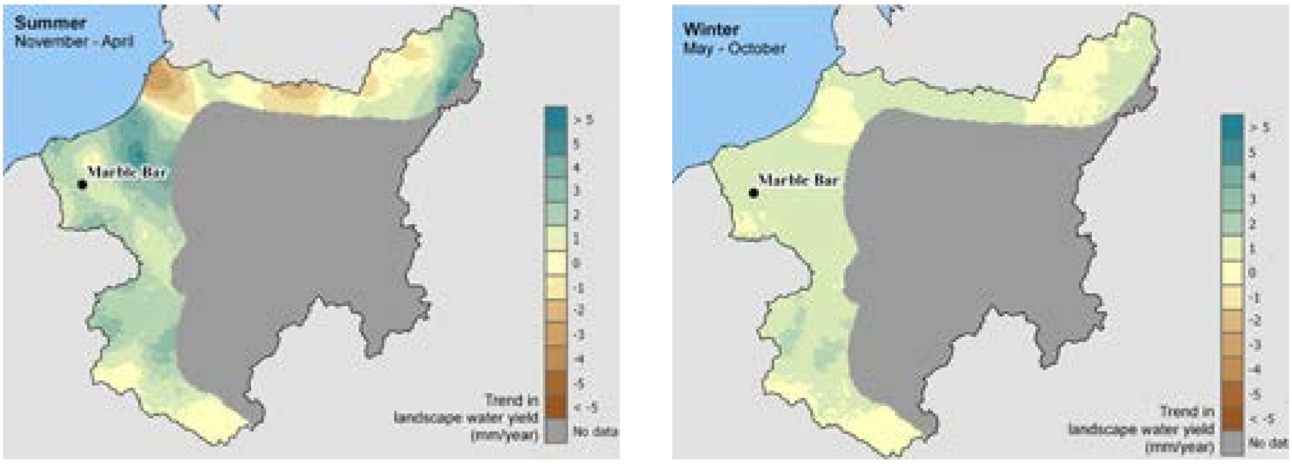
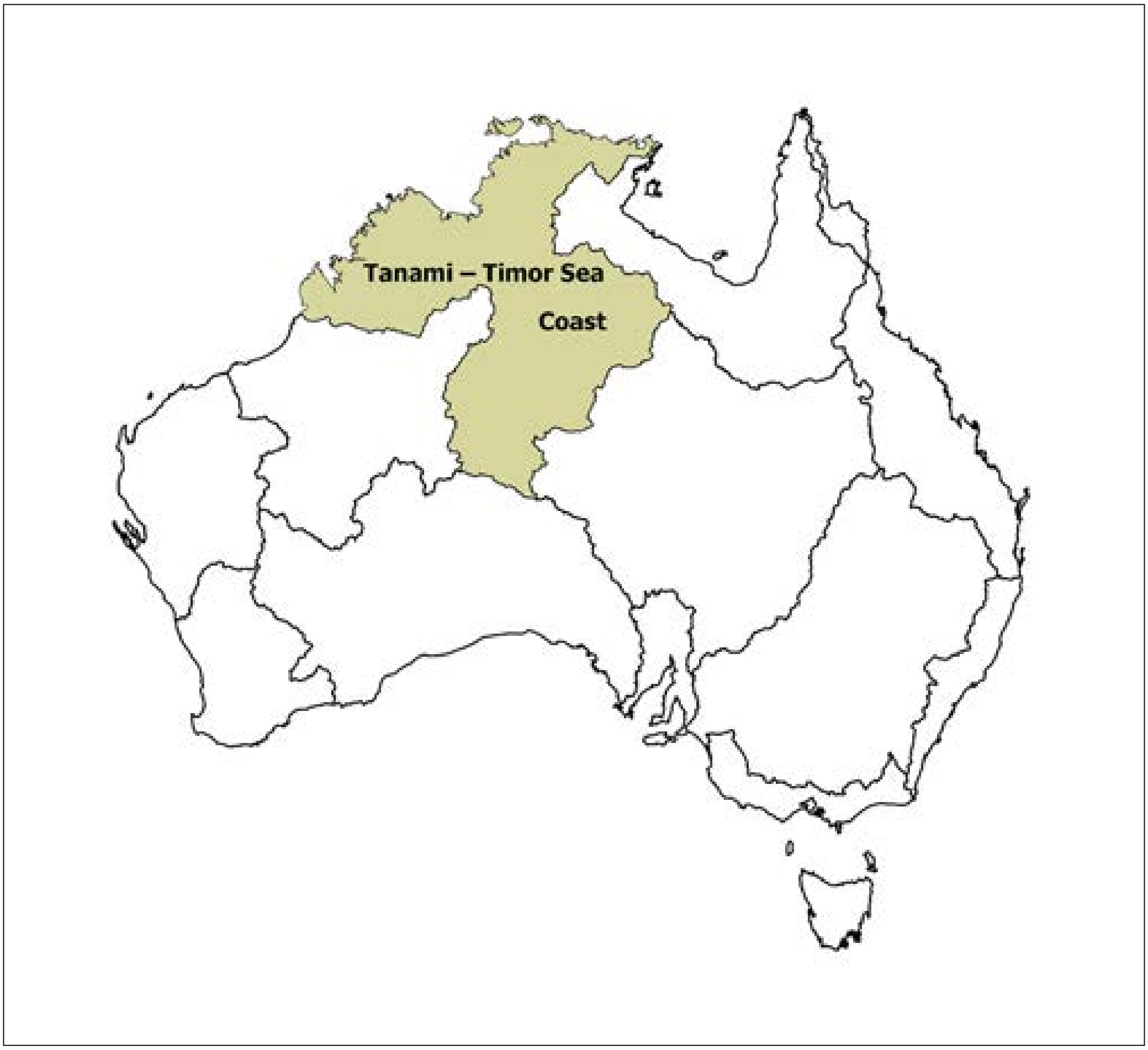


Figure 12-13. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the North Western Plateau region. The statistical significance of these trends is often very low

13. Tanami – Timor Sea Coast

13. Tanami – Timor Sea Coast



13.1 Introduction

This chapter examines water resources in the Tanami – Timor Sea Coast region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level. Information on water use is also provided for selected urban centres and irrigation areas. The chapter begins with an overview of key data and information on water flows, stores and use in the region in recent times followed by a brief description of the region.

Water quality, which is important in any water resources assessment, is not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. Groundwater and water use are only partially addressed for the same reason. In future reports, these aspects will be dealt with more thoroughly as suitable data become operationally available.

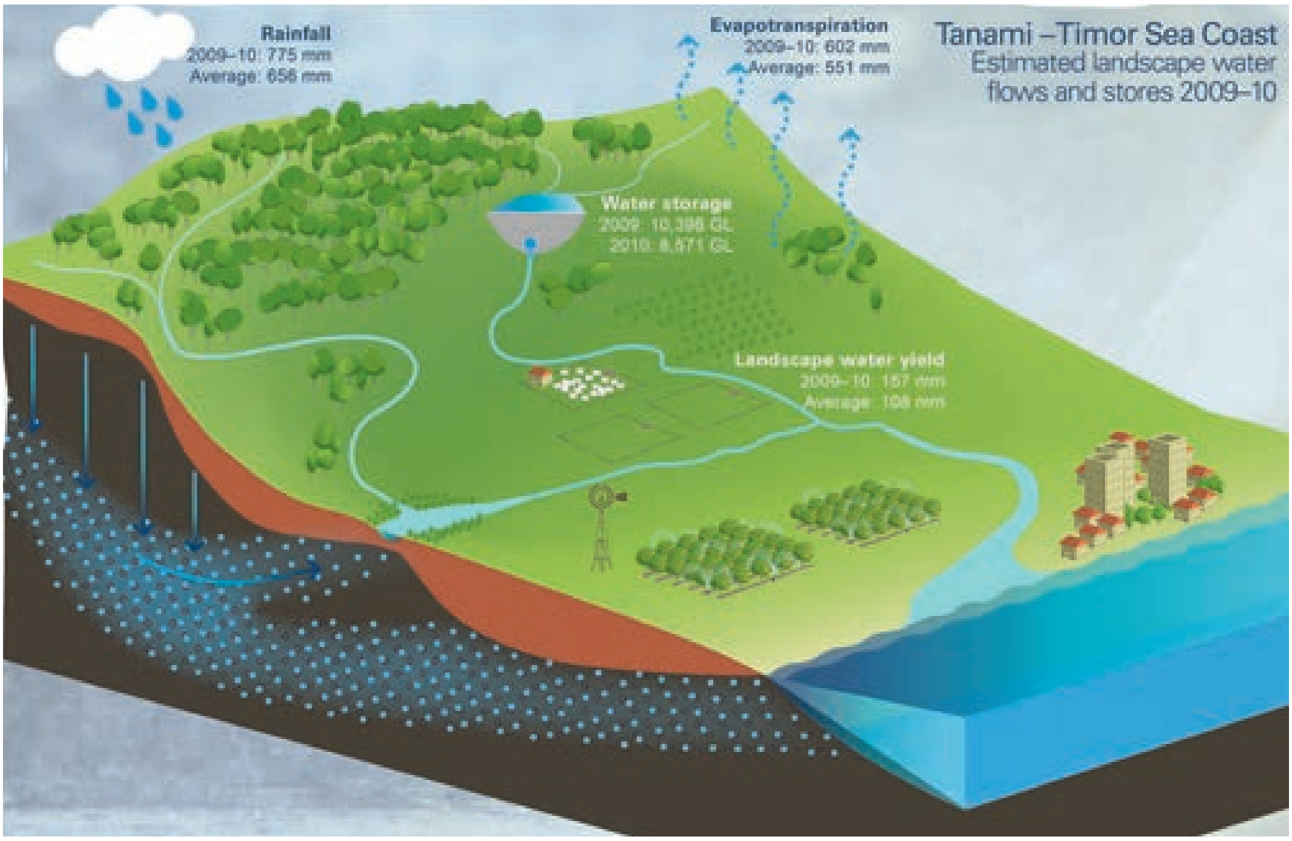


Figure 13-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the Tanami – Timor Sea Coast region

13.2 Key data and information

Figure 13-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the Tanami – Timor Sea Coast region. The region experienced above average annual rainfall and evapotranspiration for 2009–10 (see Table 13-1) and the relatively high levels of water availability also resulted in above average modelled landscape water yield[1] and also an increase in soil moisture conditions. Total accessible surface water storage in the region decreased over the year, largely due to significant releases of water from Lake Argyle concurrent with average rainfall and run-off conditions in the Ord River basin.

Table 13-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

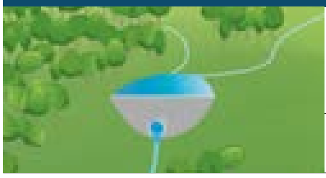
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 13-1. Key information on water flows, stores and use in the Tanami – Timor Sea Coast region[2]

Landscape water balance

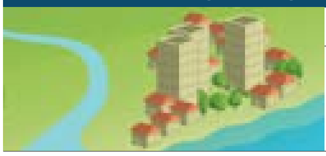
	During 2009–10			During the past 30 years	
	Region average	**Difference from long-term mean**	**Rank (out of 99)***	**Highest value (year)**	**Lowest value (year)**
Rainfall	775 mm	+18%	82	1,132 mm (1999–2000)	411 mm (1991–92)
Evapotranspiration	602 mm	+9%	76	713 mm (2000–01)	502 mm (1992–93)
Landscape water yield	157 mm	+46%	85	315 mm (2000–01)	34 mm (1989–90)

Surface water storage (comprising approximately 100% of the region's total surface water storage)



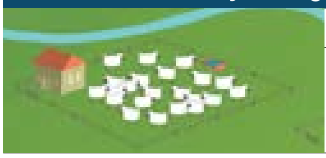
Total accessible capacity	July 2009		June 2010		% Change
	Accessible volume	**% of accessible capacity**	**Accessible volume**	**% of accessible capacity**	
10,683 GL	10,398 GL	97.3%	8,571 GL	80.2%	-17.1%

Urban water use (Darwin)



Water supplied 2009–10	Trend in recent years	Restrictions
35 GL	Steady (slightly down from recent years)	Not in place

Soil moisture for dryland agriculture



Summer 2009–10 (November–April)	Winter 2010 (May–October)
Generally average across much of the region, some areas of below average in the north and above average in the southeast	Very much above average across the entire region

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

13.3 Description of region

The Tanami – Timor Sea Coast region extends over a large area of northern Australia between the Northern Territory to the east and Western Australia to the west. The region covers approximately 1,162,000 km^2 of land area and includes the river basins of the Ord, Darwin, Daly, Fitzroy and Katherine rivers.

The topography of the region generates two dominant drainage patterns with high density northern rivers draining to the Timor Sea and drier rivers draining predominantly south to inland ephemeral lakes (Figure 13-2). The region extends across distinctive climatic zones and is dominated by a humid tropical climate to the north and a very dry arid climate to the south. River flows in the tropical northern zone experience distinct seasonal patterns, with approximately 90 per cent of the average annual discharge occurring in the four-month wet season from December to March.

The region is very sparsely populated and Darwin is the major urban centre. The two main urban surface water supply systems are the Darwin River reservoir (accessible storage capacity of 259 GL) providing water supplies for Darwin, and diversions from the Katherine River that supply the town of Katherine. Most other communities in the region rely heavily on groundwater supplies. More details of the region's significant urban water systems are described in Section 13.6.

The Ord Irrigation Scheme, located in the Ord River catchment in the far northeastern part of Western Australia, is the largest area of irrigated agriculture in the region. The Ord River is highly regulated downstream of the Ord River Dam, impounding Lake Argyle (accessible storage capacity of approximately 10,700 GL). The main industries within the Ord River catchment are agriculture, horticulture, tourism and mining. Water supply to the Ord Irrigation Scheme is described in Section 13.7.

Land use in the region mainly consists of pasture and natural conservation land (Figure 13-2). Some of the most famous natural attractions in Australia are located in this region, including the Kimberleys and Kakadu National Park.

The hydrogeology of the region is dominated by the Kimberley hard rock plateau and Canning Basin sedimentary rocks. In the hard rock plateau, groundwater occurs in lesser but valuable quantities in fractured rocks and surficial river alluvium. Substantial quantities of confined and unconfined groundwater of varying quality occur in the sedimentary basins. The extensive groundwater resources associated with the widespread fractured and cavernous limestone of the Daly Basin are important for the region. A more detailed description of the groundwater occurrence in the region is given in Section 13.5.

In the northern part of the region, watertables in shallow aquifers respond dramatically to the seasonal rains, often rising and falling several metres each year. Many shallow aquifers fill to capacity, and drain slowly to the rivers and the coast during the dry season. For example, the extensive aquifers of the Tindall Limestone and Oolloo Dolostone (in the Daly River basin) are often the primary sources of water that keep local streams flowing year-round (CSIRO 2009). Shallow groundwater is often of good quality (low salinity), reflecting the annual fill-and-spill cycle, and can provide good supplies of potable water. However, groundwater extractions adjacent to streams may need regulation to ensure groundwater input to streamflow does not fall below critical limits.

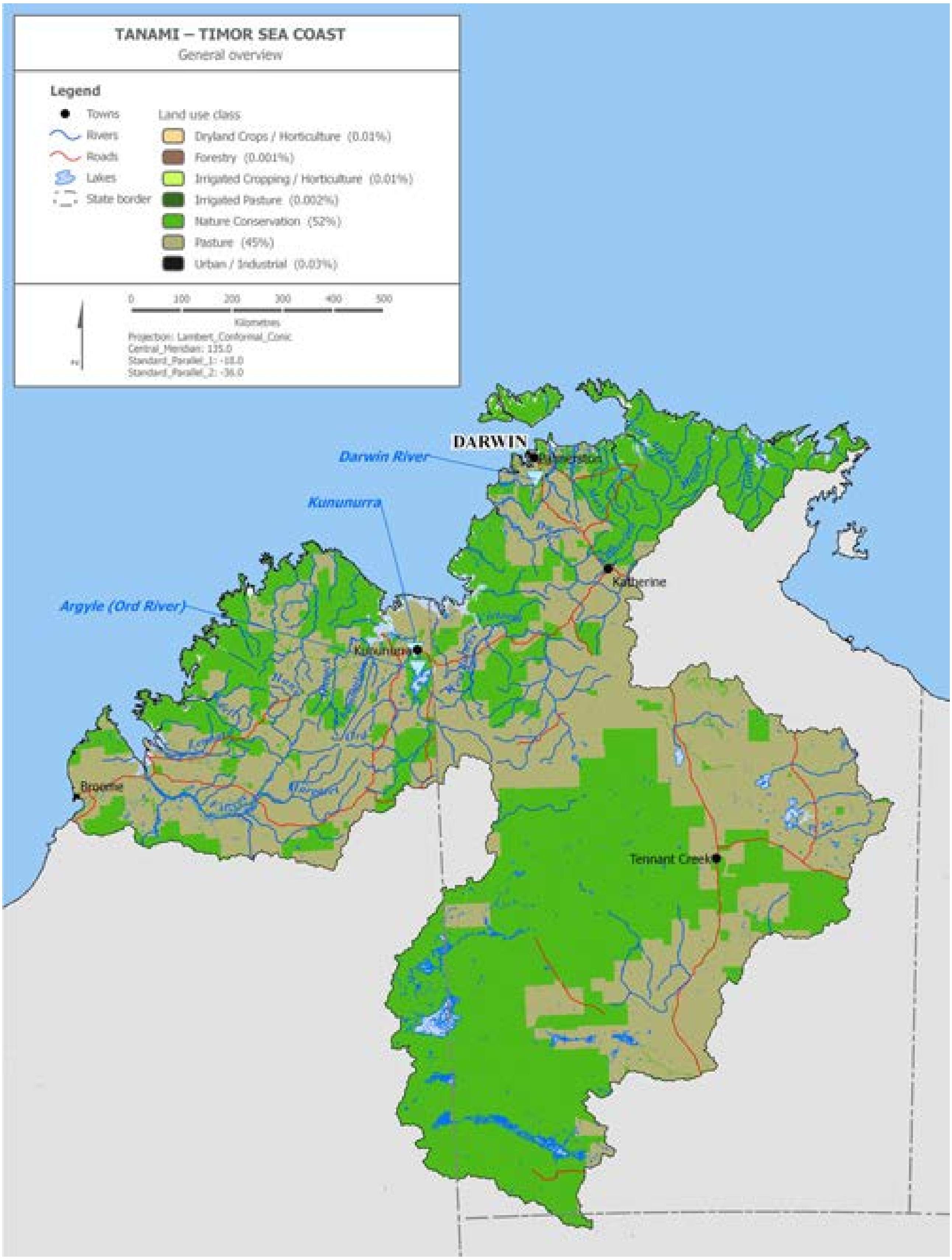


Figure 13-2. Key landscape and hydrological features of the Tanami – Timor Sea Coast region (land use classes based on Bureau of Rural Sciences 2006)

13.3 Description of region (continued)

Groundwater recharge rates are variable across the landscape, and depend on soil type, vegetation and topography as well as rainfall amount and other climate variables. The complex interplay between these parameters means there is not always a direct correlation between rainfall and groundwater recharge rates. Pathways for water infiltration to watertables can be complex and may change in importance through the year. Rivers may recharge aquifers during the wet months, while discharging groundwater may keep rivers flowing during the dry months (CSIRO 2009).

In the higher rainfall areas of the north (over 800 mm/year), recharge is relatively high and occurs regularly each year. In the low rainfall areas of the south, recharge is very low and occurs infrequently. This, and the interconnection between surface water and groundwater, has a major influence on reliability and long-term sustainability of groundwater supplies. In general, groundwater data are very sparse for most aquifers across the project area.

Darwin, Palmerston, Broome, Katherine and Kununurra are the major towns in the region. Darwin has the largest population and is subject to an extreme range of climatic conditions. The Water and Power Corporation of Northern Territory and the Water Corporation of Western Australia are the region's main water providers.

Surface and groundwater are both sources of water for the cities and towns in the region. Most of the urban area is concentrated in Darwin, Broome, Katherine and Kununurra. Surface water is a major source of water for Darwin and Katherine while smaller communities usually rely on groundwater supplies. In rural areas, domestic production bores are the main sources of water. The pastoral industry across the region also uses groundwater. Large scale irrigated agriculture occurs predominantly along the Ord River and, at a smaller scale, near Darwin and Katherine.

The major watertable aquifers present in the region are given in Figure 13-3. The region is dominated by fractured rock groundwater systems that may provide a low volume groundwater resource, and by the extensive regional karstic system in the central-east part of the region that can provide high yield. The extensive aquifers of the Tindall Limestone and Oolloo Dolostone within the Daly River basin, for example, may support the use of over 100 GL/year (CSIRO 2009). Groundwater systems that provide great potential for extraction are labelled as:

- fractured and karstic rocks, regional scale and local scale aquifers
- Mesozoic sediment aquifer (porous media – consolidated).

Figure 13-4 shows the classification of watertable aquifer as fresh and saline water according to the salinity levels. Shallow groundwater generally has good quality throughout the region, reflecting the annual fill-and-spill cycle, and can be a good source of local supplies of potable water. The areas with high salinity values are relatively small.

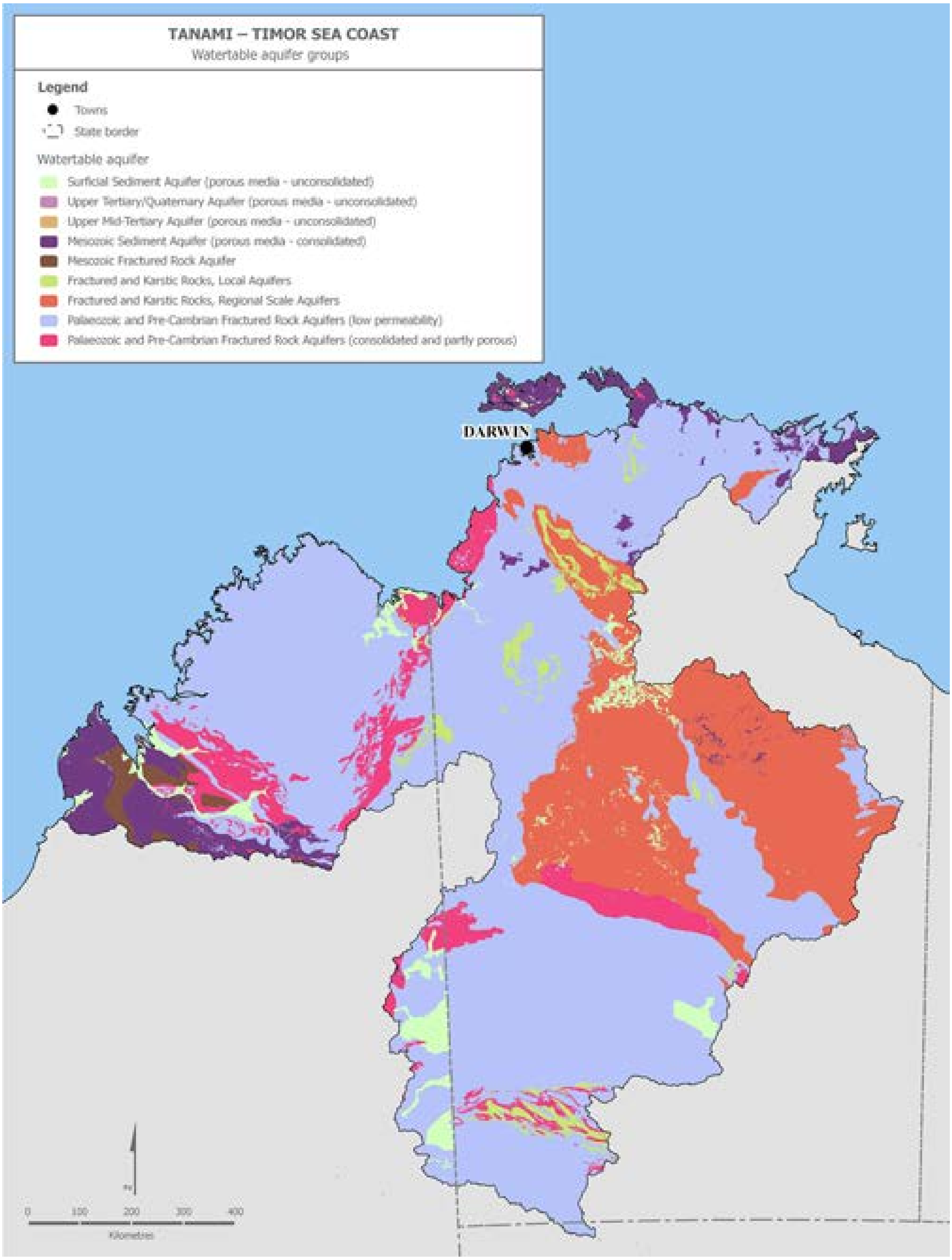


Figure 13-3. Watertable aquifer groups in the Tanami – Timor Sea Coast region (Bureau of Meteorology 2011e). The discontinuity in aquifers across the state border is the result of different state-based aquifer classification systems

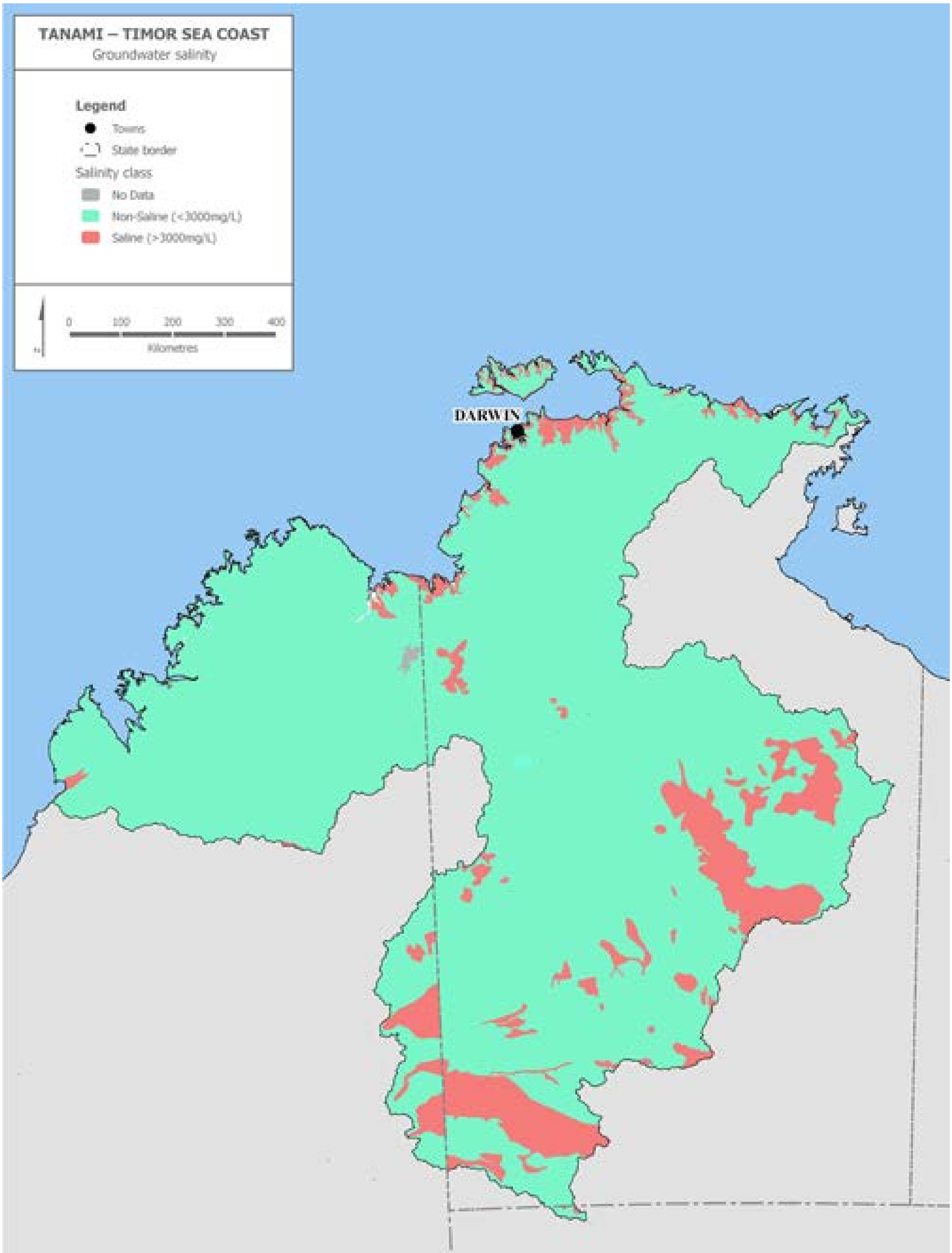


Figure 13-4. Watertable salinity classes within the Tanami – Timor Sea Coast region (Bureau of Meteorology 2011e). The discontinuity in salinity classes across the state border is the result of different state-based aquifer classification systems

13.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Large areas of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 13-5 shows that the Tanami – Timor Sea Coast region experiences a highly seasonal distribution of rainfall. The north of the region in particular has a very dominant summer wet season and dry winter season. Inland areas to the south and southwest of the region have lower annual rainfall. During 2009–10, rainfall was at relatively normal levels through the dry period at the beginning of the year. The historically wetter months of November to April were largely wetter than normal, with the exception of March 2010, and relatively high rainfall continued through to May 2010.

Evapotranspiration is strongly constrained by water availability in Australia's far north and therefore the seasonal distribution of monthly evapotranspiration is very closely linked to seasonal rainfall patterns. In 2009–10, monthly evapotranspiration was at a normal to slightly above normal level as a consequence of readily available moisture, particularly during the very wet summer months.

The region's seasonal pattern of modelled landscape water yield is also closely linked to the pattern of monthly rainfall. During the start of 2009–10, landscape water yield was constrained to very low levels, particularly from July to November 2009. A higher than normal landscape water yield response occurred during the high rainfall months of December to January, when monthly rainfall significantly exceeded the evaporative losses.

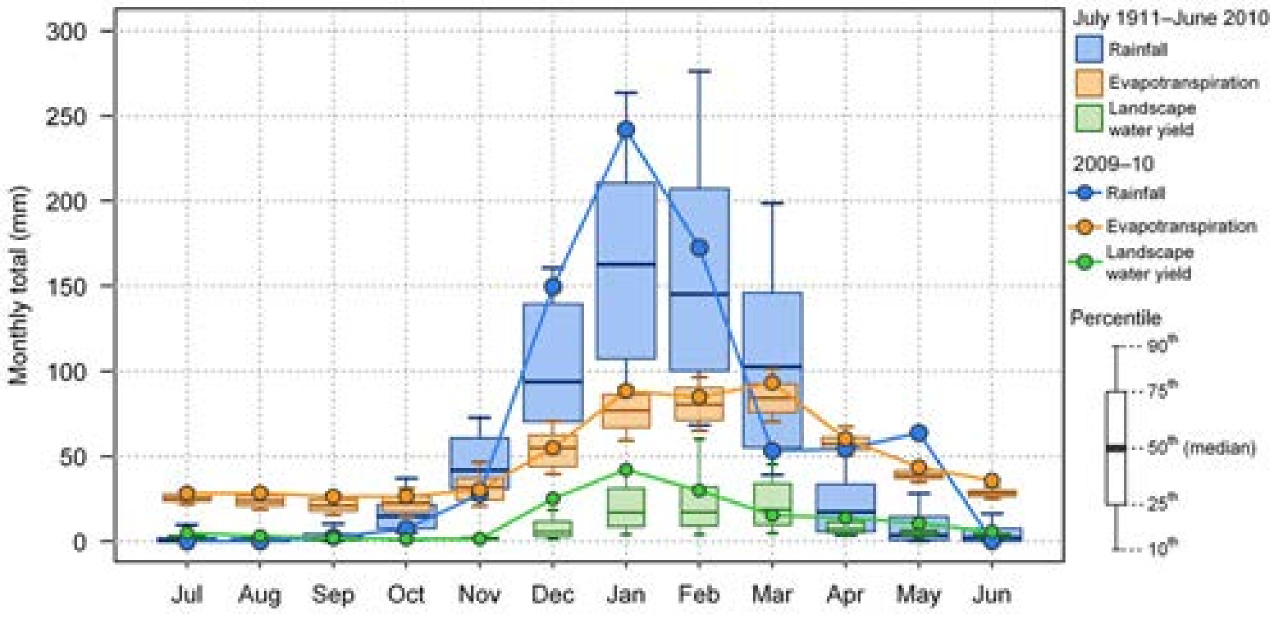


Figure 13-5. Monthly landscape water flows for the Tanami – Timor Sea Coast region in 2009–10 compared with the long-term record (July 1911 to June 2010)

13.4.1 Rainfall

Rainfall for the Tanami – Timor Sea Coast region for 2009–10 was estimated to be 775 mm, which is 18 per cent above the region's long-term (July 1911 to June 2010) average of 656 mm. Figure 13-6 (a)[3] shows that during 2009–10, the highest rainfall occurred in coastal areas in the north of the region. Rainfall deciles for 2009–10, shown in Figure 13-6 (b), indicate rainfall was above average across large parts of the region and very much above average in areas of the far north and southeast. Below average rainfall was experienced across limited areas through the region's centre.

Figure 13-7 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, annual rainfall ranged from 411 mm (1991–92) to 1,132 mm (1999–2000). The annual average for the period was 751 mm. The data indicate that annual rainfall was generally lower during the first half of the 30-year record when compared to annual rainfall over the second half of the period.

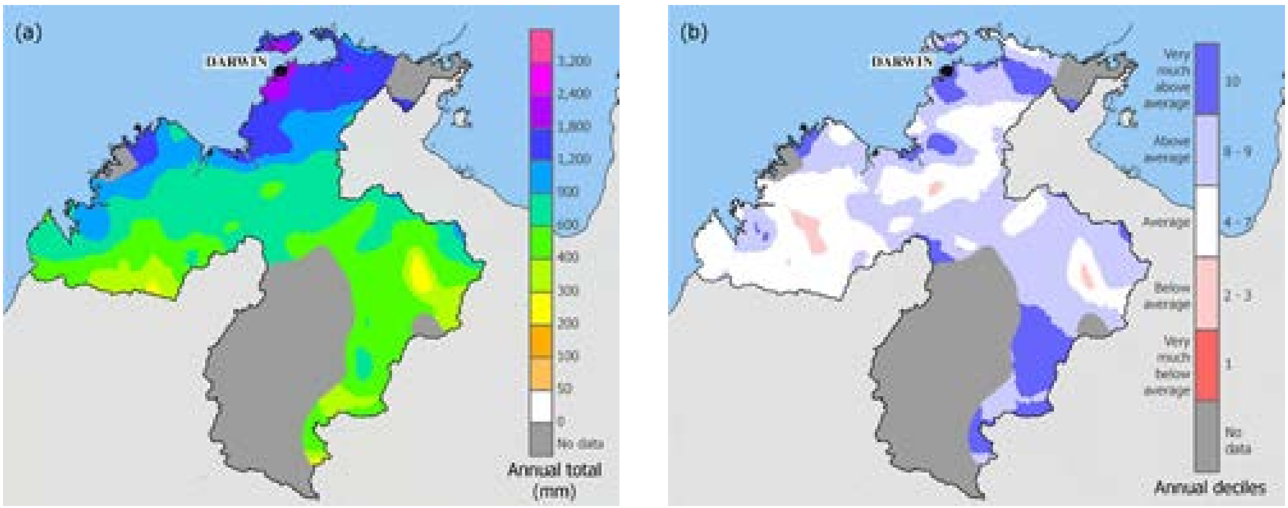


Figure 13-6. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tanami – Timor Sea Coast region

3. Areas where rainfall interpolation was assessed to be greater than 20 per cent unreliable for any period of the long-term record were excluded from the landscape water balance modelling (classified as 'No data'). More details are presented in the Technical supplement.

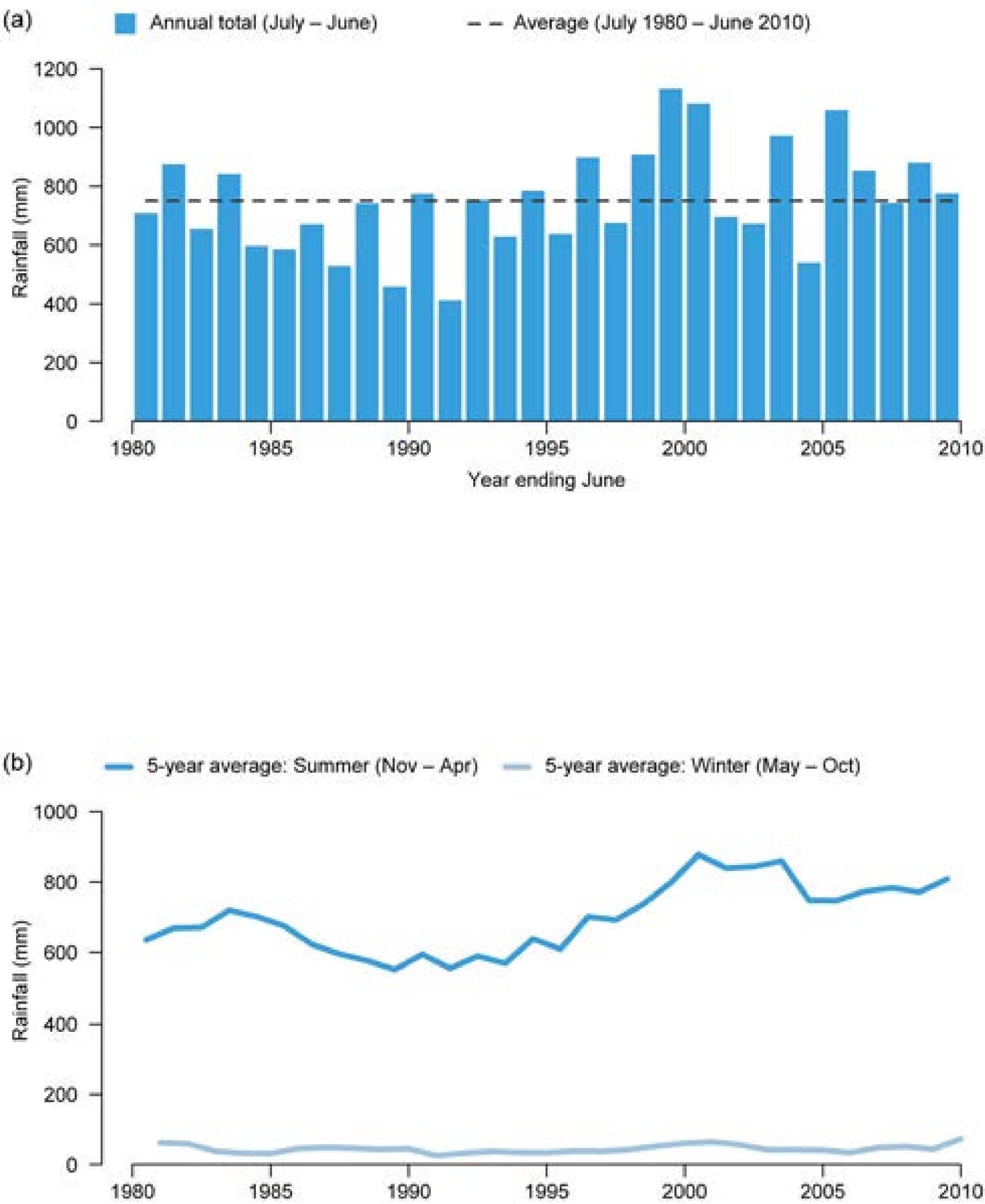


Figure 13-7. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Tanami – Timor Sea Coast region

13.4.1 Rainfall (continued)

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 13-7 (b). The data show the highly seasonal nature of rainfall for the region, characterised by very high summer rainfall and dry winters. Summer rainfall averages show an increasing trend over the 30-year period.

Figure 13-8 provides a spatial representation of the summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis indicates increasing rainfall in the summer period across the majority of the region with particularly strong positive trends in the far north. Slight reductions in summer rainfall are identified across limited areas in the far south and northwest. The analysis of the lower winter period indicates slight increases in rainfall across the region. No change in rainfall or slight negative trends in winter rainfall are observed in the far east of the region.

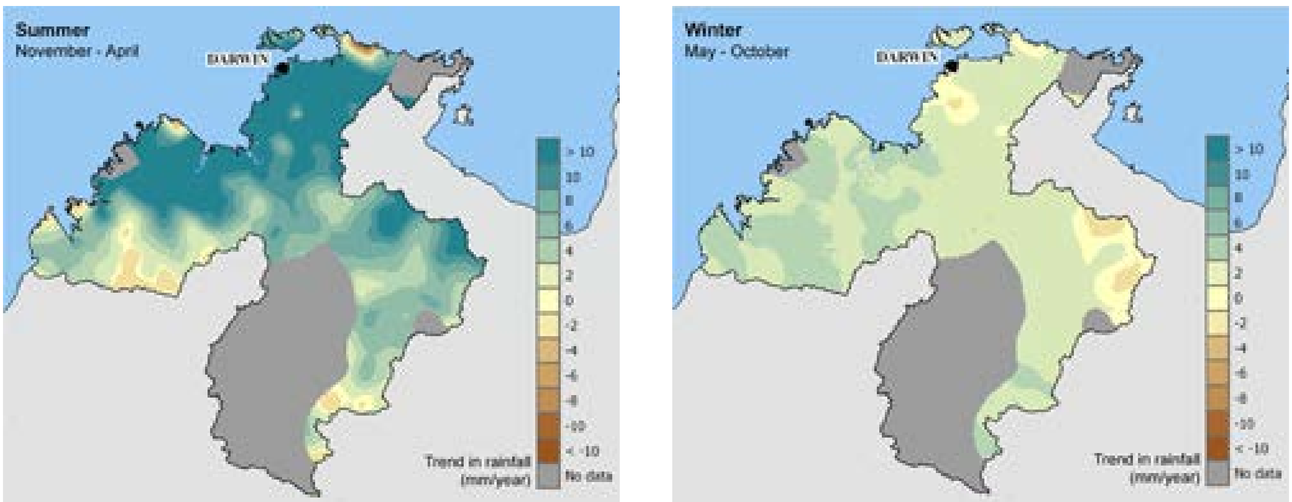


Figure 13-8. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Tanami – Timor Sea Coast region. The statistical significance of these trends is often very low

13.4.2 Evapotranspiration

Evapotranspiration for the Tanami – Timor Sea Coast region for 2009–10 was estimated to be 602 mm, which is nine per cent above the region's long-term (July 1911 to June 2010) average of 551 mm. Figure 13-9 (a) shows that evapotranspiration for 2009–10 was closely related to the distribution of annual rainfall. Highest values occurred in the region's far north with decreasing gradient to the drier inland areas in the south and southeast. Evapotranspiration deciles for 2009–10, shown in Figure 13-9 (b), indicate average or above average levels across most of the region, with very much above average values of the west. A very limited area of below average evapotranspiration is identified in the north of the region.

Figure 13-10 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 502 mm (1992–93) to 713 mm (2000–01). The annual average for this period was 597 mm. The data show that annual evapotranspiration was consistently higher over the wetter second half of the 30-year period.

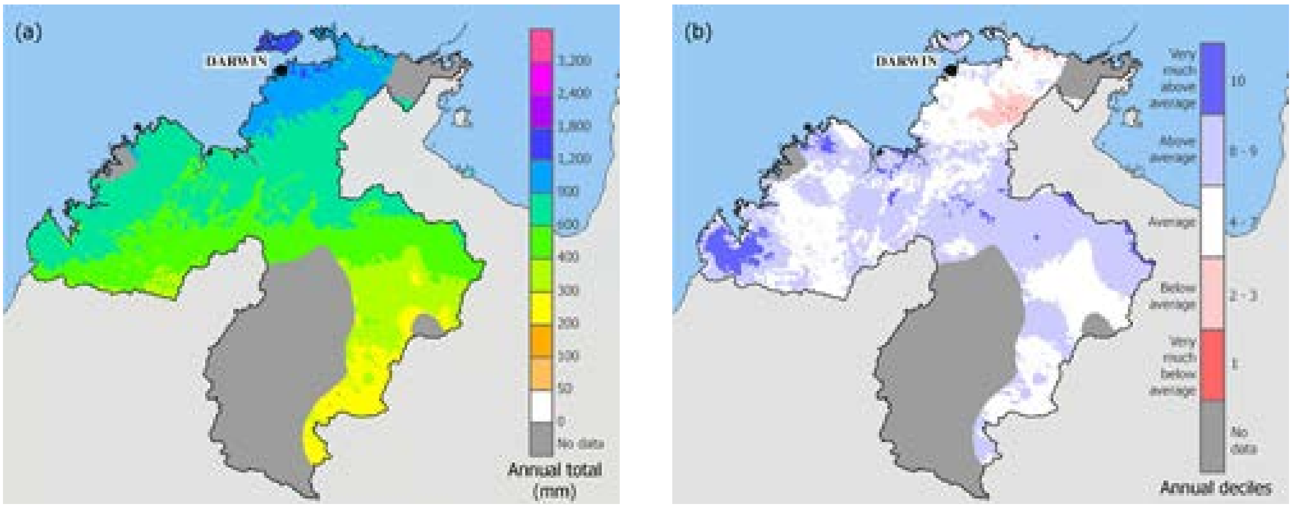


Figure 13-9. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tanami – Timor Sea Coast region

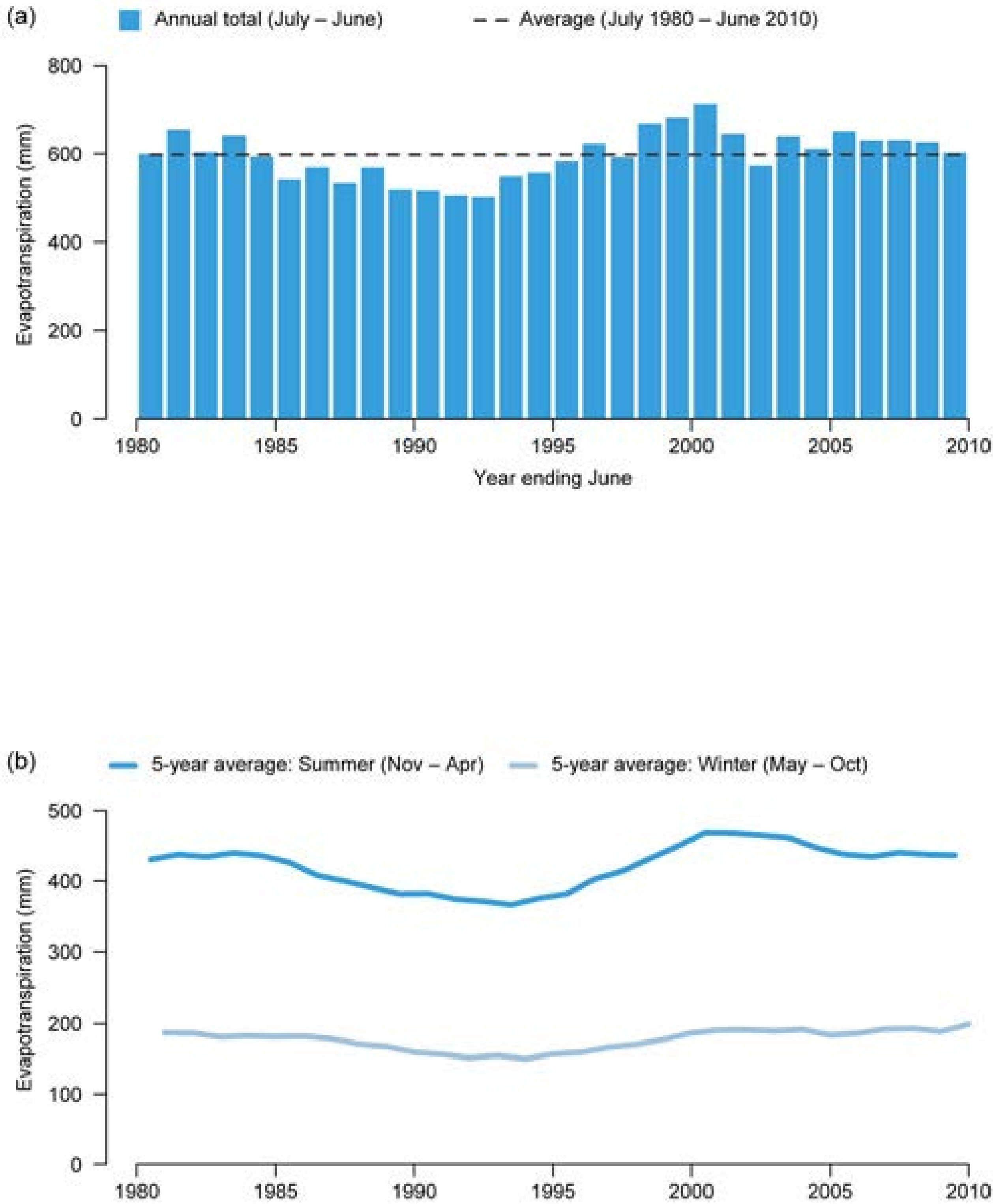


Figure 13-10. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Tanami – Timor Sea Coast region

13.4.2 Evapotranspiration (continued)

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 13-10 (b). The graph shows summer evapotranspiration is consistently higher than winter. Increases in annual evapotranspiration over the second half of the 30-year period are reflected in both seasonal averages, particularly in the summer.

Figure 13-11 provides a spatial representation of trends in summer (November–April) and winter (May–October) evapotranspiration throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

General increases in evapotranspiration are observed across almost the entire region for the summer period, with limited areas of very slight negative trends in the coastal areas of the far north. The winter period analysis shows slight increases in evapotranspiration across much of the region. The stronger increases in summer evapotranspiration are also reflected in the five-year moving averages (Figure 13-10 [b]).

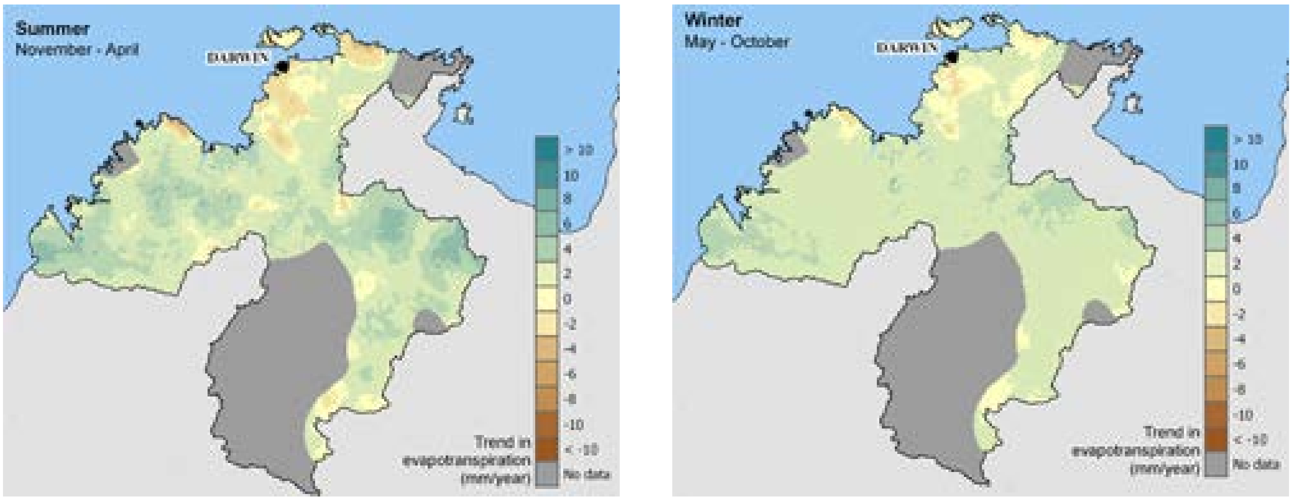


Figure 13-11. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Tanami – Timor Sea Coast region. The statistical significance of these trends is often very low

13.4.3 Landscape water yield

Landscape water yield for the Tanami – Timor Sea Coast region for 2009–10 was estimated to be 157 mm, which is 46 per cent above the region's long-term (July 1911 to June 2010) average of 108 mm. Figure 13-12 (a), shows that landscape water yield for 2009–10 was highest in the coastal areas to the north of the region with a steep decreasing gradient to the south and west. Landscape water yield deciles for 2009–10, shown in Figure 13-12 (b), indicate average and above average landscape water yield across the majority of the region. Very much above average values are observed to the southeast of the region and across areas to the north and west.

Figure 13-13 (a) shows landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, landscape water yield ranged from 34 mm (1989–90) to 315 mm (2000–01). The annual average for the period was 150 mm. The data clearly show that, as observed for rainfall, landscape water yield is consistently much higher during the second half of the 30-year period.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 13-13 (b). The data show a clear increase in summer period landscape water yield over the 30-year period, particularly since the early 1990s, with lower magnitude increases observed for the winter period.

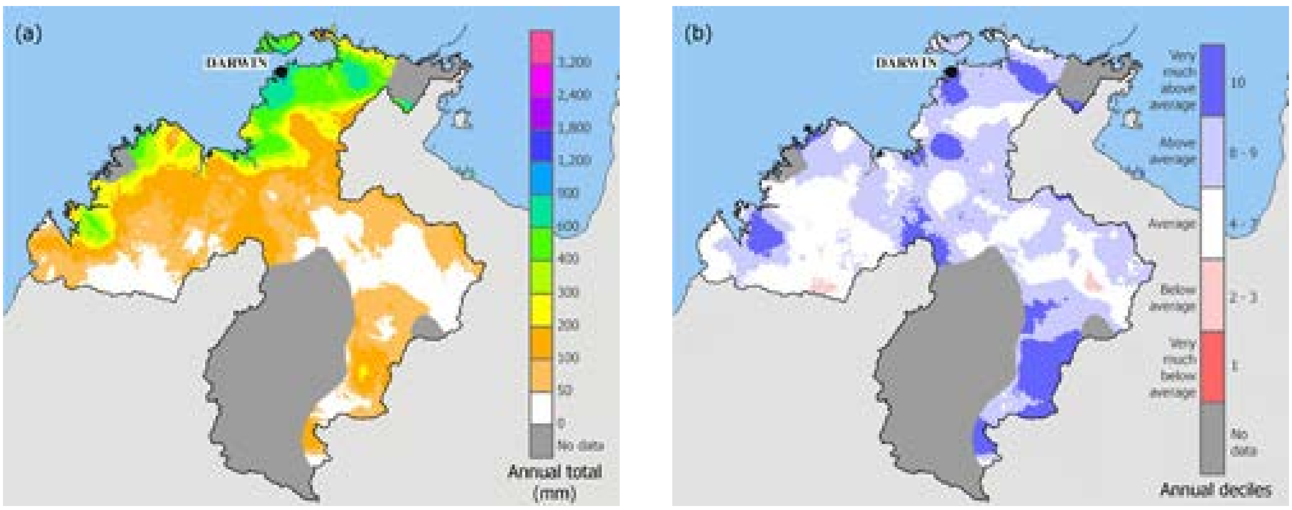
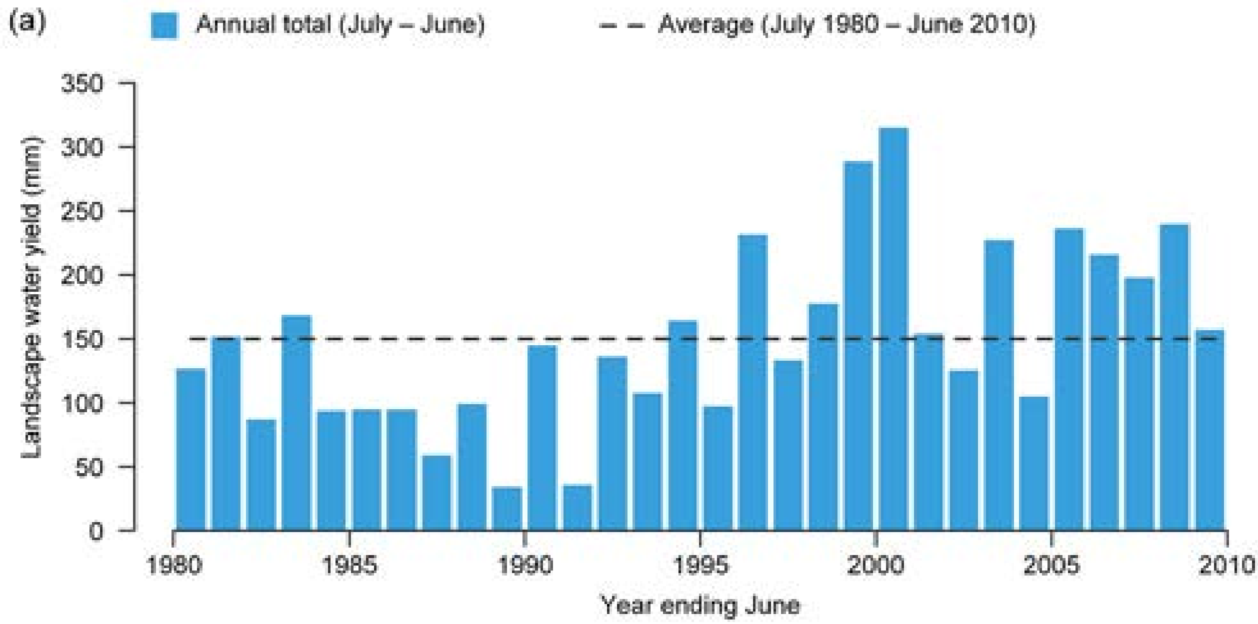


Figure 13-12. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Tanami – Timor Sea Coast region



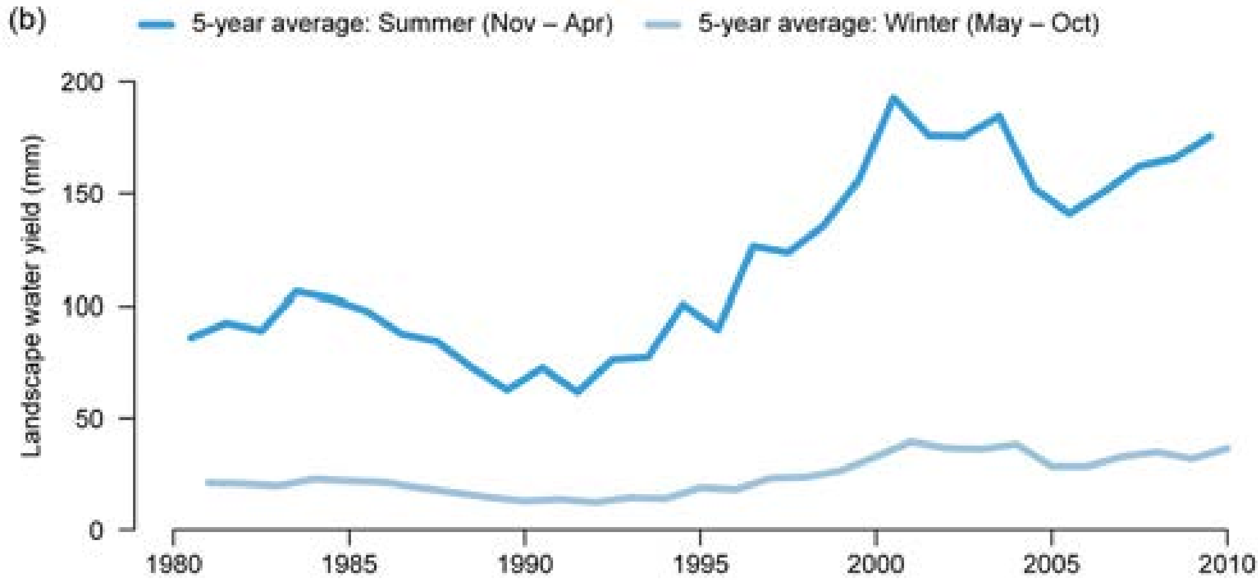


Figure 13-13. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Tanami – Timor Sea Coast region

13.4.3 Landscape water yield (continued)

Figure 13-14 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

Strong positive trends in summer landscape water yield are identified in the region's far north, where strong positive trends are also identified in the equivalent summer rainfall analysis (Figure 13-8). Slight negative trends are identified in the far south and west. Winter period landscape water yield show slight increases over the 30-year period in northern areas with no clearly identifiable trends across the south and east of the region.

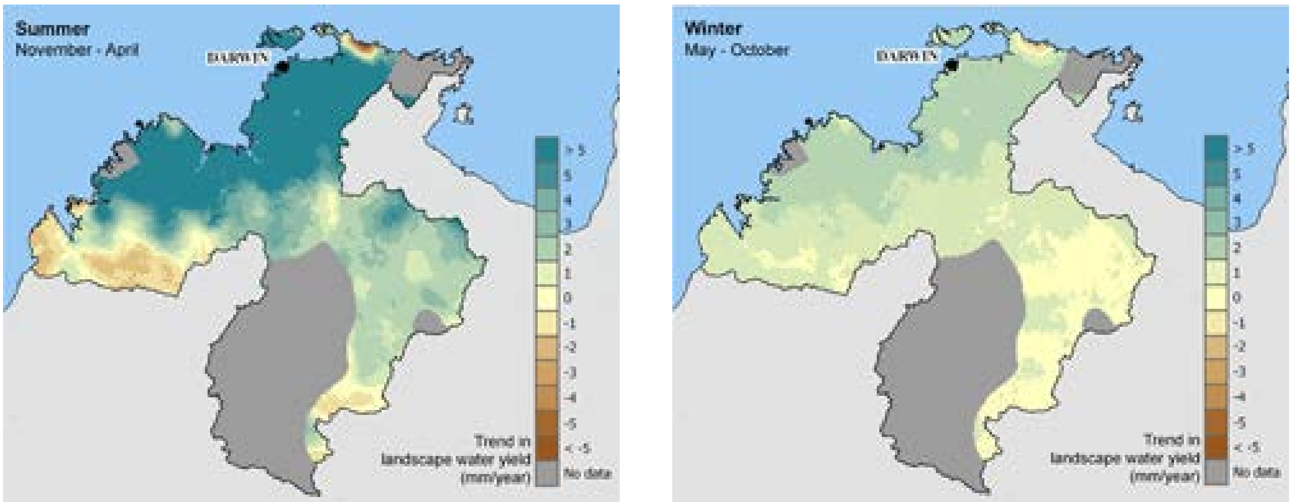


Figure 13-14. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Tanami – Timor Sea Coast region. The statistical significance of these trends is often very low

13.5 Rivers, wetlands and groundwater

The groundwater management units within the region are key features that control the extraction of groundwater through planning mechanisms. Figure 13-15 shows that most of the major groundwater management units within the Northern Territory are located within the fractured and karstic rocks (see Figure 13-3).

The status of rivers, wetlands and groundwater for the Tanami – Timor Sea Coast region were not able to be addressed in this report. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Australian Bureau of Meteorology 2010a) were not available.

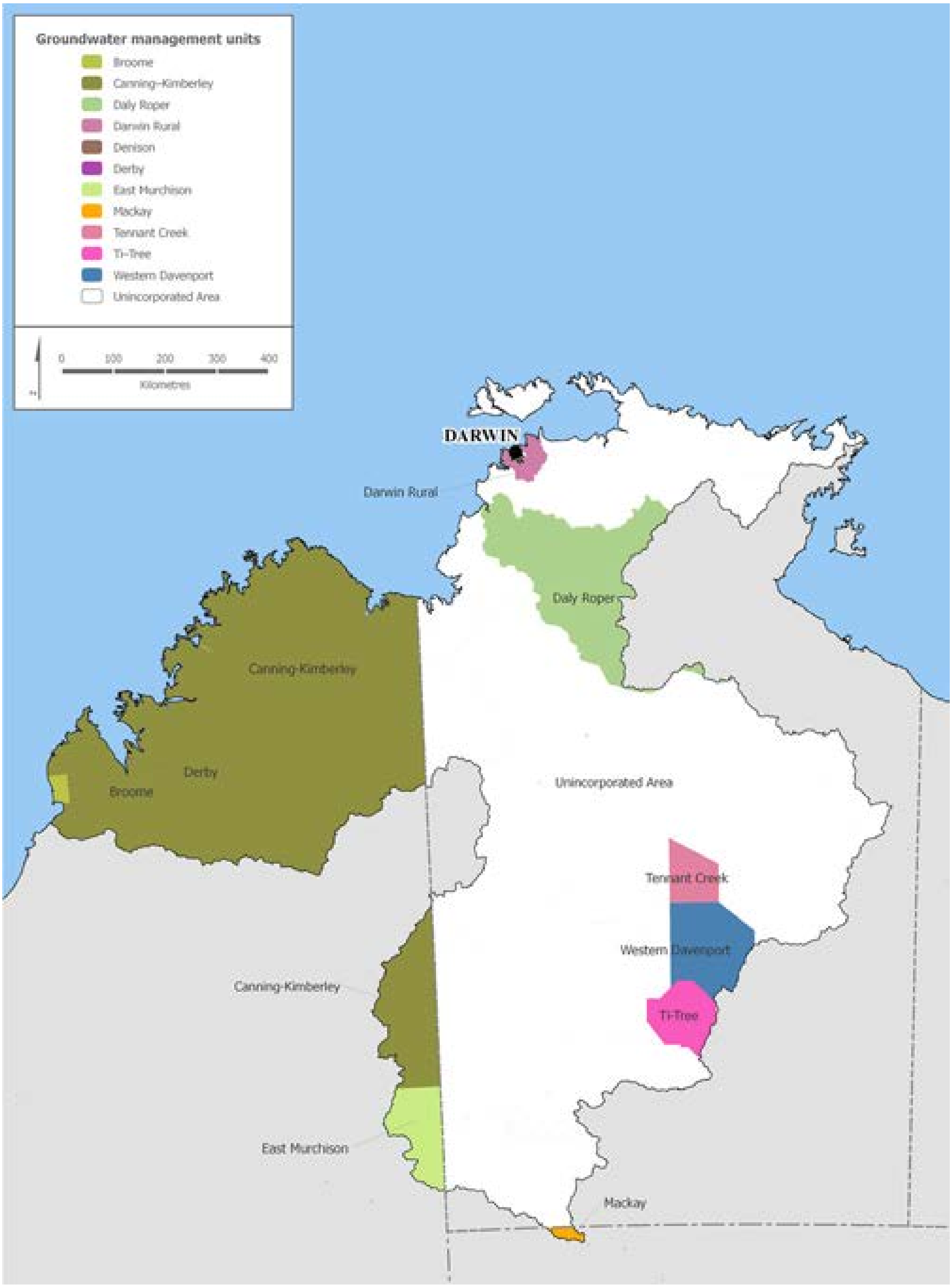


Figure 13-15. Major groundwater management units in the Tanami – Timor Sea Coast region (Bureau of Meteorology 2011e)

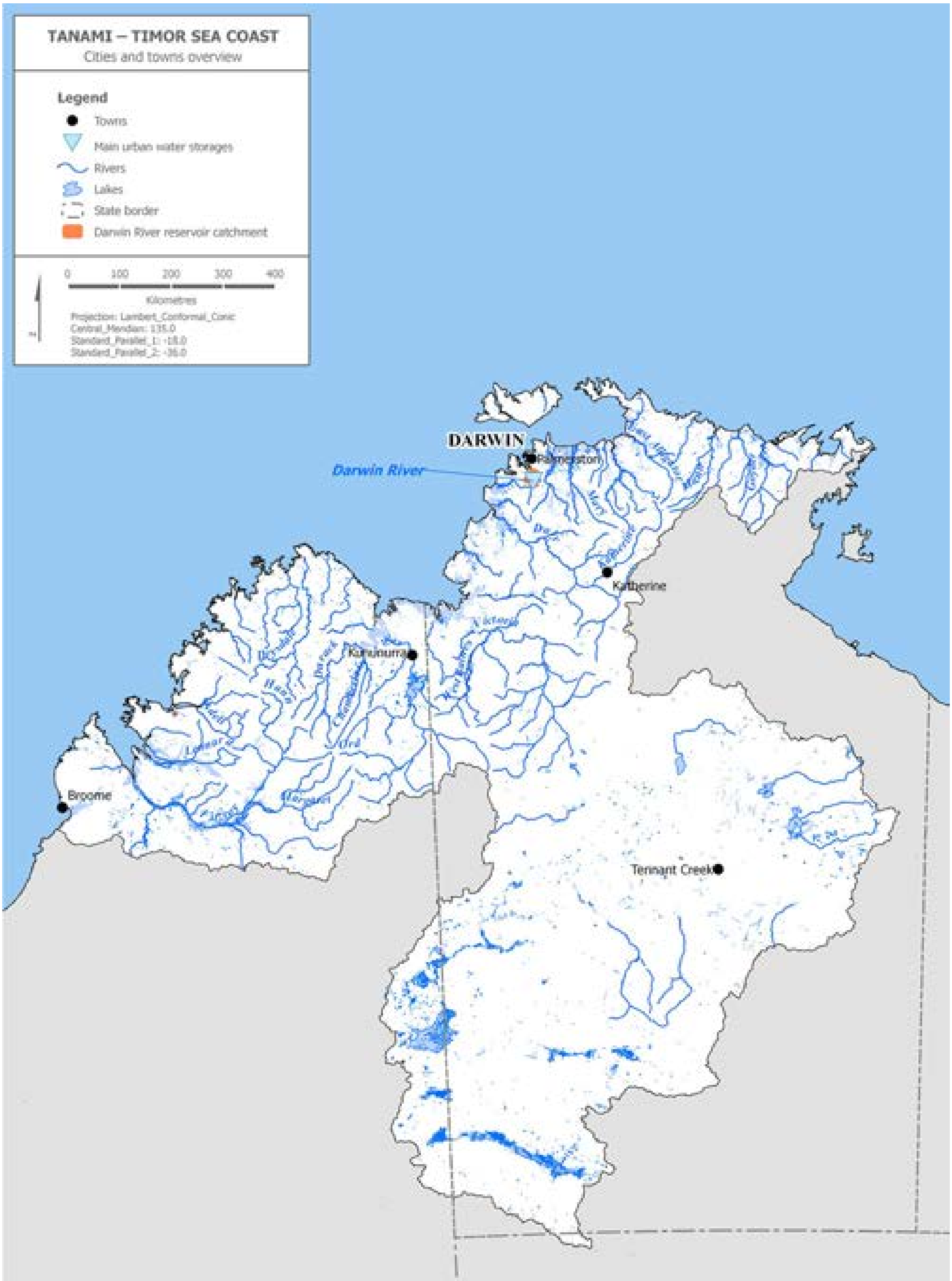


Figure 13-16. Urban areas and supply storages in the Tanami – Timor Sea Coast region

13.6 Water for cities and towns

13.6.1 Regional overview

Darwin, Palmerston, Broome, Katherine and Kununurra are the major urban centres in the Tanami – Timor Sea Coast region. These are shown in Figure 13-16 in relationship to the rivers and major water storages. Surface and groundwater are both significant sources of water in the region. Small communities rely mainly on groundwater supplies.

The Darwin–Palmerston area is the major urban centre with a population of 114,000. The major supply storage for the area is the Darwin River reservoir. Broome represents the next largest urbanised area and is located at the southwestern extreme of the Dampier Peninsula in the southwest of the Kimberley district. Water supplies to Broome and the surrounding areas are sourced mainly from groundwater. Katherine is the third largest centre in the region and also depends on groundwater for most of its supply and Kununurra also relies largely on groundwater.

The Power and Water Corporation is owned by the Northern Territory Government and supplies water to both Darwin and other communities in the Northern Territory. The Water Corporation of Western Australia supplies groundwater to the towns of Broome and Kununurra. In the Northern Territory, management of groundwater and surface water resources is the responsibility of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport.

The Darwin–Palmerston area with a population of 114,000 receives water supplies from the Northern Territory Power and Water Corporation. Water is supplied from a combination of surface water and groundwater sources. Most of this water is sourced from the Darwin River reservoir and is supplemented from Howard East and McMinns bore fields.

In 1972, the Darwin River reservoir was built to address growing water needs arising from the increasing population in the supply area. The reservoir has an accessible storage capacity of 259 GL and is the largest in the region. It is located approximately 45 km southeast of Darwin.

Darwin has a tropical savannah climate with distinct wet and dry seasons, which impacts greatly on the availability of surface water in the storages and recharge to the groundwater. Most of the annual rainfall is experienced from December to April. The timing of the onset of regular evening storms, together with the presence or absence of dry season rainfall, significantly influences water consumption.

13.6.2 Darwin water supply area

Sources and supply of urban water in recent years

Figure 13-17 illustrates the different sources of water from 2005–06 to 2009–10. Data were obtained from the *National Performance Report for 2009–10* (National Water Commission 2011a). On average about 88 per cent of the water sourced is from surface water. Groundwater sourced constitutes on average about 11 per cent of the supply. The use of recycled water is very limited; (approximately one per cent).

The use of surface water ranged from about 35 to 38 GL between 2005–06 and 2009–10. Despite no water restrictions being in place, there was less surface water used in 2009–10 as compared to 2008–09 which may be due to increased community awareness of the need to conserve water. Groundwater use was 3.6 and 5.5 GL in 2005–06 and 2009–10, respectively. This illustrates an increasing trend in groundwater use for the area.

The use of recycled water is less in Darwin than compared with other major cities in Australia. About 0.36 GL of water was sourced from recycling in 2005–06. Most of the recycled water was used for a range of activities such as the irrigation of agriculture, vineyards, market gardens, conservation areas and golf courses.

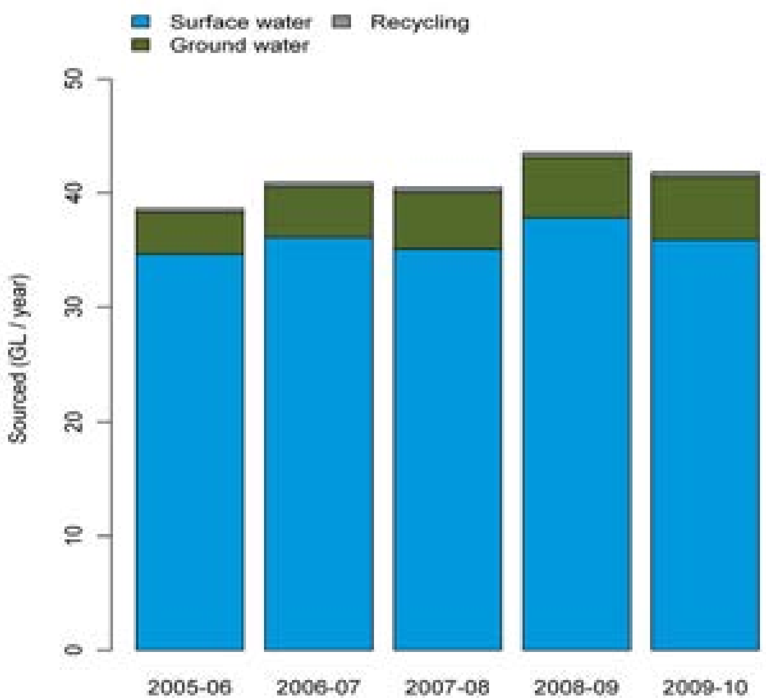


Figure 13-17. Total urban water sourced for the Darwin water supply area from 2005–06 to 2009–10

13.6.2 Darwin water supply area (continued)

Figure 13-18 (National Water Commission 2011a) shows total volume of water delivered to residential, commercial, municipal and industrial consumers by the Power and Water Corporation. From 2005–06 to 2008–09, between 50 and 55 per cent of the water was supplied for residential use and between 41 and 45 per cent was for commercial, municipal and industrial use. The total water use increased slowly from 35 GL to 38 GL between 2005–06 and 2008–09 largely due to population increase. The commercial, municipal and industrial use of water was about 16 GL in 2005–06 and 15 GL in 2009–10. Similarly, the water used for other purposes dropped from 1.6 GL to 0.6 GL during this period.

Based on the figures provided in the *National Performance Report* (National Water Commission 2011a) for population and total water supplied, the per capita water use is estimated to be 892 litres/day in 2005–06 and 855 litres/day in 2009–10. This represents per capita water savings of 37 litres/day. This water saving did not arise from water restrictions and may be due to an increased public awareness of the need to conserve water.

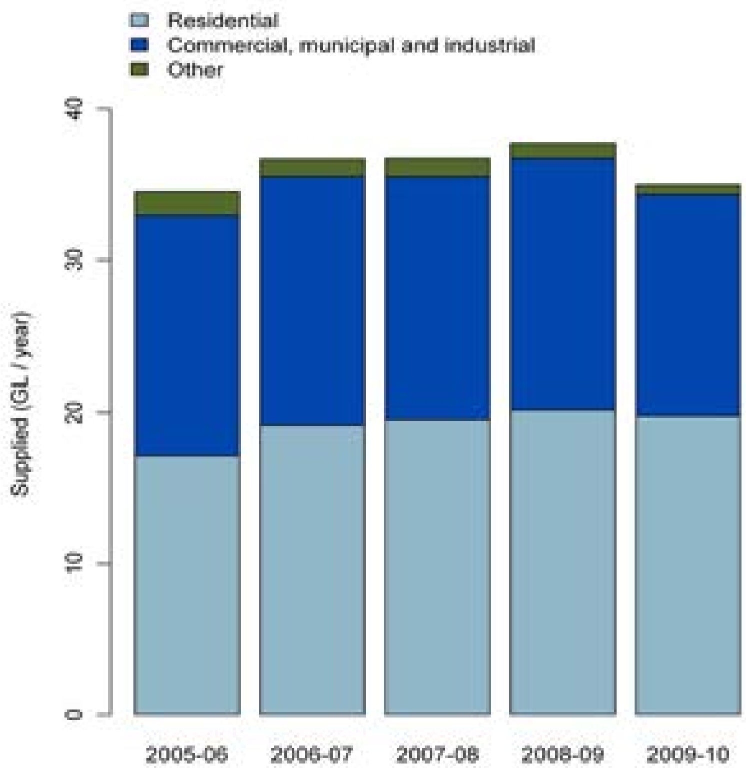


Figure 13-18. Total urban water supplied to the Darwin water supply area from 2005–06 to 2009–10

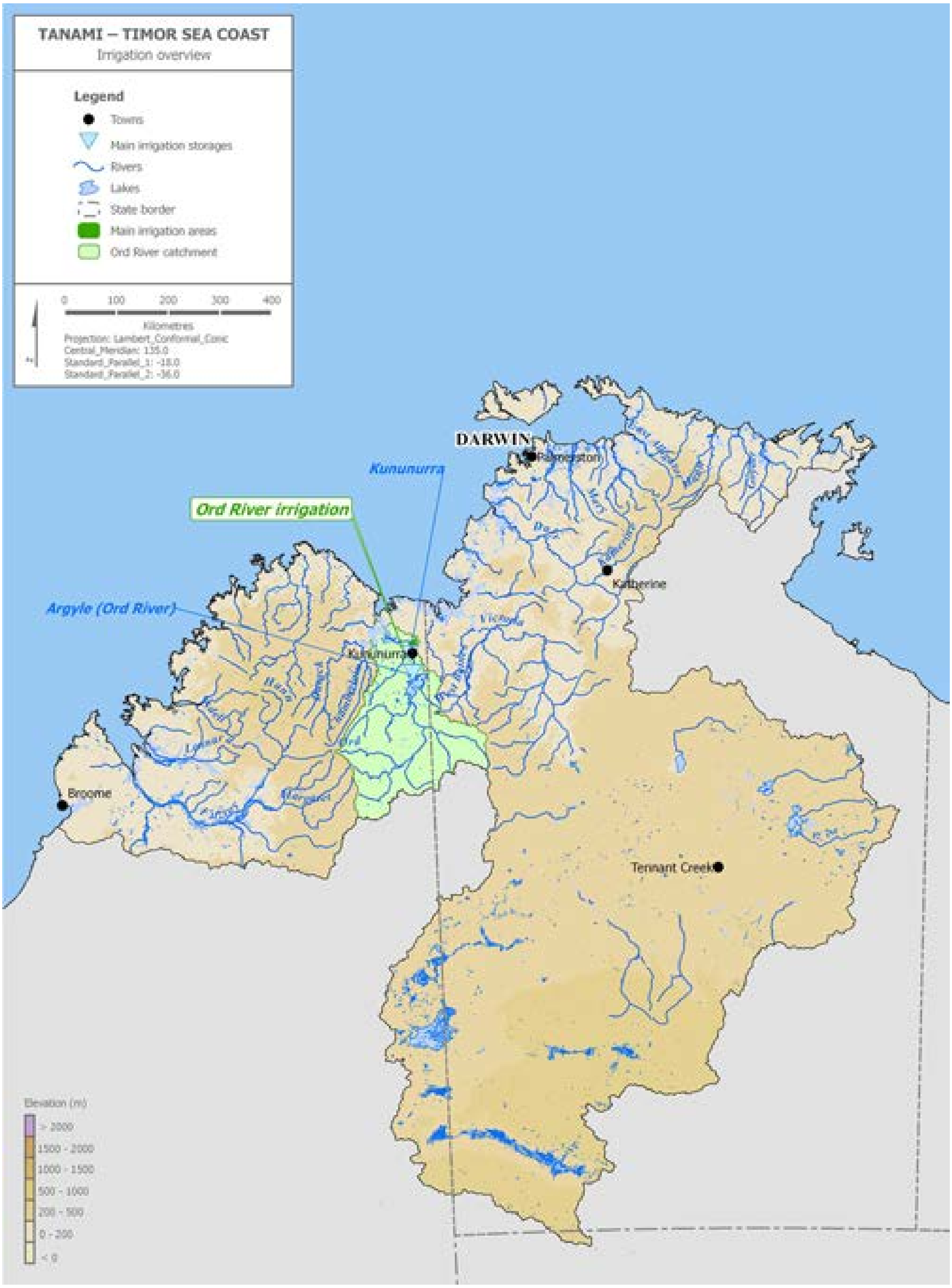


Figure 13-19. Context map of irrigation areas and infrastructure in the Tanami – Timor Sea Coast region

13.7 Water for agriculture

The Tanami – Timor Sea Coast region extends across a range of climatic zones including a humid tropical climate to the north and arid conditions across the southern inland areas. In addition to nature conservation, much of the region is pastoral lands. Irrigated agriculture constitutes only a very small portion (0.01 per cent) of the region and is concentrated in the Ord River catchment (Figure 13-19).

13.7.1 Soil moisture

Upper soil moisture content during the summer (November to April) of 2009–10 shows a mix of average, below average and above average conditions across dryland agricultural areas. Below average conditions were estimated in some central areas to the south of Darwin (Figure 13-20).

Upper soil moisture content for the winter (May to October) of 2010 shows a notable increase since the summer period. Almost the entire region demonstrates very much above average conditions (Figure 13-20). This increase in soil moisture is a result of above average summer and autumn rainfall experienced through to April and May 2010.

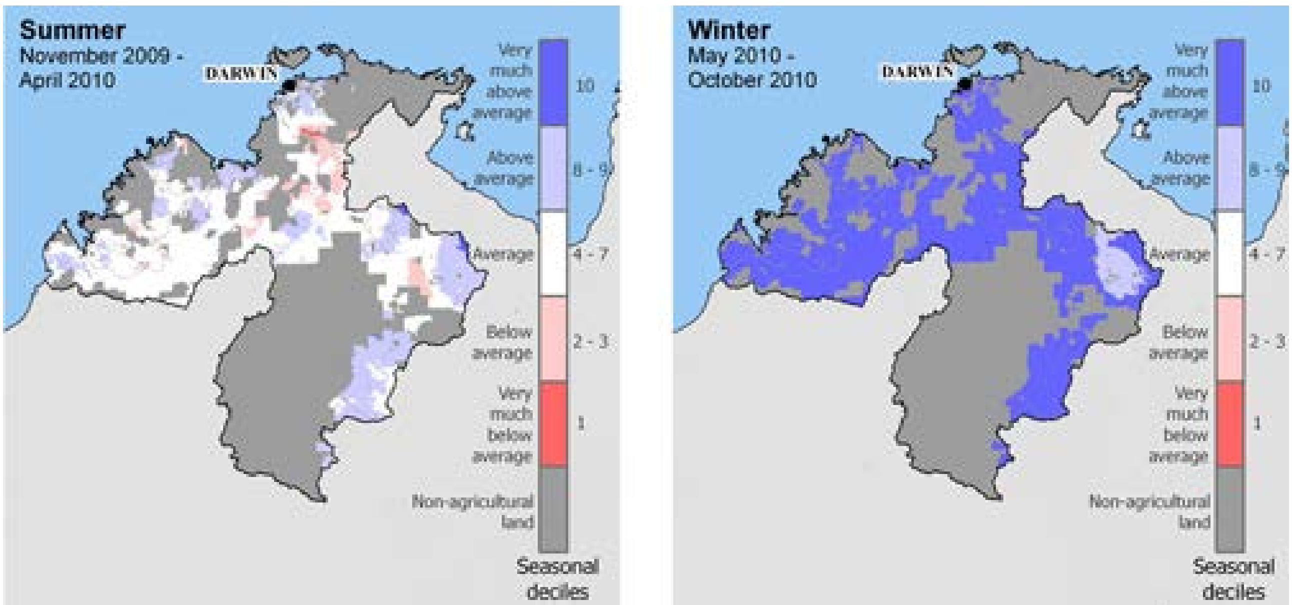


Figure 13-20. Deciles rankings over the 1911–2010 period for modelled soil moisture in the summer (November–April) and winter (May–October) of 2009–10 for the Tanami – Timor Sea Coast region

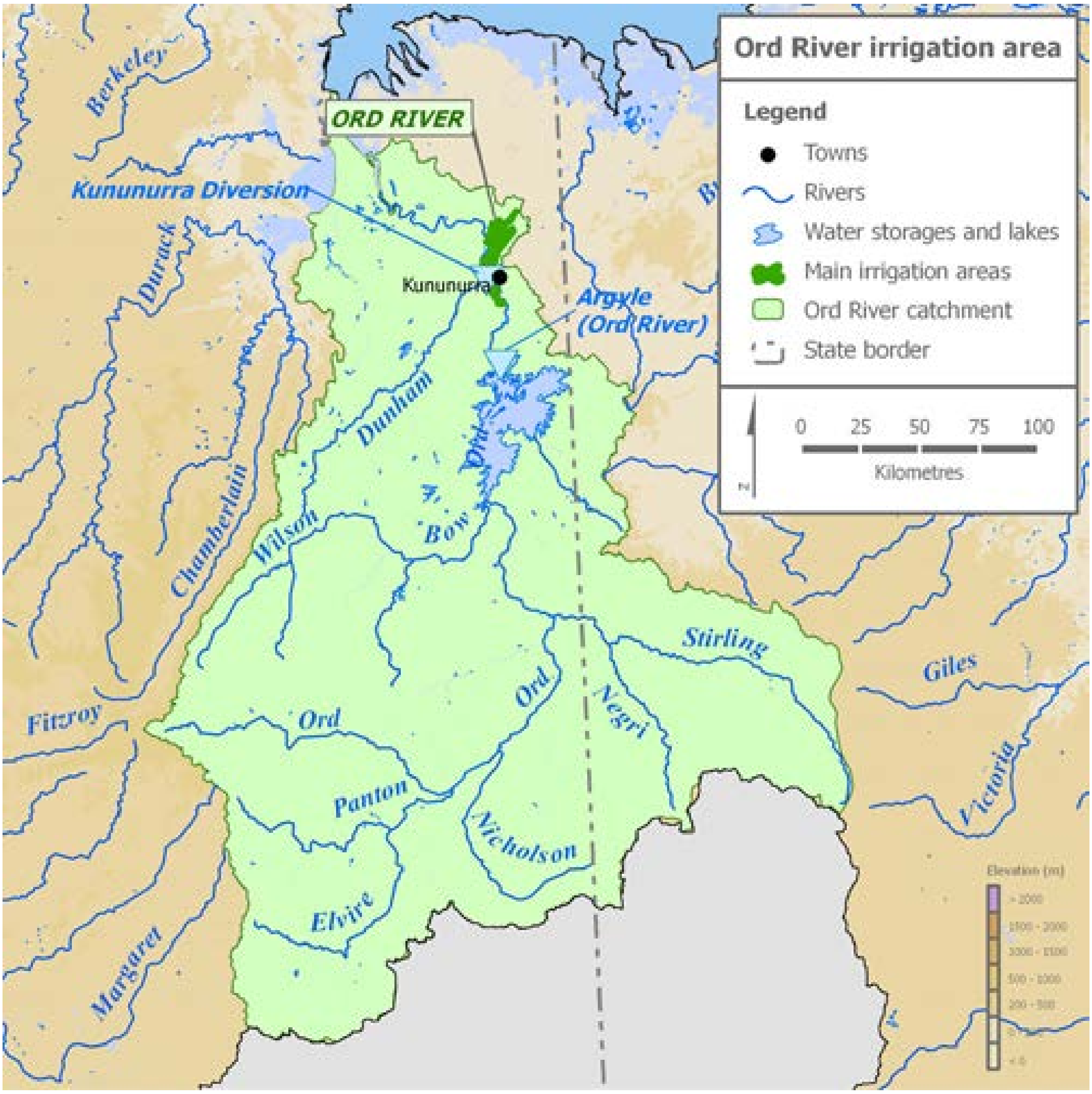


Figure 13-21 Overview map of the Ord River catchment

13.7.2 The Ord River Irrigation Area

The Ord River catchment, located in the east of northern Western Australia, contains the region's major irrigation area. The Ord River, 650 km long, is one of the major rivers of Western Australia. The main tributaries of the Ord River include the Negri, Wilson and Bow rivers (upstream of Lake Argyle), and the Dunham River, which joins the Ord River downstream of the Kununurra Diversion dam.

Rainfall is highly seasonal in the catchment, with over 90 per cent of annual rainfall occurring during the wet season (November to March). Average annual rainfall ranges from 780 mm in the north to 450 mm in the south.

Construction of major dams enabled the development of a 15,000 ha irrigation scheme at Kununurra as well as the generation of hydro-power. The main industries within the Ord River catchment are agriculture, horticulture, tourism and mining.

The Ord River dam was constructed in 1972 and this backs up river flows to form Lake Argyle which is the largest irrigation water storage in Australia (Figure 13-21). It has a hydro-power station which supplies over 90 per cent of the power to the towns of Wyndham and Kununurra, as well as to the Argyle diamond mine. The Kununurra Diversion dam, located 50 km downstream of Lake Argyle, enables water to be diverted for extensive irrigation areas near the town of Kununurra (Government of Western Australia Department of Water 2010a). Lake Argyle has an accessible storage capacity of approximately 10,700 GL. Water is released from Lake Argyle through a hydro-power outlet and a series of controlled release valves at the bases of the dam. Additional flow is released through a spillway plug to provide the dry season flow. These combined releases provide inflow into Lake Kununurra from where it is diverted to the Ivanhoe Plains systems and the Packsaddle pumping stations (Ord Irrigation 2011). The Ord Irrigation Cooperative provides water and drainage services to the farms within the Ord Irrigation Area.

13.7.2 The Ord River Irrigation Area (continued)

Annual rainfall (1907–2004) at Lake Argyle ranges from 302 to 1,637 mm and has a mean of 693 mm. Simulation of the Ord River system over a 100-year period showed that, despite the large storage capacity of Lake Argyle, prolonged dry periods could have a major impact on water supply reliability (Government of Western Australia Department of Water 2010b). It does, however, buffer the system against isolated drier years. Open water evaporation also accounts for a large component of loss from the lake.

The historic data (Figure 13-22) shows that the volume of water in the lake regularly exceeded its total storage capacity for short periods. In 2009–10, the water level in the storage changed from 95 per cent to just below 80 per cent of the accessible storage capacity.

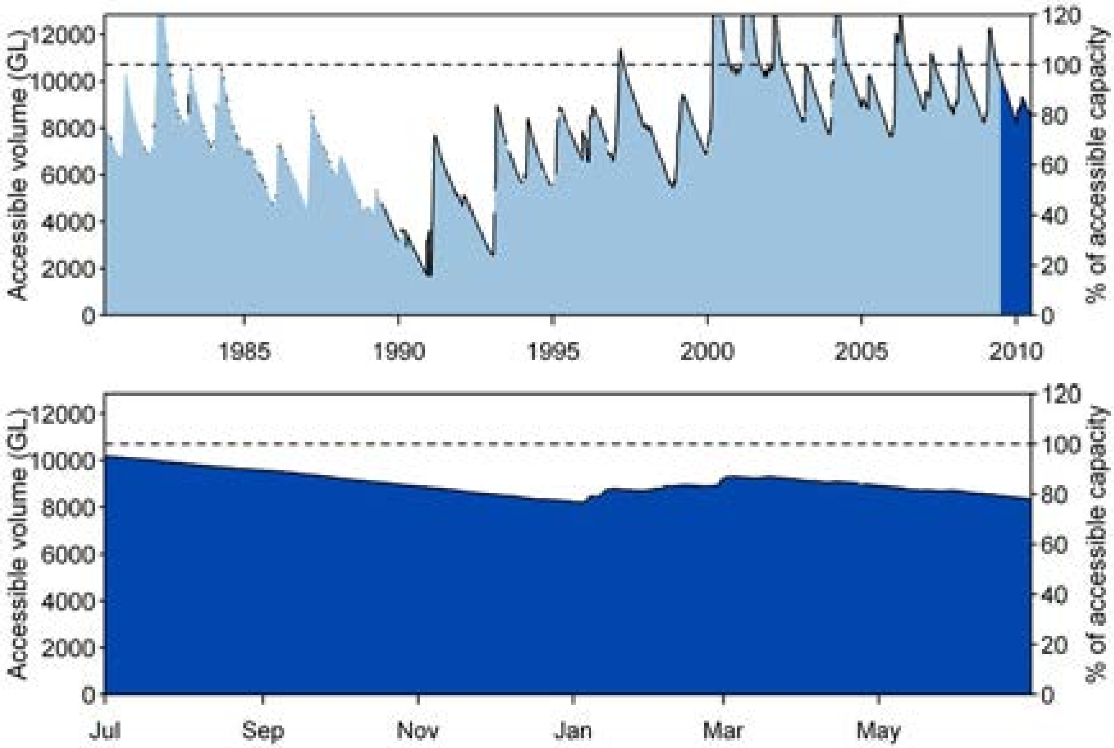


Figure 13-22. Water storage volumes available for irrigation at Lake Argyle since 1980 (left) and during 2009–10 (right). Gaps in the black line indicate unavailable data points

14. Lake Eyre Basin

14. Lake Eyre Basin

14.1 Introduction

This chapter examines water resources in the Lake Eyre Basin region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level.

Details for selected rivers, wetlands, groundwater, urban areas and agriculture are not addressed. At the time of writing, suitable quality controlled and assured information was not identified in the Australian Water Resources Information System (Bureau of Meteorology 2011a).

The chapter begins with an overview of key data and information on water flows in the region in recent times followed by a description of the region.

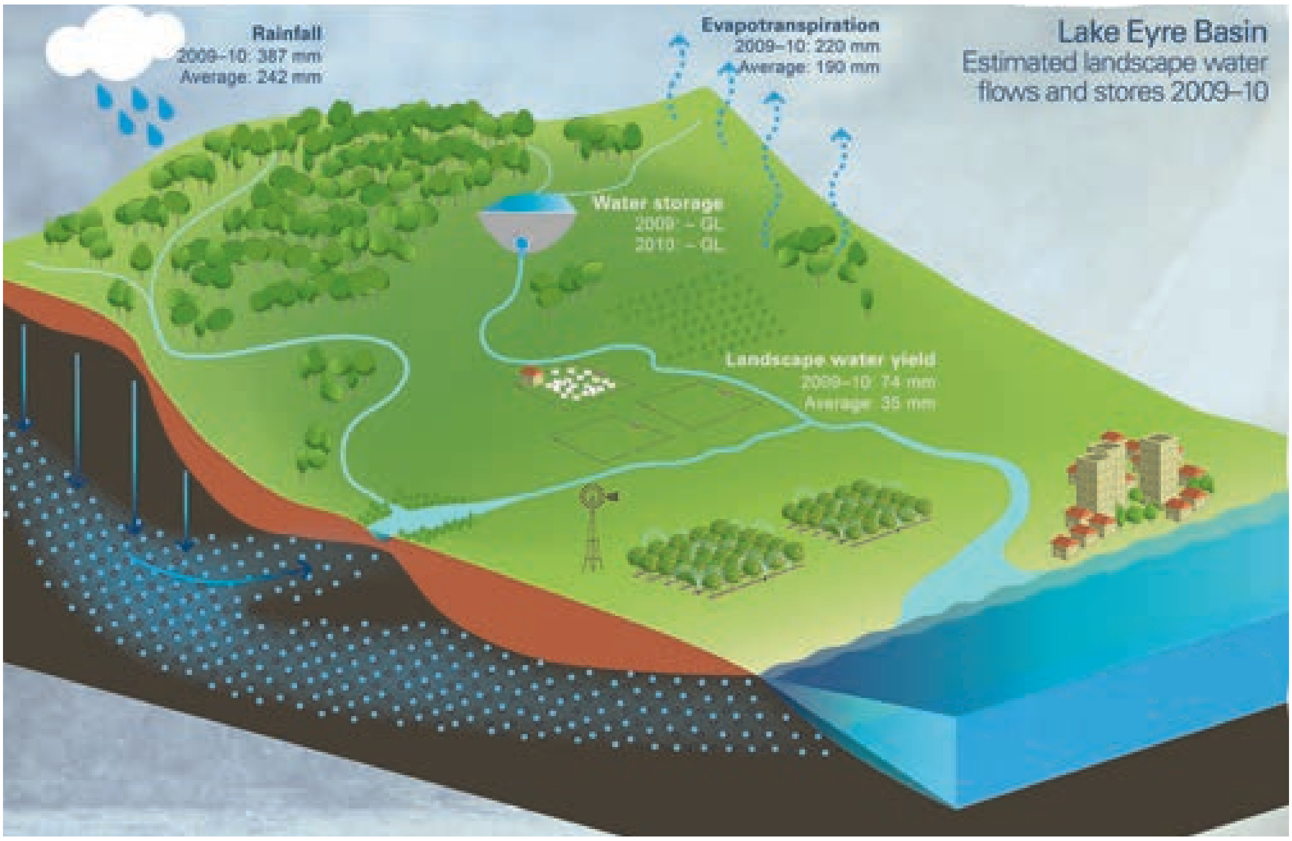


Figure 14-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) for the Lake Eyre Basin region

14.2 Key data and information

Figure 14-1 presents the 2009–10 annual landscape water flows in the Lake Eyre Basin region (no information is available for major storages in the region). The region experienced very much higher than average rainfall in 2009–10 (see Table 14-1) and this high level of water availability also resulted in very much above average levels of evapotranspiration and landscape water yield[1].

Table 14-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 14-1. Key information on water flows in the Lake Eyre Basin region[2]

Landscape water balance	During 2009–10			During the past 30 years	
	Region average	Difference from long-term mean	Rank (out of 99)*	Highest value (year)	Lowest value (year)
Rainfall	387 mm	+60%	92	421 mm (1999–2000)	168 mm (2002–03)
Evapotranspiration	220 mm	+16%	81	242 mm (2000–01)	160 mm (1982–83)
Landscape water yield	74 mm	+111%	96	74 mm (2009–10)	22 mm (2005–06)

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

14.3 Description of region

The Lake Eyre Basin region covers approximately 1.2 million km^2 of arid and semi-arid central Australia. It represents 17 per cent of the continent and stretches, north to south, from just below Mount Isa in Queensland to Marree in South Australia. From west to east, it extends from Alice Springs in the Northern Territory to Longreach and Blackall in central Queensland. Lake Eyre is the world's largest internally draining system and fifth largest terminal lake in the world.

The region's climate is arid throughout. Rainfall is much below potential evaporation and the region is driest in the northeast of the Lake Eyre Basin, but it receives some monsoonal rain from the upper reaches of the Diamantina and Georgina rivers.

Landforms are typical of desert conditions. The region mainly consists of plains, inland dunes, sandplains, floodplains, and low relief hills and plateaus. Seasonal or persistent aridity has resulted in low vegetation cover and intermittent river systems.

The region is divided into several major drainage catchments, including Cooper's Creek, Georgina–Diamantina, desert rivers, western rivers and Lake Frome basins. The major rivers in the region are the Georgina, Diamantina, Thomson and Barcoo rivers and Cooper Creek, which flow from central and western Queensland into South Australia; as well as the Finke, Todd and Hugh rivers in central Australia. These waterways all drain into Lake Eyre. The rivers and creeks are characterised by high variability and unpredictability in their flow with high transmission losses and very low gradients. All creeks and rivers of the basin are ephemeral with short periods of flow following rain and long periods with no flow.

The region includes only two Ramsar wetland sites (Coongie Lakes and Lake Pinaroo), which are an important habitat for rare bird species. These lakes only fill under unusually high rainfall intensities northeast of the lakes and, when full, they can hold water for several years.

The region is sparsely populated, with about 57,000 people. Approximately 26,000 live in Alice Springs. The major towns (with a population greater than 1,000) are Alice Springs, Birdsville, Longreach and Winton. Alice Springs and most other towns in central Australia rely almost completely on groundwater aquifers as a source of water. A large portion of the Alice Springs municipal area is situated on a floodplain of the Todd River.

There are no reported major water storages in the region and irrigated agriculture is only practised very locally in the northeast.

Most of the land use within the Lake Eyre Basin is pasture and nature conservation (Figure 14-2). There are numerous dry lakes which form a substantial part of the region. Only a small patch in the far south includes some dryland agriculture.

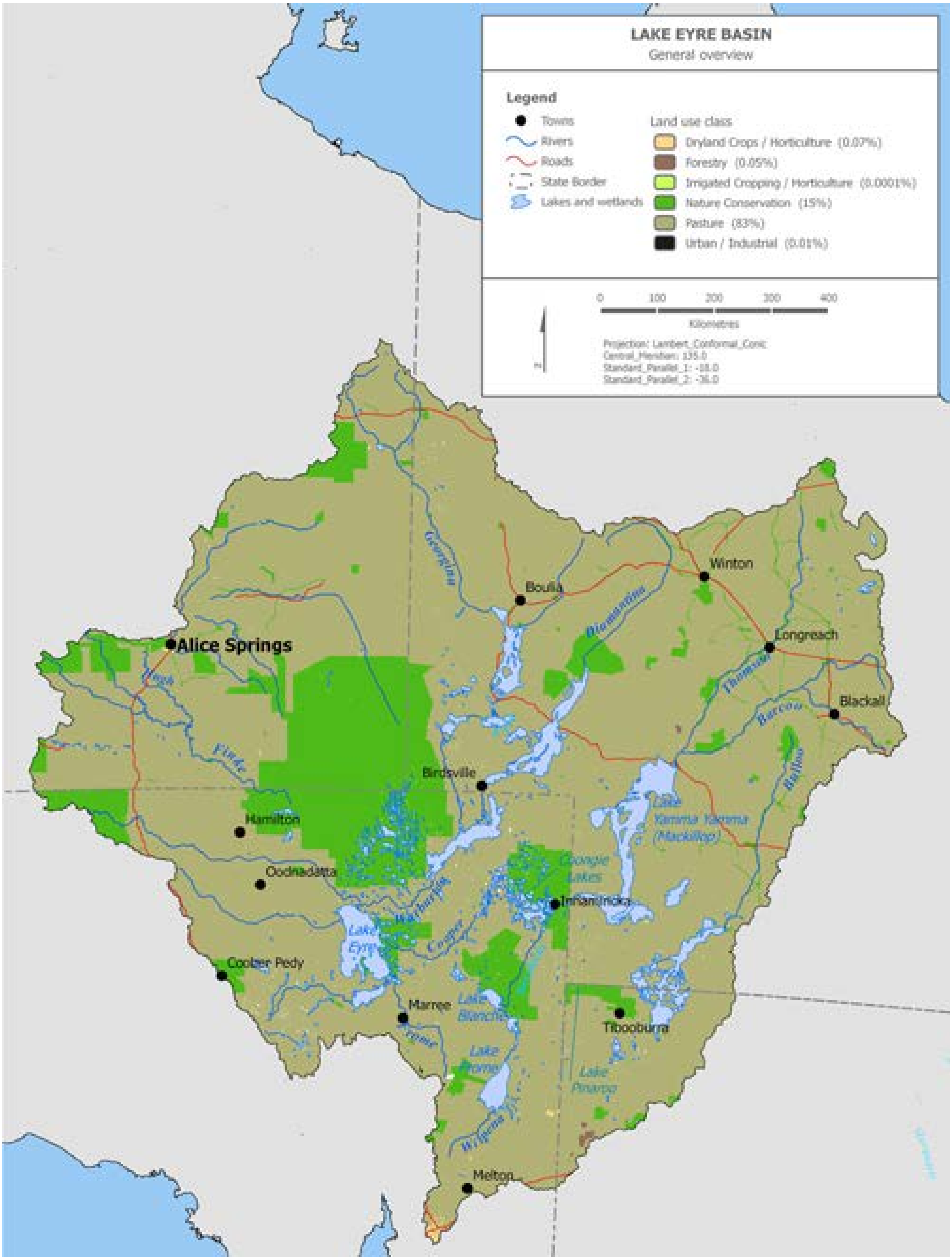


Figure 14-2. Key landscape and hydrological features of the Lake Eyre Basin region (land use classes based on Bureau of Rural Sciences 2006)

14.3 Description of region (continued)

The hydrogeology of the region is dominated by the sediments of the Great Artesian Basin (GAB) with porous sandstone aquifers of the Triassic, Jurassic and Cretaceous. This groundwater basin underlies the Lake Eyre Basin from the northeast, (Figure 14-3), and extends through to the central and southwest margins of the Lake Eyre Basin.

It is one of Australia's most significant groundwater basins. There is notable extraction of groundwater for stock and domestic purposes. The areas identified as Palaeozoic fractured rock (low permeability) in the northwest of this region typically offer restricted low volume groundwater resources. In contrast, the areas identified as fractured and karstic and Palaeozoic fractured rock (consolidated and partly porous) offer a usable groundwater resource in some parts. These units provide 95 per cent of the town water supply for Alice Springs.

The major watertable aquifers present in the region are given in Figure 14-3 (extracted from the Bureau of Meteorology's Interim Groundwater Geodatabase). Groundwater systems that provide more potential for extraction are labelled as:

- fractured and karstic rocks (regional) and (local)
- Mesozoic (porous media – consolidated)
- Mesozoic sediment aquifer (porous media – consolidated).

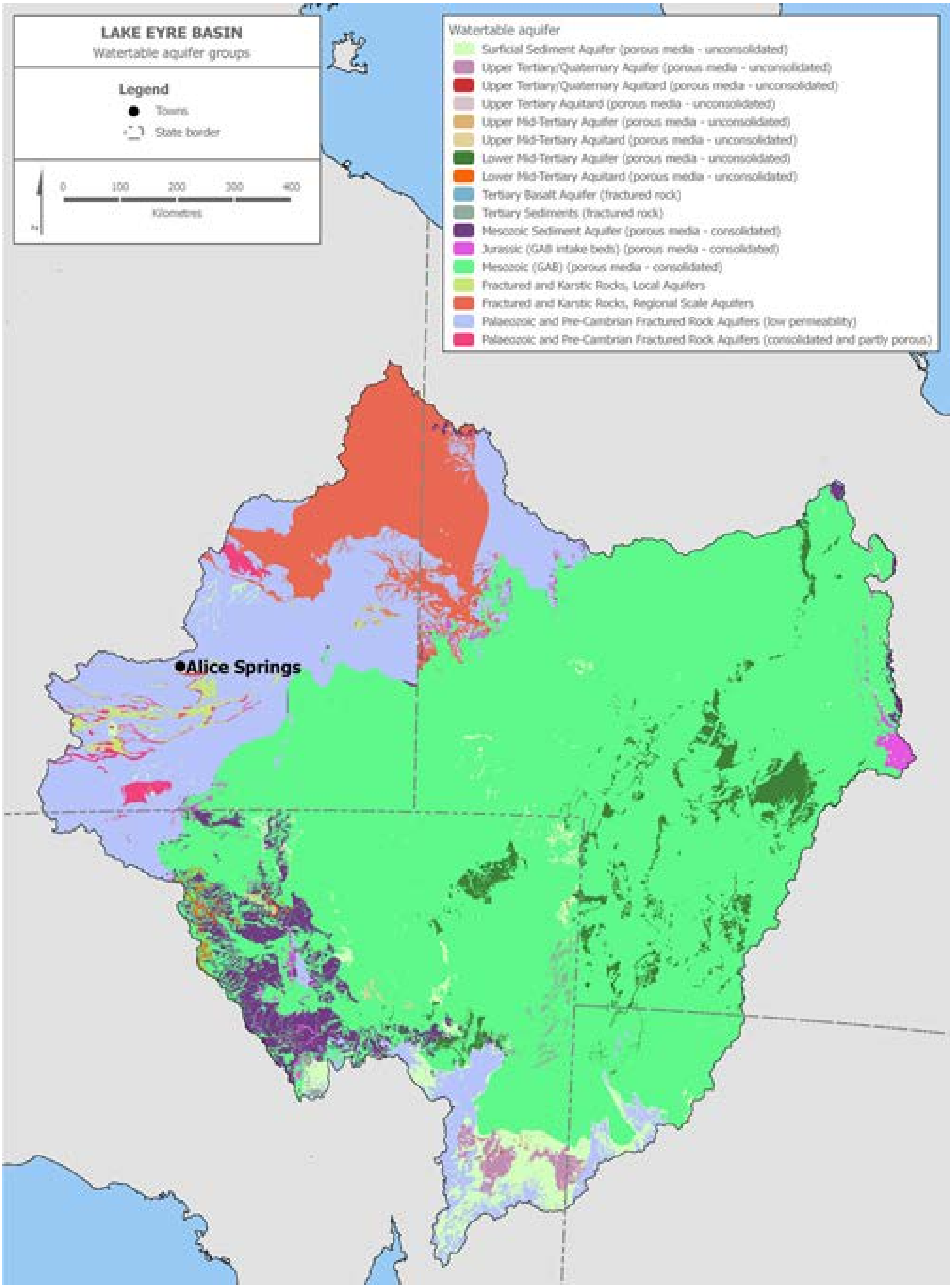


Figure 14-3. Watertable aquifer groups in the Lake Eyre Basin region (Bureau of Meteorology 2011e)

14.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Some areas of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data or absence of model parameter data for areas such as salt lakes, salt pans and inland water. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 14-4 shows that the Lake Eyre Basin region experienced a generally drier than average start to 2009–10 (July to October). The relatively dry start to the year was followed by a wetter than usual summer (November to April), especially in February 2010.

This period of high rainfall was due in large part to a significant rain event in the middle of February and to a monsoonal low event of late February/early March 2010 that generated widespread heavy, and in some places record-breaking, rainfall across much of central and eastern Australia (Bureau of Meteorology 2011d). Total rainfall for February 2010 represented the second highest February total in the long-term record (July 1911 to June 2010).

The extremely high rainfall during the summer of 2009–10 led to very much higher than normal evapotranspiration rates from January through to April 2010. As rainfall returned to more normal monthly levels towards the end of the year, evapotranspiration losses were also within the typical range.

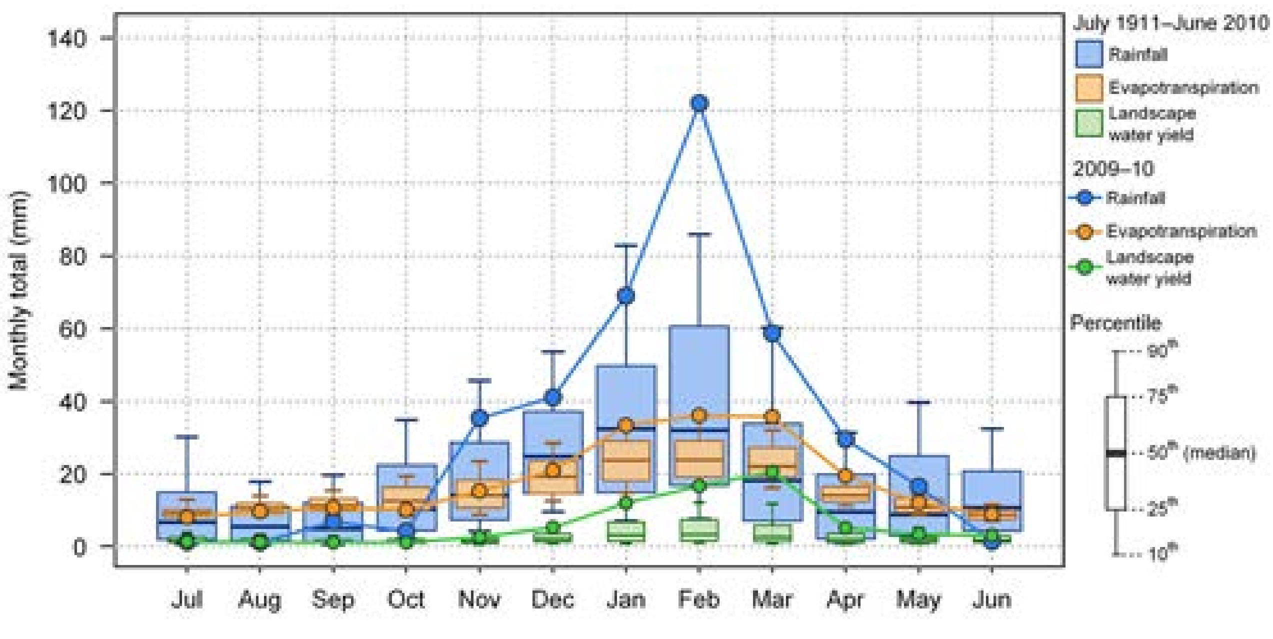


Figure 14-4. Monthly landscape water flows for the Lake Eyre Basin region in 2009–10 compared with the long-term record (July 1911 to June 2010)

14.4 Recent patterns in landscape water flows (continued)

Despite the higher than normal estimated evaporative losses through the wet summer of 2009–10, monthly modelled landscape water yield from November 2009 through to June 2010 was very much higher than normal for the region. The months from February to April 2010 experienced total landscape water yields in the highest decile range for their respective months in the long-term record (July 1911 to June 2010).

14.4.1 Rainfall

Rainfall for the Lake Eyre Basin region for 2009–10 was estimated to be 387 mm, which is 60 per cent above the region's long-term (July 1911 to June 2010) average of 242 mm. Figure 14-5 (a)[3] shows that during 2009–10 the highest rainfall was experienced across the north and northeast of the region. Total rainfall for the year shows a general decreasing gradient running from the northeast to the southwest. Rainfall deciles for 2009–10, shown in Figure 14-5 (b), indicate rainfall was above average across the majority of the region, with very much above average rainfall occurring across much of the east, centre and west.

Figure 14-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 168 mm (2002–03) to 421 mm (1999–2000). The annual average for the period was 257 mm. The data show that the rainfall experienced in 2009–10 represents the second highest annual total of the past 30 years and follows a period of relatively low annual rainfall since 2001–02.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 14-6 (b). The seasonal distribution of rainfall for the region is characterised by higher summer than winter rainfall. The summer rainfall averages exhibit a higher level of variability over the 30-year period, particularly for the relatively wet years of 1999–2000 and 2009–10, which are not reflected in the winter period rainfall averages.

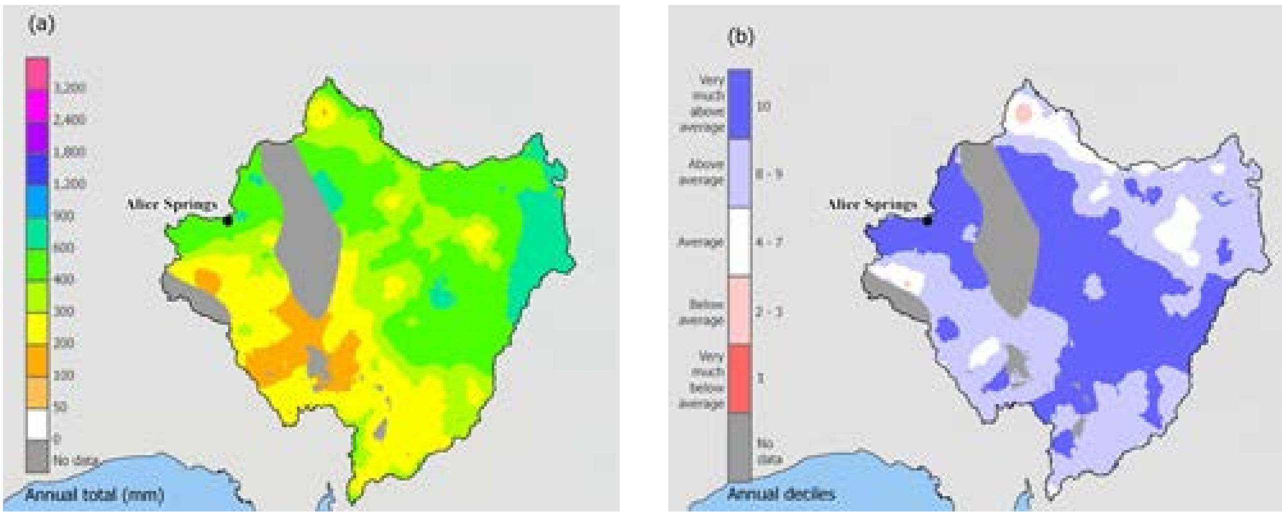
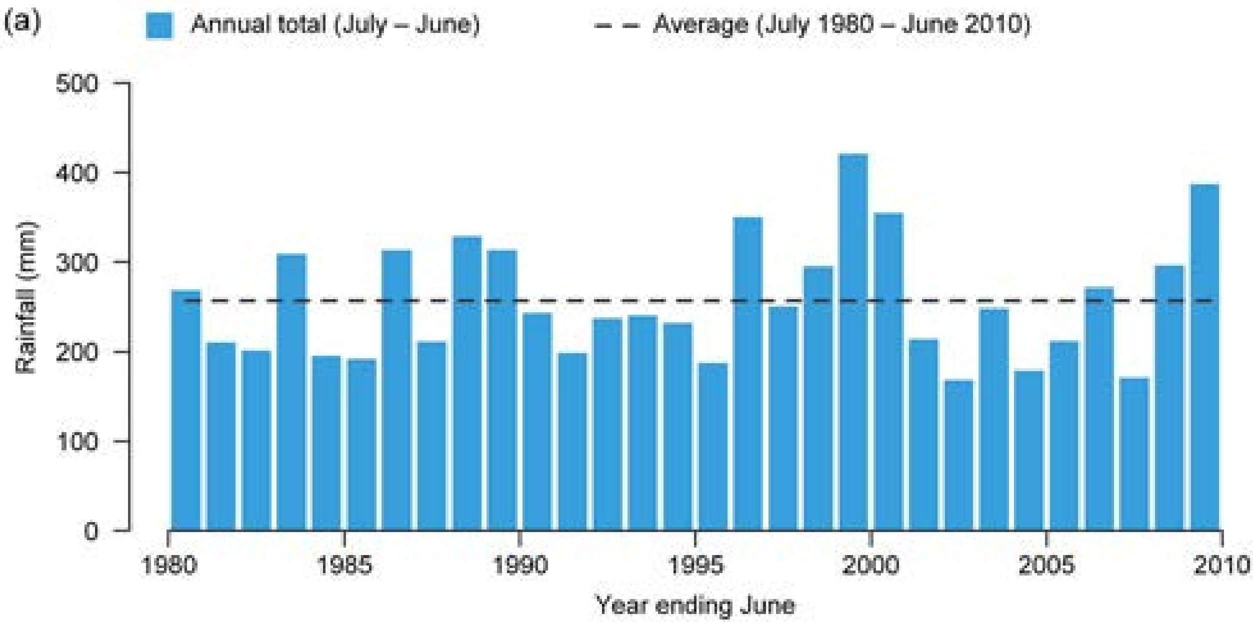


Figure 14-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Lake Eyre Basin region

3. Areas where rainfall interpolation was assessed to be greater than 20 per cent unreliable for any period of the long-term record were excluded from the landscape water balance modelling (classified as 'No data'). More details are presented in the Technical supplement.



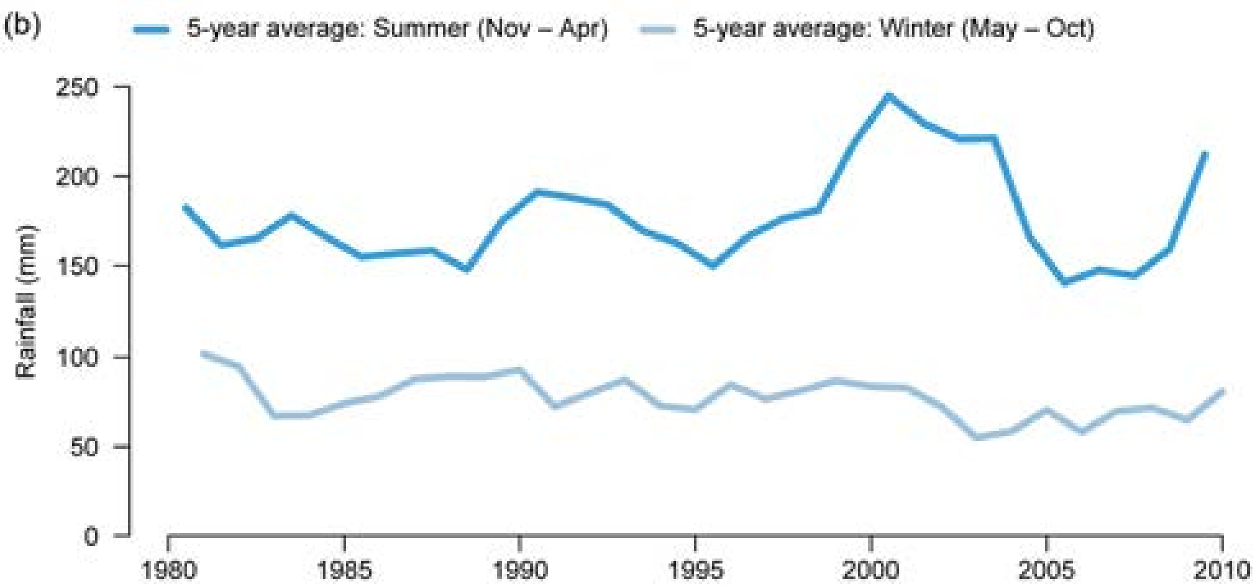


Figure 14-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Lake Eyre Basin region

14.4.1 Rainfall (continued)

Figure 14-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The summer period rainfall shows generally positive trends across the region, with strongest increases in the north and northeast. Slight negative trends are observed across the south and southwest of the region. The analysis of the winter period rainfall indicates reductions in rainfall across much of the north and east of the region. Slight increasing trends are identified across the centre and west of the region.

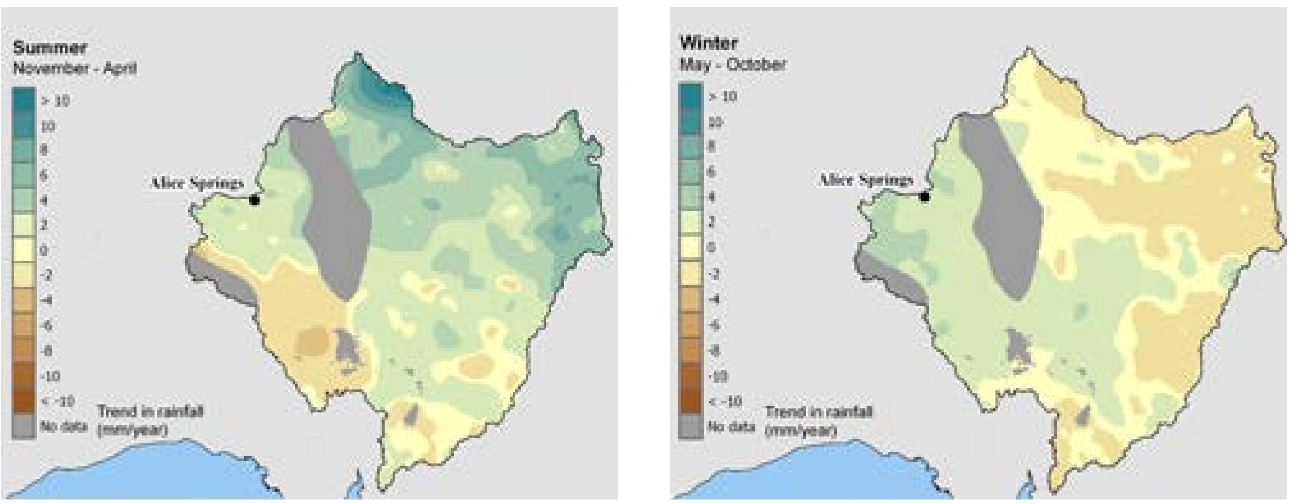


Figure 14-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Lake Eyre Basin region. The statistical significance of these trends is often very low

14.4.2 Evapotranspiration

Evapotranspiration for the Lake Eyre Basin region for 2009–10 was estimated to be 220 mm, which is 16 per cent above the region's long-term (July 1911 to June 2010) average of 190 mm. Figure 14-8 (a) shows that evapotranspiration for 2009–10 has a similar regional distribution to annual rainfall (Figure 14-5 [a]). The highest values were estimated in the wetter north and northeast areas with a generally decreasing gradient from north to south. Evapotranspiration deciles for 2009–10, shown in Figure 14-8 (b), indicate above average levels were experienced across almost the entire region. Very much above average values are estimated across much of the southern half of the region.

Figure 14-9 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual evapotranspiration ranged from 160 mm (1982–83) to 242 mm (2000–01). The annual average for the period was 197 mm. The data show evapotranspiration for the past two years was above the 30-year average following a period of relatively low annual evapotranspiration.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 14-9 (b). Winter period evapotranspiration averages remain relatively consistent over the 30 years, whereas the summer period averages show higher levels of variability, particularly over the second half of the period.

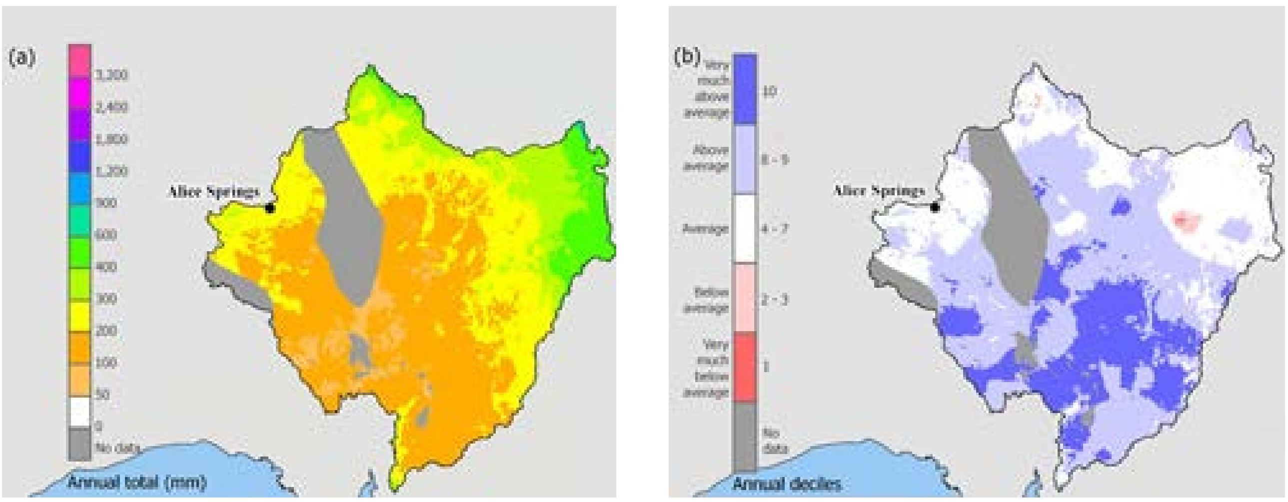


Figure 14-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Lake Eyre Basin region

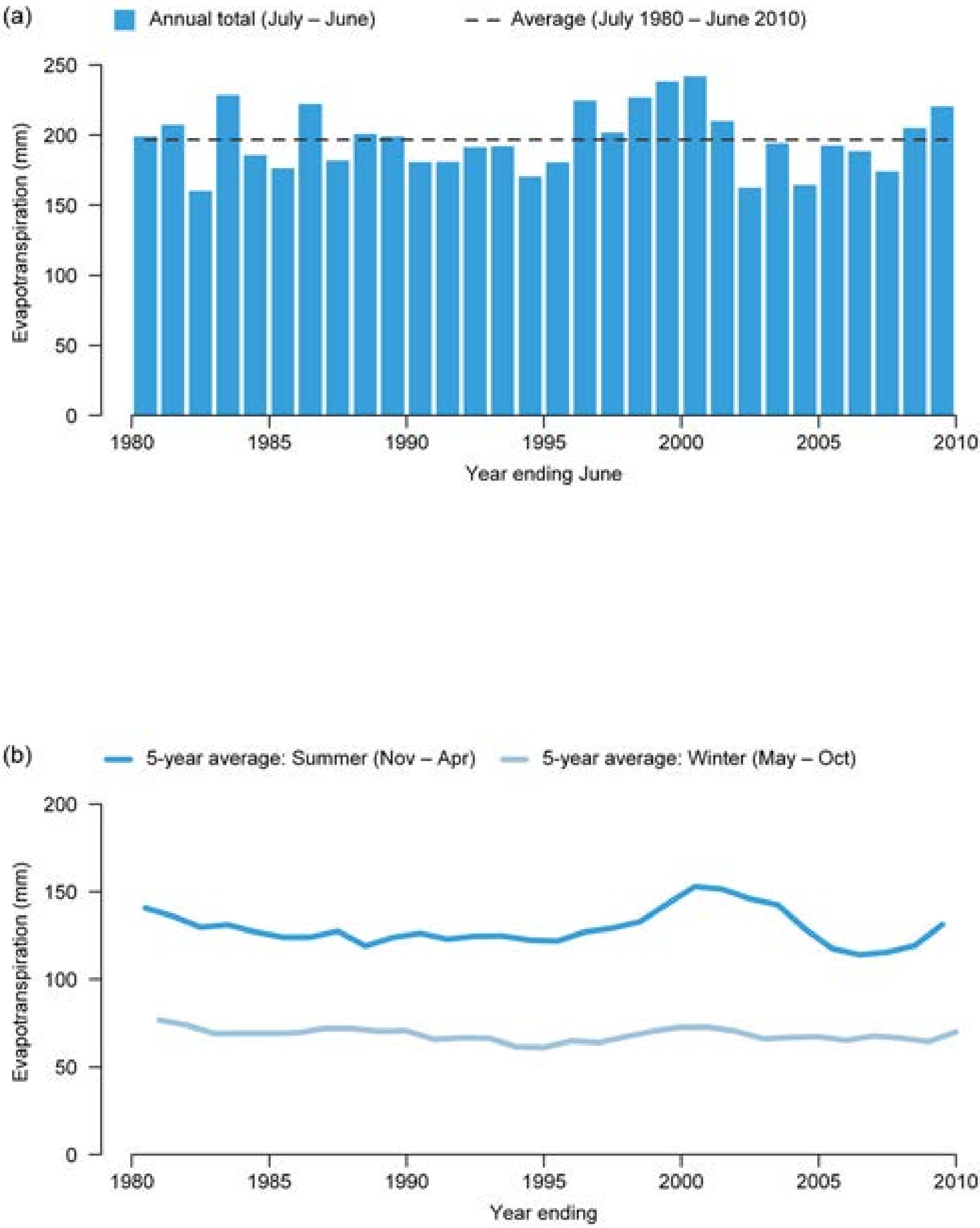


Figure 14-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Lake Eyre Basin region

14.4.2 Evapotranspiration (continued)

Figure 14-10 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The summer period analysis indicates very slight increases in evapotranspiration across much of the north of the region with no clearly defined trends across the southern areas. The winter period analysis indicated no trend in evapotranspiration across the region over the 30-year period.

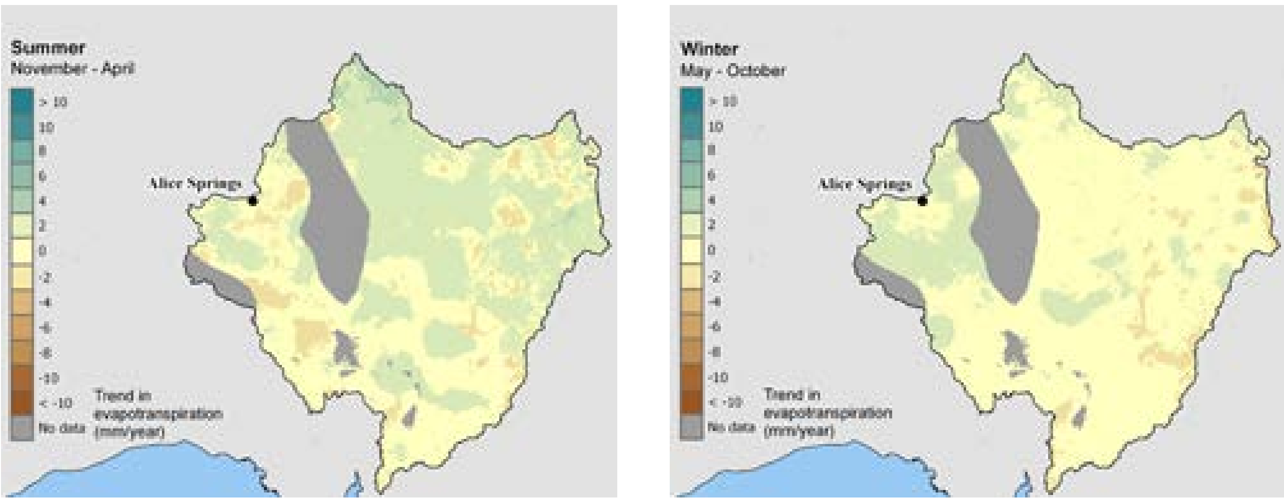


Figure 14-10. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Lake Eyre Basin region. The statistical significance of these trends is often very low

14.4.3 Landscape water yield

Landscape water yield for the Lake Eyre Basin region for 2009–10 was estimated to be 74 mm, which is 111 per cent above the region's long-term average (July 1911 to June 2010) of 35 mm. Landscape water yield for 2009–10, shown in Figure 14-11 (a), indicates that highest totals were experienced across the centre and northeast of the region. Lower levels are shown across the south of the region. Landscape water yield deciles for 2009–10, shown in Figure 14-11 (b), indicate much of the region experienced average or above average levels of landscape water yield. Very much above average values are observed across a large area in the centre of the region.

Figure 14-12 (a) shows annual landscape water yield for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield ranged from 22 mm (2005–06) to 74 mm (2009–10). The annual average for the period was 40 mm. The graph shows that total landscape water yield for 2009–10 was very much higher than the 30-year average with similarly high totals experienced in 1999–2000 and 2000–01.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 14-12 (b). Landscape water yield is consistently higher during the summer period than for the winter. The summer period average exhibits higher levels of variability over the 30-year period. The winter period shows a slight decreasing trend over time.

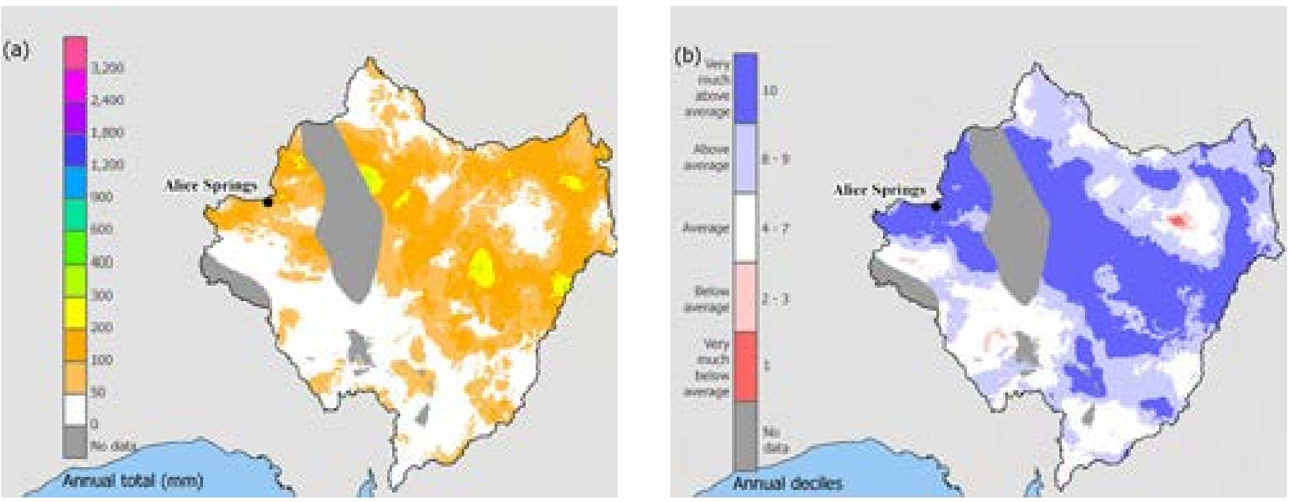


Figure 14-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Lake Eyre Basin region

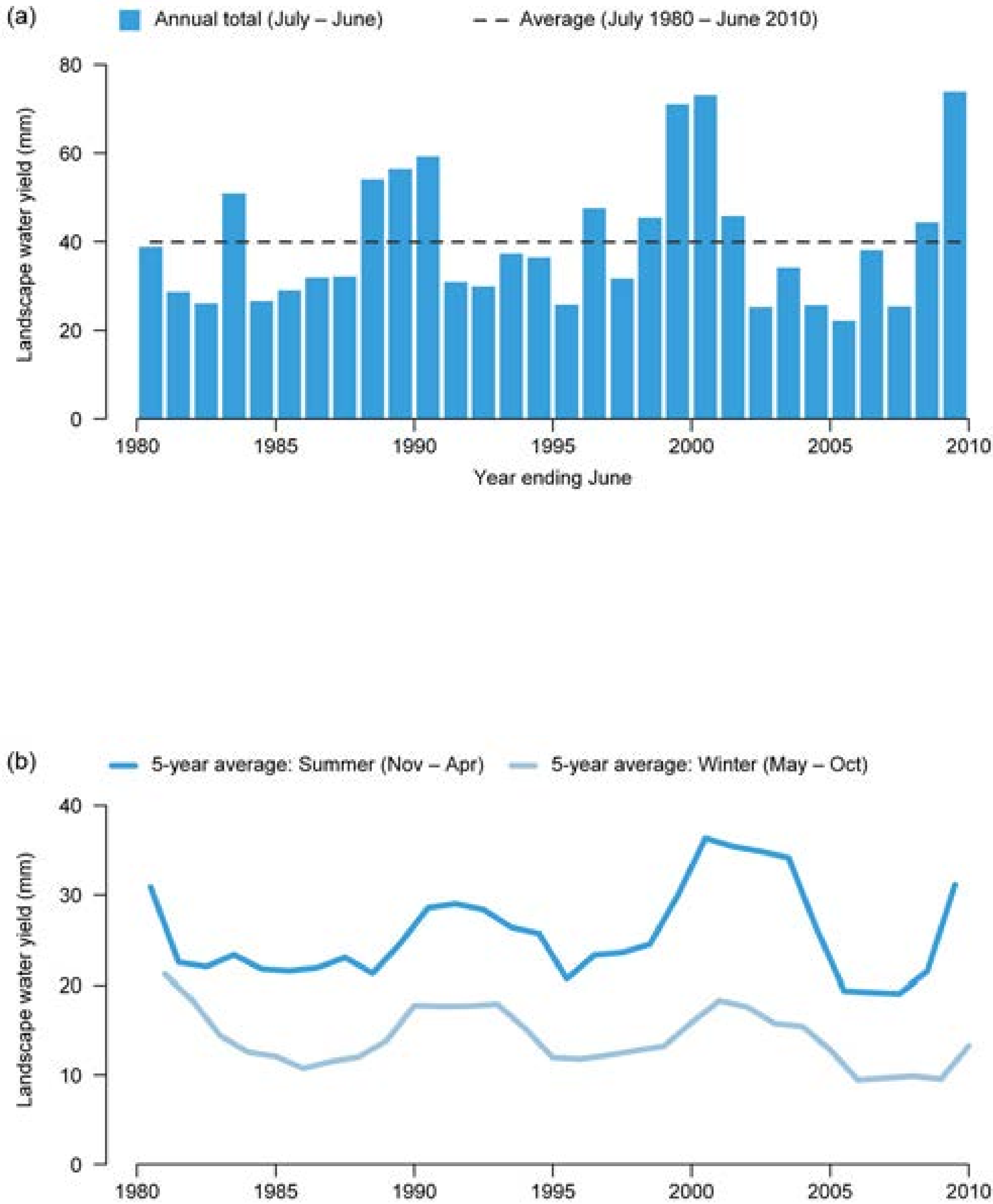


Figure 14-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Lake Eyre Basin region

Figure 14-13 provides a spatial representation of summer (November–April) and winter (May–October) landscape water yield trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The analysis for the summer period shows increases in landscape water yield across the north of the region with decreases apparent across the far south. The winter period shows no clear trends in the region.

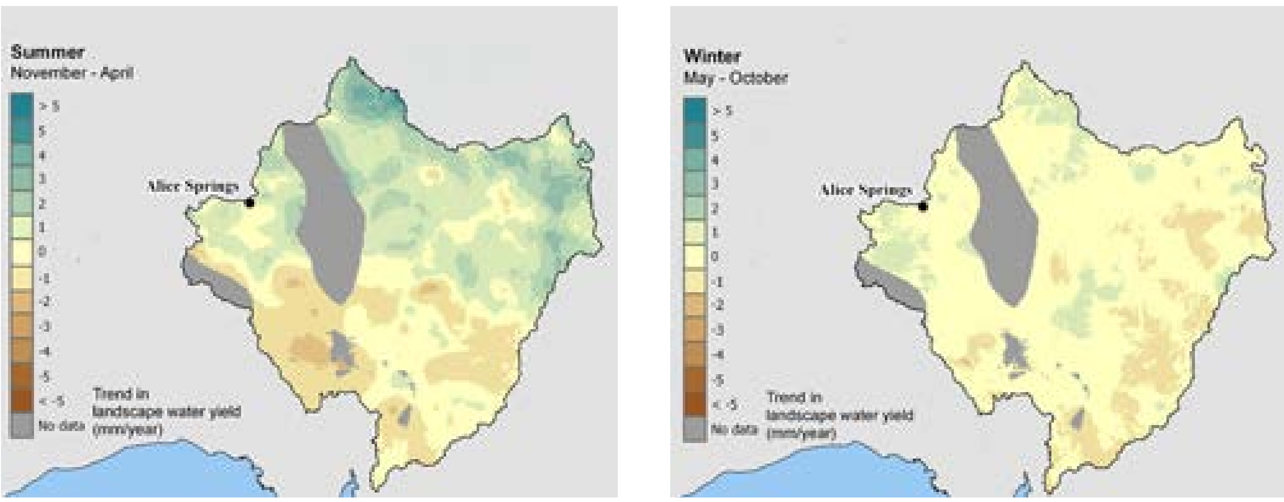
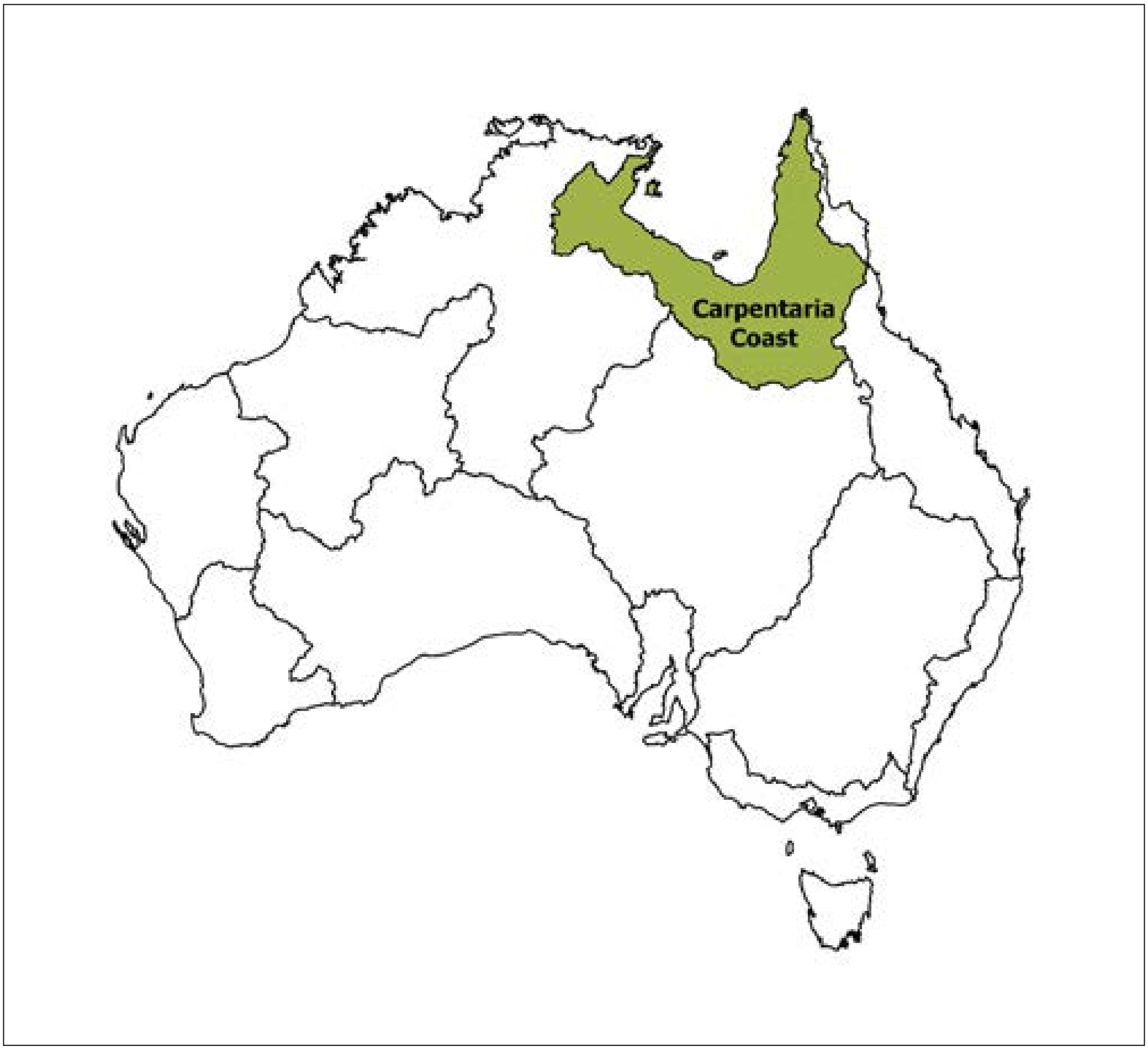


Figure 14-13. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Lake Eyre Basin region. The statistical significance of these trends is often very low

15. Carpentaria Coast

15. Carpentaria Coast



15.1 Introduction

This chapter examines water resources in the Carpentaria Coast region in 2009–10 and over recent decades. Seasonal variability and trends in modelled water flows, stores and levels are considered at the regional level.

Details for selected rivers, wetlands, groundwater, urban areas and agriculture are not addressed. At the time of writing, suitable quality controlled and assured surface water quality data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available.

The chapter begins with an overview of key data and information on water flows in the region in recent times followed by a description of the region.

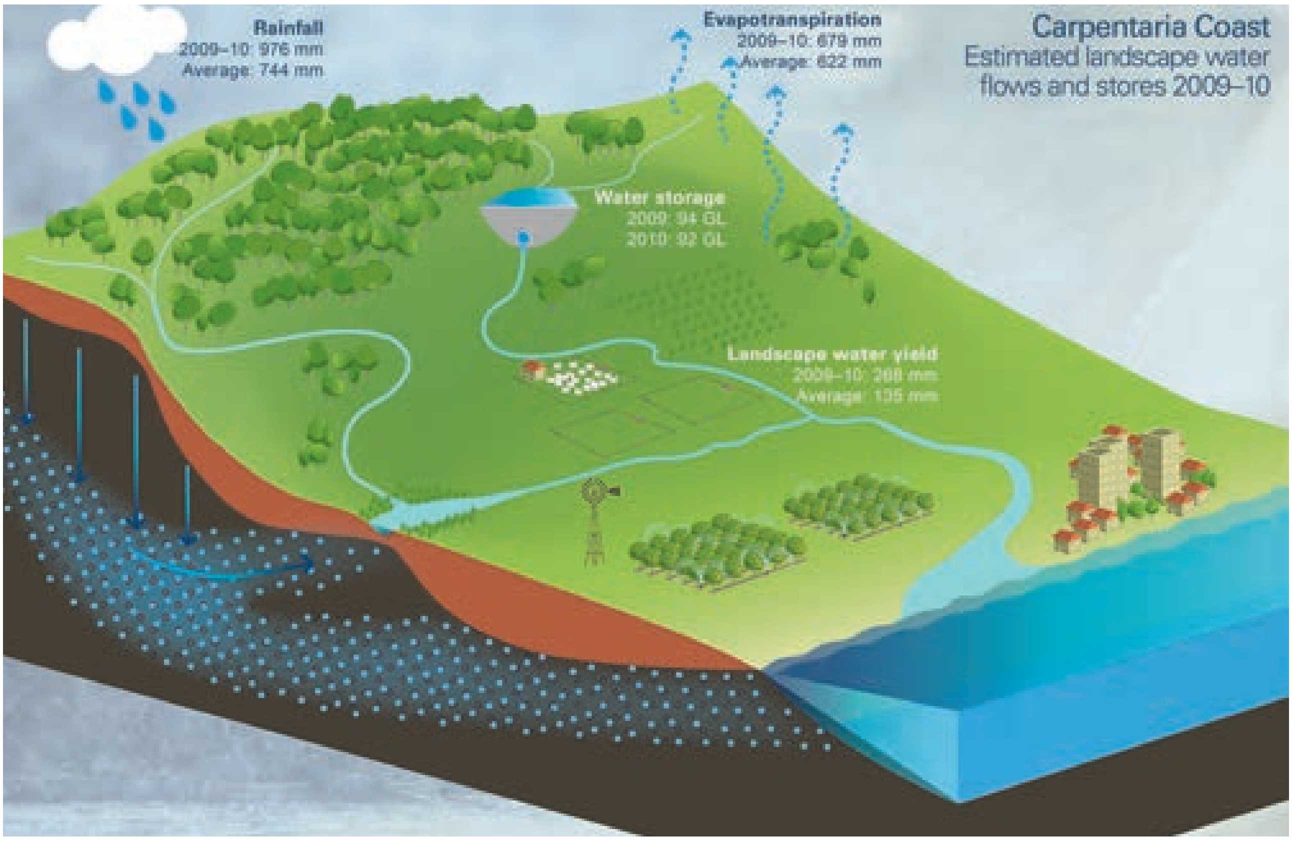


Figure 15-1. Overview of annual landscape water flow totals (mm) in 2009–10 compared to the long-term average (July 1911 to June 2010) and accessible surface water storage volumes (GL) for the 1st July 2009 and 30th June 2010 for the Carpentaria Coast region

15.2 Key data and information

Figure 15-1 presents the 2009–10 annual landscape water flows and the change in accessible surface water storage in the Carpentaria Coast region. The region experienced above average rainfall and evapotranspiration for 2009–10 and the high rainfall resulted in very much higher than average modelled landscape water yield[1] (see Table 15-1). The reported surface water storage in this region is Lake Julius (only 26 per cent of the total storage capacity in the region). Other main storages in the region that are not reported include Lake Mitchell and Lake Moondarra. The decrease in accessible volume, over the year given that this was a wetter than average year, was due to some deliberate releases from storage during May 2010.

Table 15-1 gives an overview of the key findings extracted from the detailed assessments performed in this chapter.

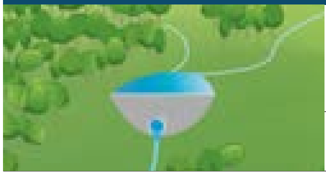
1. See Section 1.4.3 of Chapter 1–Introduction for the definition of this term.

Table 15-1. Key information on water flows and stores in the Carpentaria Coast region[2]

Landscape water balance

	During 2009–10			During the past 30 years	
	Region average	**Difference from long-term mean**	**Rank (out of 99)***	**Highest value (year)**	**Lowest value (year)**
Rainfall	976 mm	+31%	89	1,181 mm (2000–01)	496 mm (1987–88)
Evapotranspiration	679 mm	+9%	82	805 mm (2000–01)	549 mm (1987–88)
Landscape water yield	268 mm	+99%	94	358 mm (2008–09)	47 mm (1987–88)

Surface water storage (comprising approximately 26% of the region's total surface water storage)



Total accessible capacity	July 2009		June 2010		
	Accessible volume	**% of accessible capacity**	**Accessible volume**	**% of accessible capacity**	**% Change**
99 GL	94 GL	94.9%	92 GL	92.9%	-2.0%

* A rank of 1 indicates the lowest annual result on record, 99 the highest on record

2. See Section 1.4.3 of Chapter 1–Introduction for the definition of these terms.

15.3 Description of region

The Carpentaria Coast region covers approximately 647,000 km^2. The landscape is generally flat and low-lying. To the west is Arnhem Land and Groote Eylandt, the largest island in the Gulf. To the east is the Cape York Peninsula.

The climate is hot and humid with two distinct seasons per year. The dry season runs from about May to October and the monsoonal wet season from November to April. Almost all rainfall is compressed into two or three months.

Much of the region drains into the Gulf and comprises floodplains. The rivers, though mostly rather short, are very large by Australian standards and carry approximately a quarter of the continent's total yearly streamflow. Most rivers, however, flow only during the short wet season. Therefore, all perennial rivers and perennial springs are important sources of water. The main rivers flowing north to the Gulf of Carpentaria are the Mitchell, Flinders, Gilbert and Leichhardt rivers. The region includes no Ramsar wetland sites.

The region is sparsely populated, with about 56,000 people overall; approximately 23,000 of those are in the mining town of Mount Isa. The indigenous population is a significant component (more than 25 per cent) of the population.

The main urban centres (with more than 1,000 people) are Mount Isa, Cloncurry, Normanton, Doomadgee and Kowanyama. Mount Isa is the largest centre in this region. The Julius Dam and Moondarra Dam Water Supply Schemes, extracting water from Lake Julius and Lake Moondarra, are the major water supply sources for the Mount Isa area. Other centres source water supply predominantly from groundwater.

Pasture is the dominant land use (Figure 15-2). There are significant areas of nature conservation, Indigenous land use and some forestry. Irrigated agriculture only exists on a very local scale, supported by water from the two storages.

The hydrogeology of the region is dominated by the sediments of the Great Artesian Basin, fractured and karstic rock in some areas and some outcropping basement rock.

The Great Artesian Basin is one of Australia's largest and most significant groundwater basins with porous sandstone aquifers from the Triassic, Jurassic and Cretaceous periods. There is significant extraction of groundwater from this large resource for stock and domestic purposes. Fractured and karstic rock occurs in the Daly–Roper groundwater management unit (in the region's west) and Mount Isa groundwater management unit (in the south). In the hard rock of the basement, significant groundwater flow only occurs in rock fractures and this type of groundwater system typically offers restricted low volume groundwater resources.

The major watertable aquifers present in the region are given in Figure 15-3 (extracted from the Bureau of Meteorology's Interim Groundwater Geodatabase). Groundwater systems that provide more potential for extraction are labelled as:

- fractured and karstic rock
- Mesozoic (porous media – consolidated)
- Mesozoic sediment aquifer (porous media – consolidated)
- Surficial sediment aquifer (porous media – unconsolidated).

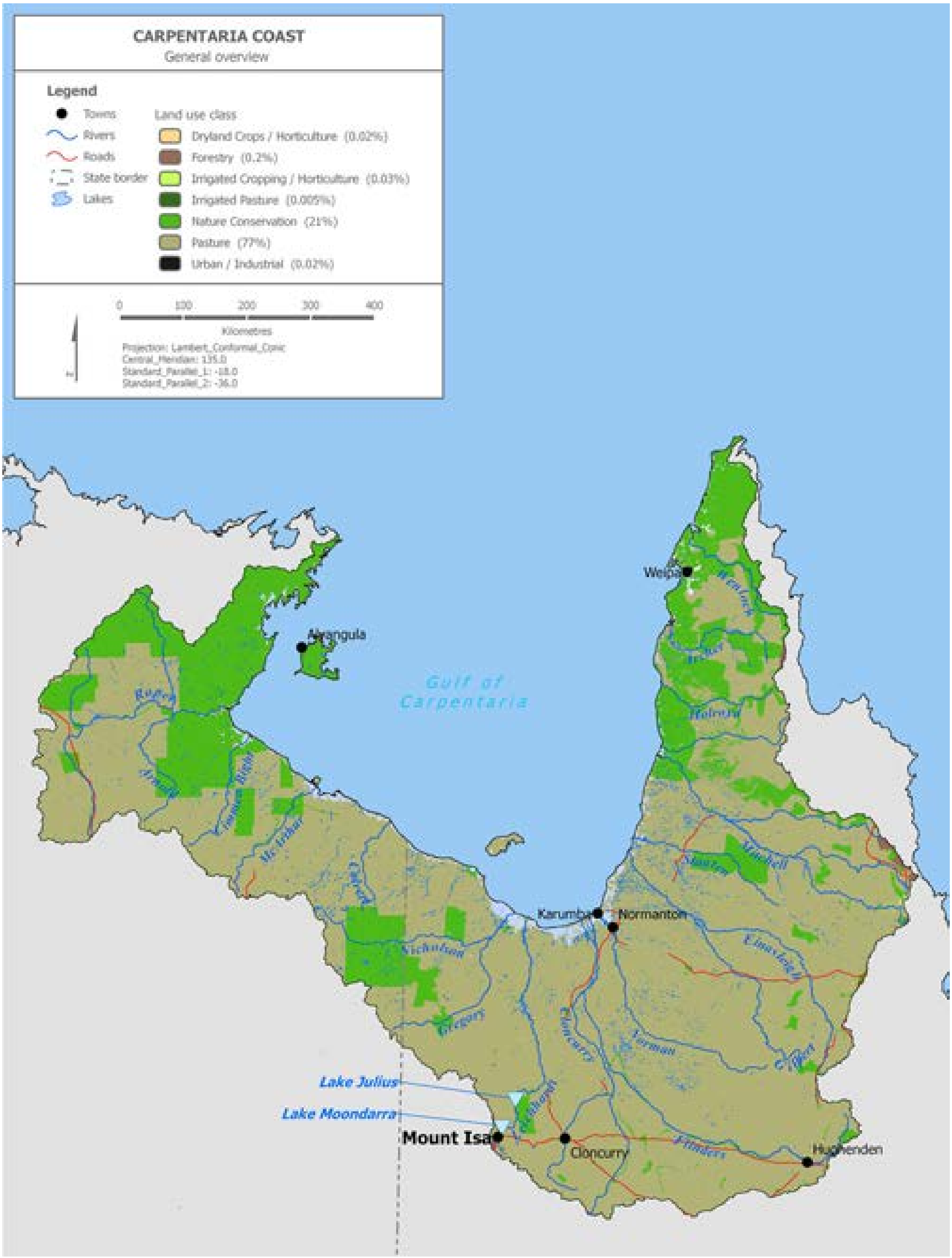


Figure 15-2. Key landscape and hydrological features of the Carpentaria Coast region (land use classes based on Bureau of Rural Sciences 2006)

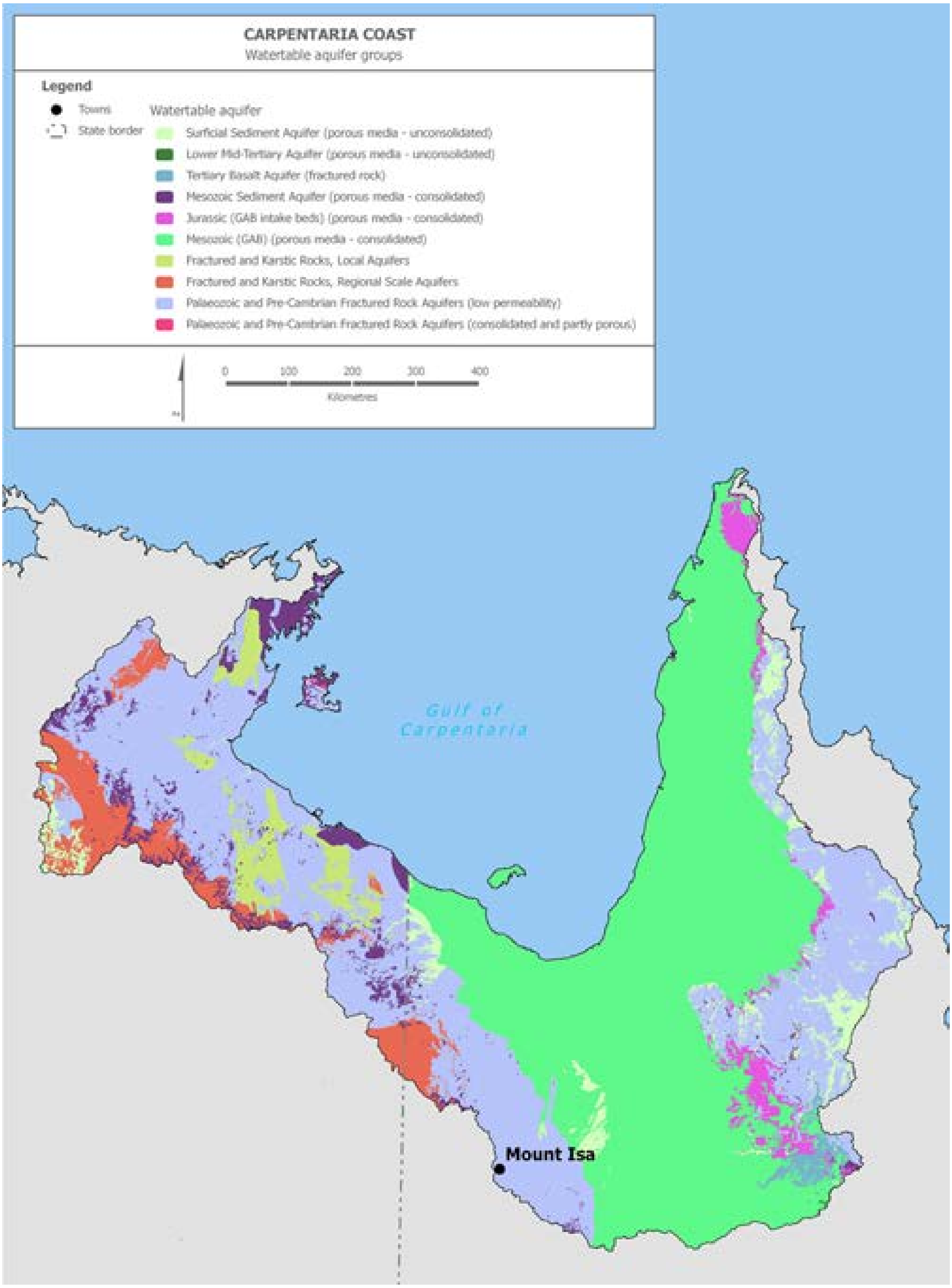


Figure 15-3. Watertable aquifer groups in the Carpentaria Coast region (Bureau of Meteorology 2011e)

15.4 Recent patterns in landscape water flows

The landscape water flows analyses presented in this section were derived from water balance models and are estimates of the real world situation. Some areas of the region have been excluded from the landscape water balance modelling results (classified as 'No data') due to the unreliability of rainfall data for these areas. The models used and the associated output uncertainties are discussed in Chapters 1 and 2, with more details presented in the Technical supplement.

Figure 15-4 shows that historically the Carpentaria Coast region experiences extremely seasonal rainfall with a dominant wet summer period and a dry winter. The seasonal distribution of rainfall was particularly marked for 2009–10. Monthly rainfall was extremely low from July to November 2009 and was followed by very high rainfall during the wet season between December 2009 and April 2010. Total rainfall for January and April 2010, in particular, was very much higher than normal and the region experienced its second wettest April of the long-term record (July 1911 to June 2010).

Evapotranspiration in northern Australia exhibits a seasonal pattern closely linked to rainfall and water availability. Regional evapotranspiration was higher than normal during the high rainfall months of January to April 2010. Monthly totals remained relatively high through to the end of the year as a result of the high soil moisture availability generated by high April 2010 rainfall that extended the wet season.

Modelled landscape water yield for the region shows clear responses to the high summer rainfall, particularly during January and April 2010. Landscape water yield for April was estimated to be the second highest April total in the long-term record (July 1911 to June 2010).

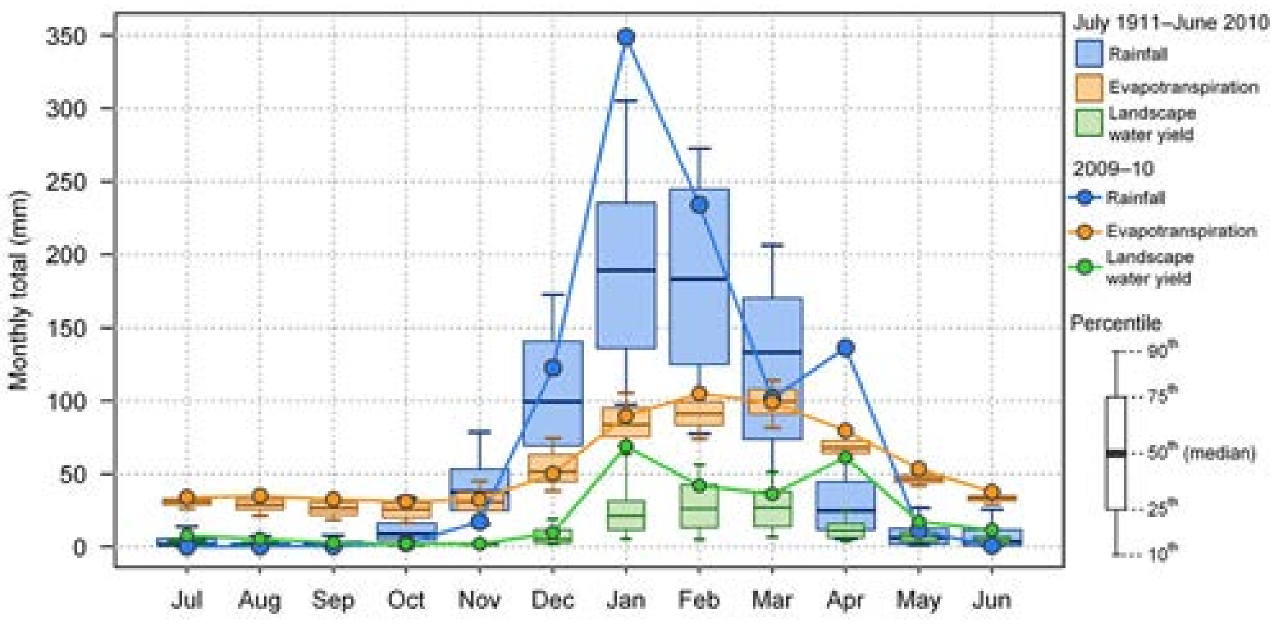


Figure 15-4. Monthly landscape water flows for the Carpentaria Coast region in 2009–10 compared with the long-term record (July 1911 to June 2010)

15.4.1 Rainfall

Rainfall for the Carpentaria Coast region for 2009–10 was estimated to be 976 mm, which is 31 per cent above the region's long-term (July 1911 to June 2010) average of 744 mm. Figure 15-5 (a)[3] shows that during 2009–10, the highest rainfall occurred along coastal areas in the north and northeast. Lowest rainfall totals were observed across the southern inland areas. Rainfall deciles for 2009–10, shown in Figure 15-5 (b), indicate rainfall was above average or very much above average across much of the region, particularly in the centre and west. Limited areas of below average rainfall are indicated along the western coast of the Cape York Peninsula.

Figure 15-6 (a) shows annual rainfall for the region over the past 30 years (July 1980 to June 2010). Over the 30-year period, rainfall ranged from 496 mm (1987–88) to 1,181 mm (2000–01). The annual average for the period was 801 mm. The data show that the region was noticeably wetter during the second half of the 30-year period. Total annual rainfall for the region was consistently at an average or above average level over the past four years.

An indication of patterns, trends and variability in the seasonal rainfall over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 15-6 (b). The data clearly show summer rainfall averages are very much higher than winter, reflecting the highly seasonal distribution of rainfall for the region. Summer period rainfall averages increased noticeably over the 30-year period, particularly from the lowest level reached at the end of the 1980s.

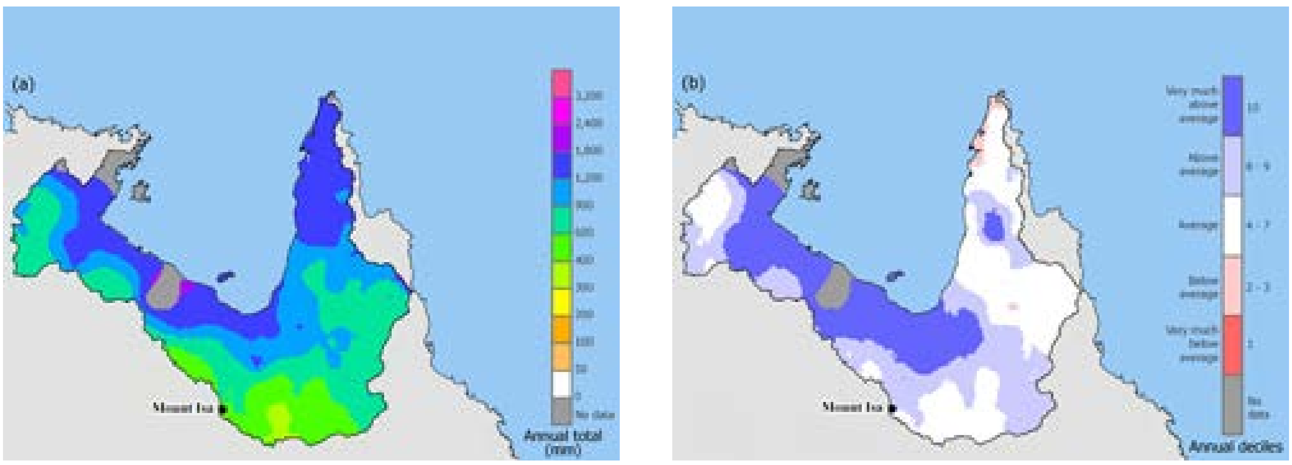


Figure 15-5. Maps of annual rainfall totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Carpentaria Coast region

3. Areas where rainfall interpolation was assessed to be greater than 20 per cent unreliable for any period of the long-term record were excluded from the landscape water balance modelling (classified as 'No data'). More details are presented in the Technical supplement.

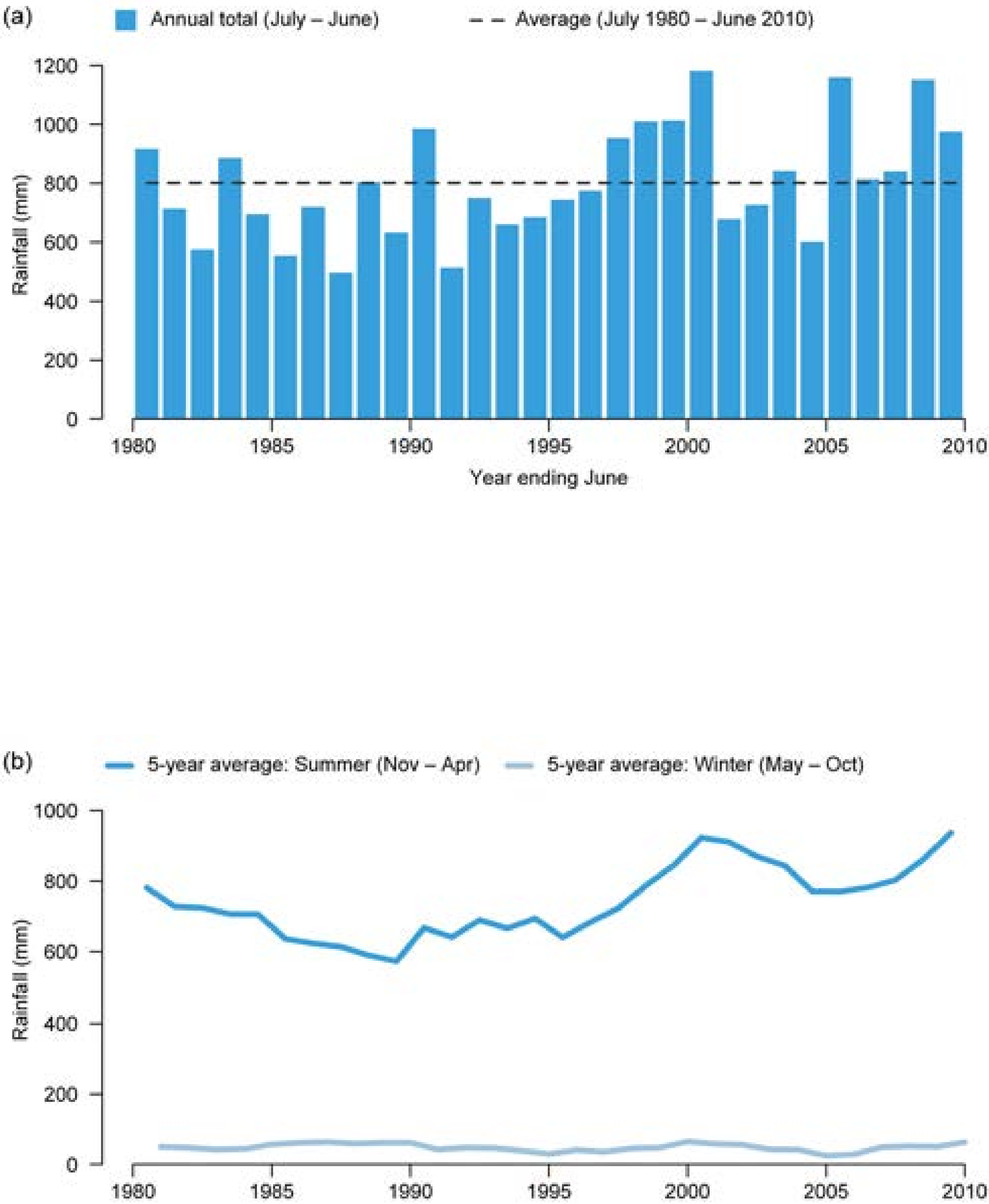


Figure 15-6. Time-series of annual rainfall (a) and five-year (backward looking) moving average of November–April (summer) and May–October (winter) totals (b) for the Carpentaria Coast region

15.4.1 Rainfall (continued)

Figure 15-7 provides a spatial representation of summer (November–April) and winter (May–October) rainfall trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal rainfall over the 30 years.

The analysis shows that over the past 30 years there were large increases in summer rainfall across almost the entire region. A small area of decreasing rainfall is indicated in the northeast of the region, potentially an artefact of erroneous rainfall data at a single station. The analysis of the lower magnitude winter rainfall shows very slight reductions in rainfall across the far south of the region and slight increases in the northeast and west.

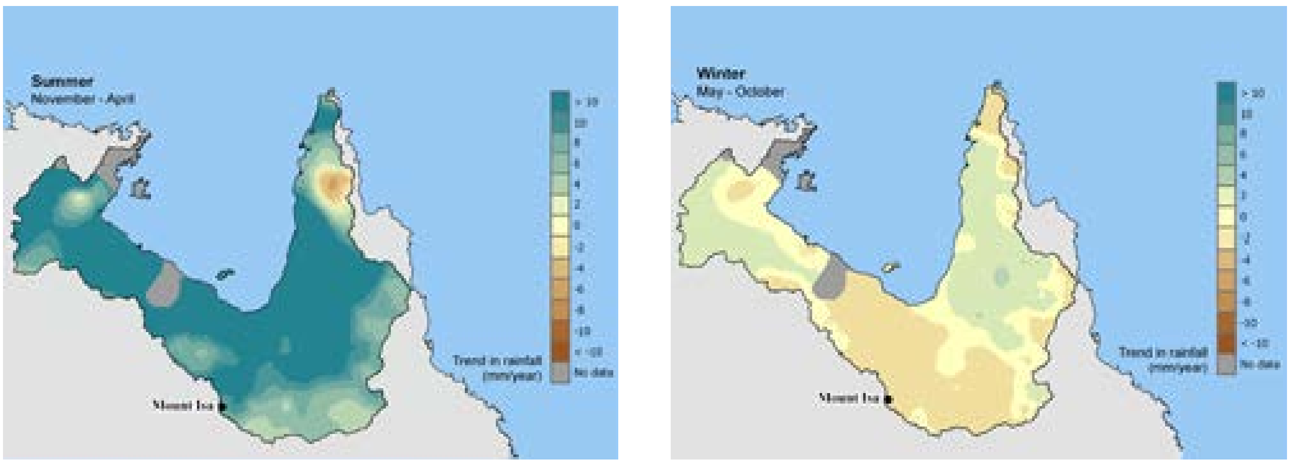


Figure 15-7. Linear trends in summer (November–April) and winter (May–October) rainfall over 30 years (November 1980 to October 2010) for the Carpentaria Coast region. The statistical significance of these trends is often very low

15.4.2 Evapotranspiration

Evapotranspiration for the Carpentaria Coast region for 2009–10 was estimated to be 679 mm, which is nine per cent above the region's long-term (July 1911 to June 2010) average of 622 mm. Figure 15-8 (a) shows that evapotranspiration for 2009–10 was estimated to be highest in the far northeast of the region. Lowest annual evapotranspiration occurred in the drier inland areas to the south. Evapotranspiration deciles for 2009–10, shown in Figure 15-8 (b), indicate evapotranspiration was above average across much of the centre and west of the region. Limited areas of below average values are identified across the east and northeast of the region.

Figure 15-9 (a) shows annual evapotranspiration for the past 30 years (July 1980 to June 2010). Over the 30-year period, evapotranspiration ranged from 549 mm (1987–88) to 805 mm (2000–01). The annual average for the period was 643 mm. The data show regional evapotranspiration is closely linked to water availability and clearly reflects the changes between periods of relatively low and high rainfall.

An indication of patterns, trends and variability in the seasonal evapotranspiration over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 15-9 (b). These data show that summer evapotranspiration is higher than during the winter. The seasonal averages for both summer and winter seasons show slight reductions through the drier first half of the 30 years and increase over the relatively wet second half of the period.

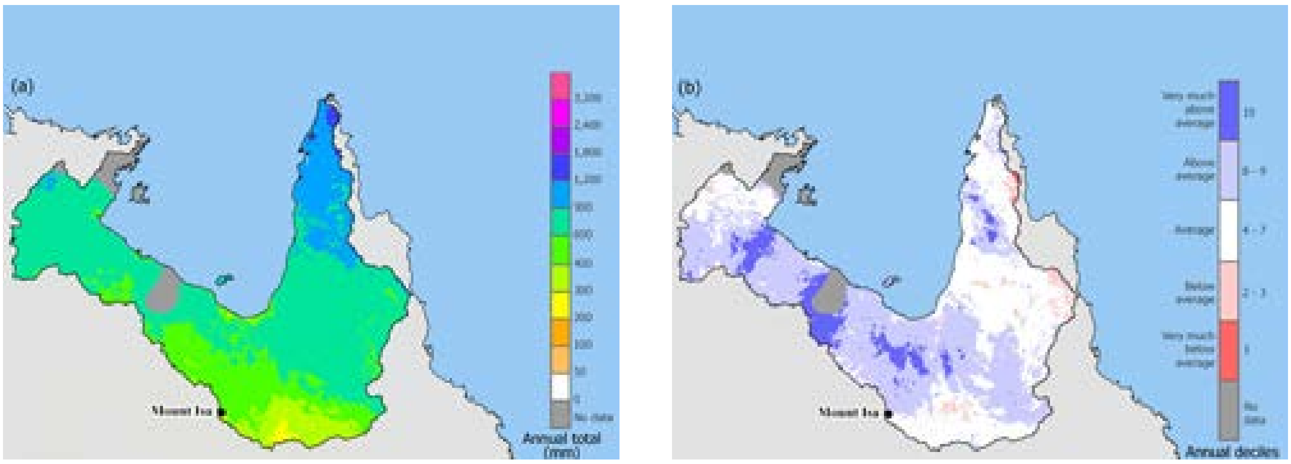


Figure 15-8. Maps of modelled annual evapotranspiration totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Carpentaria Coast region

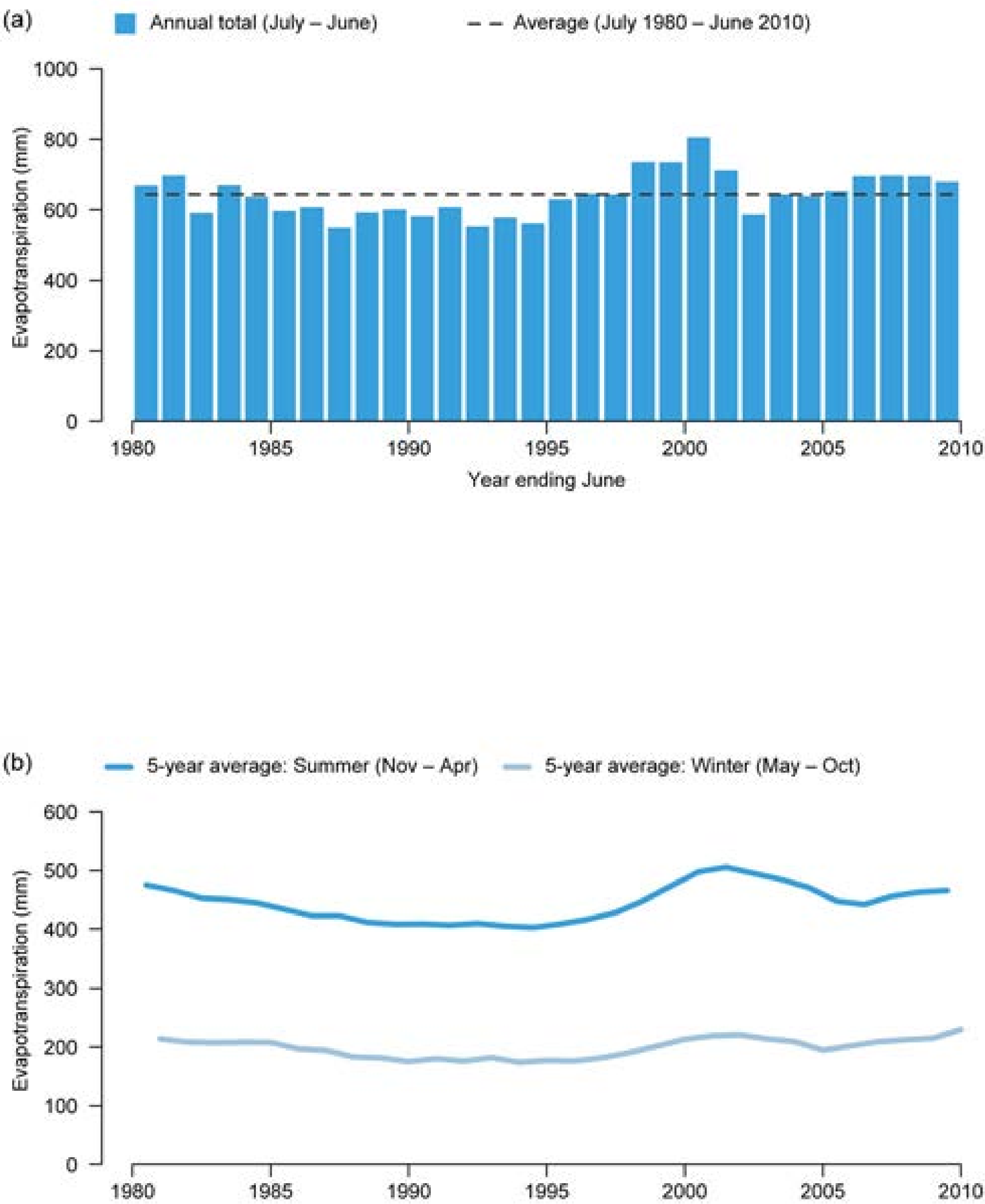


Figure 15-9. Time-series of modelled annual evapotranspiration (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) evapotranspiration (b) for the Carpentaria Coast region

15.4.2 Evapotranspiration (continued)

Figure 15-10 provides a spatial representation of summer (November–April) and winter (May–October) evapotranspiration trends throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal evapotranspiration over the 30 years.

The analysis indicates a slight increasing trend in evapotranspiration across the region for both the summer and winter periods. These increases are more apparent for the higher summer evapotranspiration period.

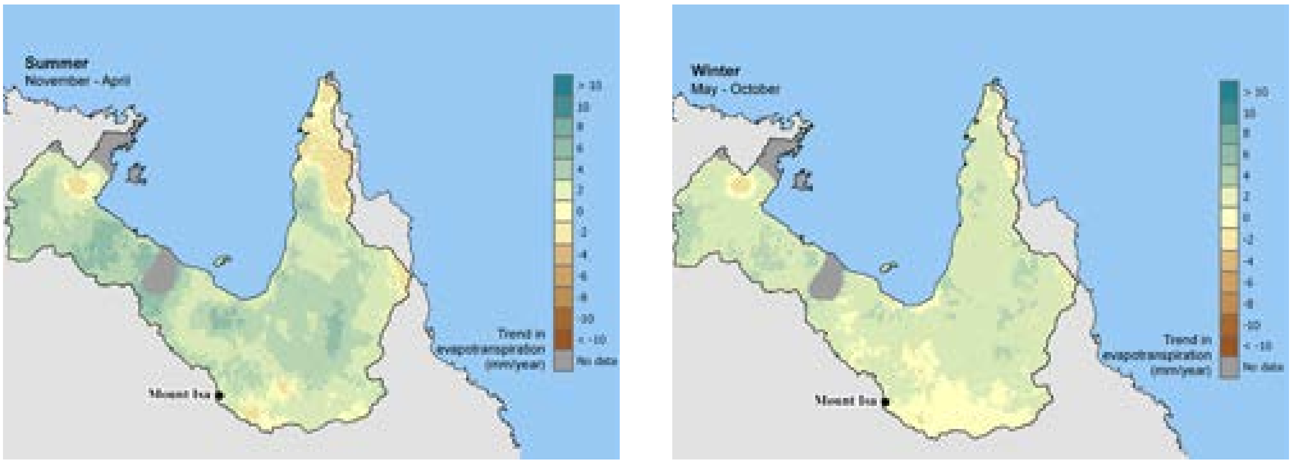


Figure 15-10. Linear trends in modelled summer (November–April) and winter (May–October) evapotranspiration over 30 years (November 1980 to October 2010) for the Carpentaria Coast region. The statistical significance of these trends is often very low

15.4.3 Landscape water yield

Landscape water yield for the Carpentaria Coast region for 2009–10 was estimated to be 268 mm, which is 99 per cent above the region's long-term (July 1911 to June 2010) average of 135 mm. Figure 15-11 (a) shows that during 2009–10, the pattern and distribution of landscape water yield is closely related to those observed for the region's rainfall (see Figure 15-5 [a]). The highest landscape water yield occurred in the coastal zone in the north and northwest of the region. Landscape water yield deciles for 2009–10, shown in Figure 15-11 (b), indicate much of the region experienced above average and very much above average values.

Figure 15-12 (a) shows annual landscape water yield for the region for the past 30 years (July 1980 to June 2010). Over the 30-year period, annual landscape water yield varied from 47 mm (1987–88) to 358 mm (2008–09). The annual average for the period was 165 mm. The data clearly show that landscape water yield over the wetter second half of the 30-year period was consistently much higher than during the first half of the period.

An indication of patterns, trends and variability in the seasonal landscape water yield over the 30-year period summer (November–April) and winter (May–October) are presented using moving averages in Figure 15-12 (b). Landscape water yield averages are consistently higher for the summer period. Both seasonal averages show increases in water yield since around the early 1990s, with particularly marked increases in the higher summer period landscape water yield.

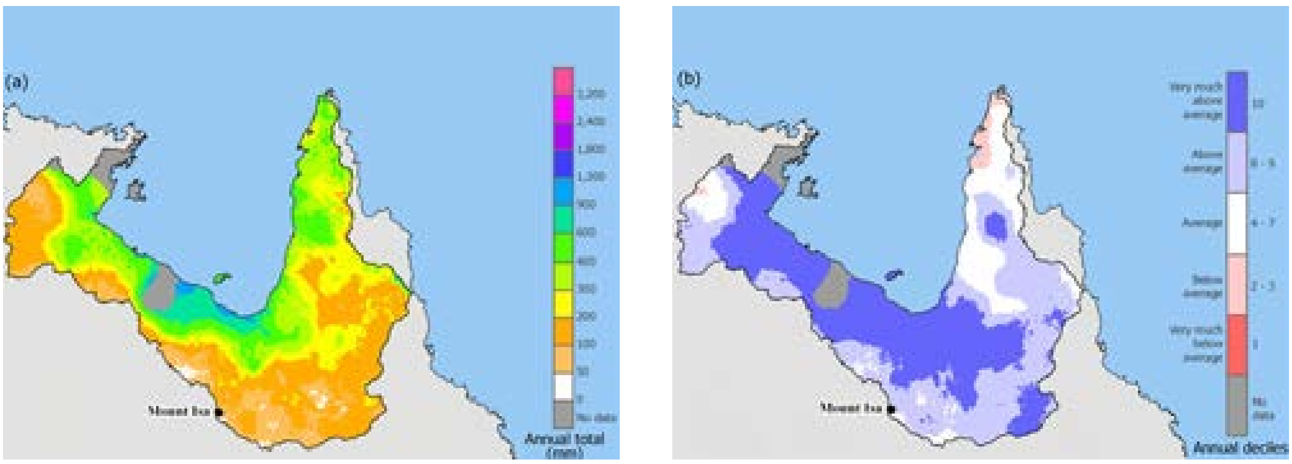


Figure 15-11. Maps of modelled annual landscape water yield totals in 2009–10 (a) and their decile rankings over the 1911–2010 period (b) for the Carpentaria Coast region

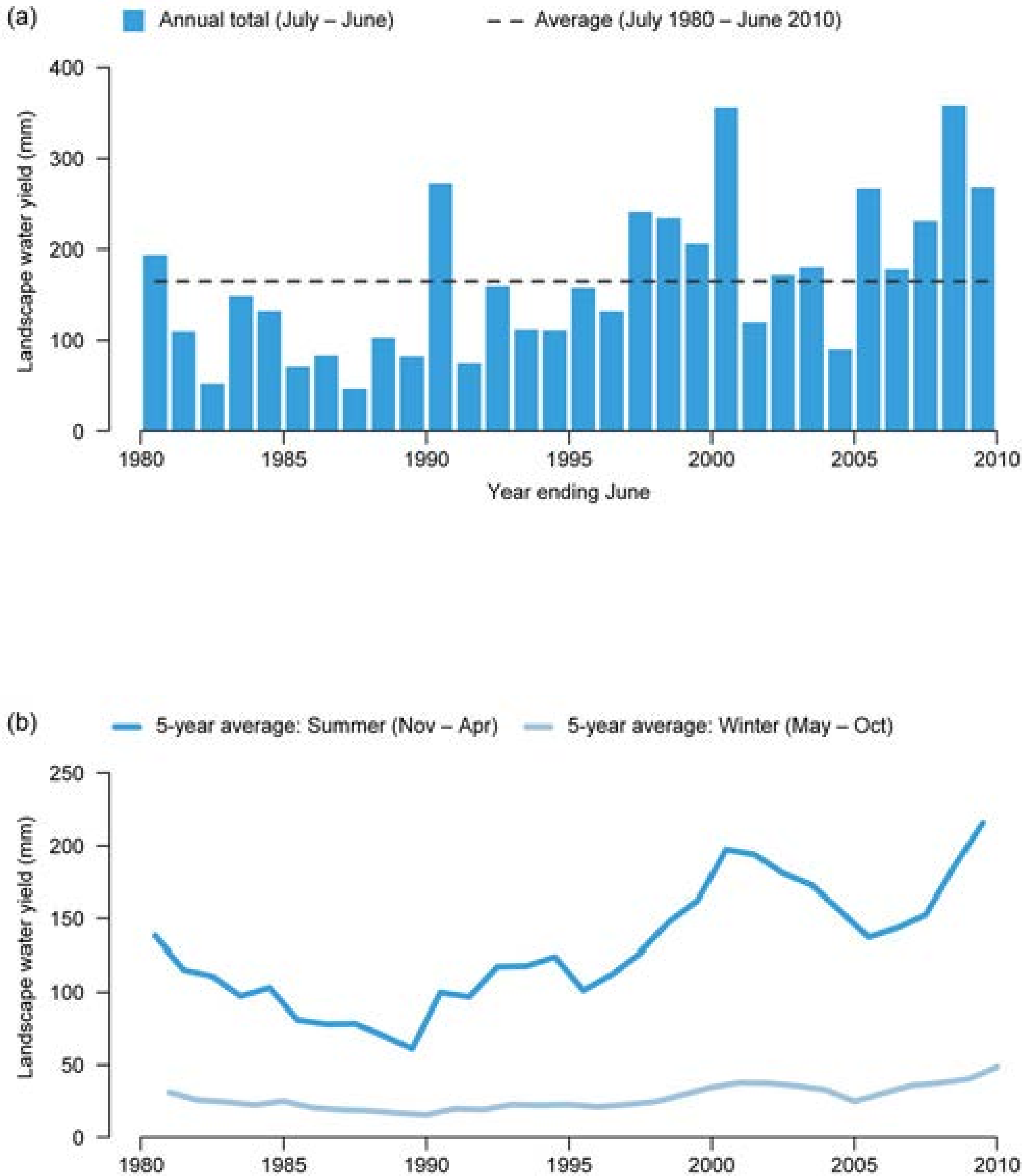


Figure 15-12. Time-series of modelled annual landscape water yield (a) and five-year (backward looking) moving averages for summer (November–April) and winter (May–October) landscape water yield (b) for the Carpentaria Coast region

15.4.3 Landscape water yield (continued)

Figure 15-13 provides a spatial representation of summer (November–April) and winter (May–October) trends in landscape water yield throughout the region between November 1980 and October 2010. The linear regression slope calculated for each 5 x 5 km grid cell depicts the change in seasonal landscape water yield over the 30 years.

The summer period analysis shows strong positive trends in landscape water yield across much of the region. This reflects a very clear link to the patterns of summer rainfall trends observed across the region. The summer period landscape water yield trends also clearly highlight the area of potentially erroneous negative trends in the northeast of the region. The lower magnitude winter landscape water yield shows slight increases across the north and centre of the region with negligible trends identified in the drier southern areas.

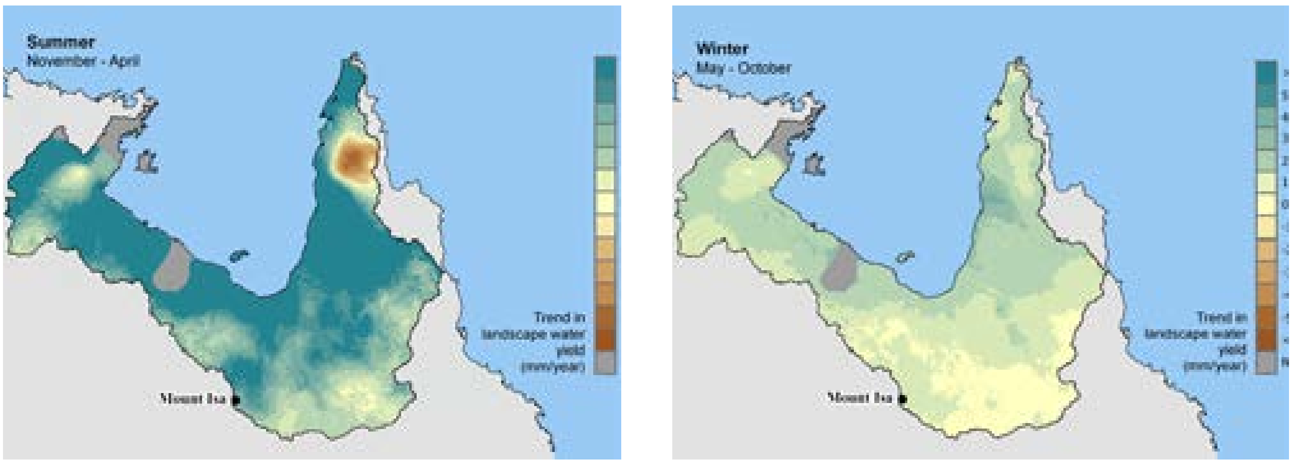


Figure 15-13. Linear trends in modelled summer (November–April) and winter (May–October) landscape water yield over 30 years (November 1980 to October 2010) for the Carpentaria Coast region. The statistical significance of these trends is often very low

Technical supplement

1. Previous water resources assessments in Australia

1.1 Introduction

The Australian Water Resources Assessment 2010 (the 2010 Assessment) is the first of its kind produced by the Bureau of Meteorology (the Bureau). The report presents assessments of Australia's climate and water resources in 2009–10 (July 2009 to June 2010). It discusses regional variability and trends in water resources and patterns of water use over recent seasons, years and decades, based on currently accessible data.

This technical supplement to the Australian Water Resources Assessment Report 2010 provides additional information on particular aspects of the report, including background information on:

- the context of the report particularly in relation to previous water resources assessments
- the choice of landscape water balance modelling methods used
- the analysis methods used
- the data selection procedures.

The supplement is organised into four chapters incorporating the above topics in the order in which they are listed.

1.2 Australian Water Resources Assessment 2010 region boundaries

The 2010 Assessment is structured around 13 regions covering the Australian continent, based on drainage division boundaries. Drainage divisions represent the catchments of major surface water drainage systems, generally comprising a number of river basins. Drainage divisions provide a scientifically robust framework for assessing hydrological flows in the landscape while also allowing information to be presented and discussed in broadly identifiable regional and climatic contexts.

The 13 regions were derived from the Australian Hydrological Geospatial Fabric (Bureau of Meteorology 2011f). This is a specialised geographic information system that identifies the spatial relationships of important hydrological features such as rivers, lakes, reservoirs, dams, canals and catchments.

Hierarchically-nested catchments were derived using an automated drainage analysis procedure based on a nine second digital elevation model (Bureau of Meteorology 2010c). Twelve drainage divisions were defined at the highest level of the hierarchy. At the next level, there are 191 catchment units. This work builds on and approximates the drainage boundaries developed by Geoscience Australia (1997) which were the result of a joint State, Territory and Australian Government project to create a national spatial database of major hydrological basins.

For the Australian Water Resources Assessment 2010 report, one drainage division, the South East Coast, was split in two, using selected catchment boundaries at the second level of the hierarchy. This division was chosen to best approximate the border between New South Wales (NSW) and Victoria, creating the 'South East Coast (NSW)' and 'South East Coast (Victoria)' regions.

The differences between the original Geoscience Australia boundaries and those used in the 2010 Assessment are illustrated in Figure 1-1.

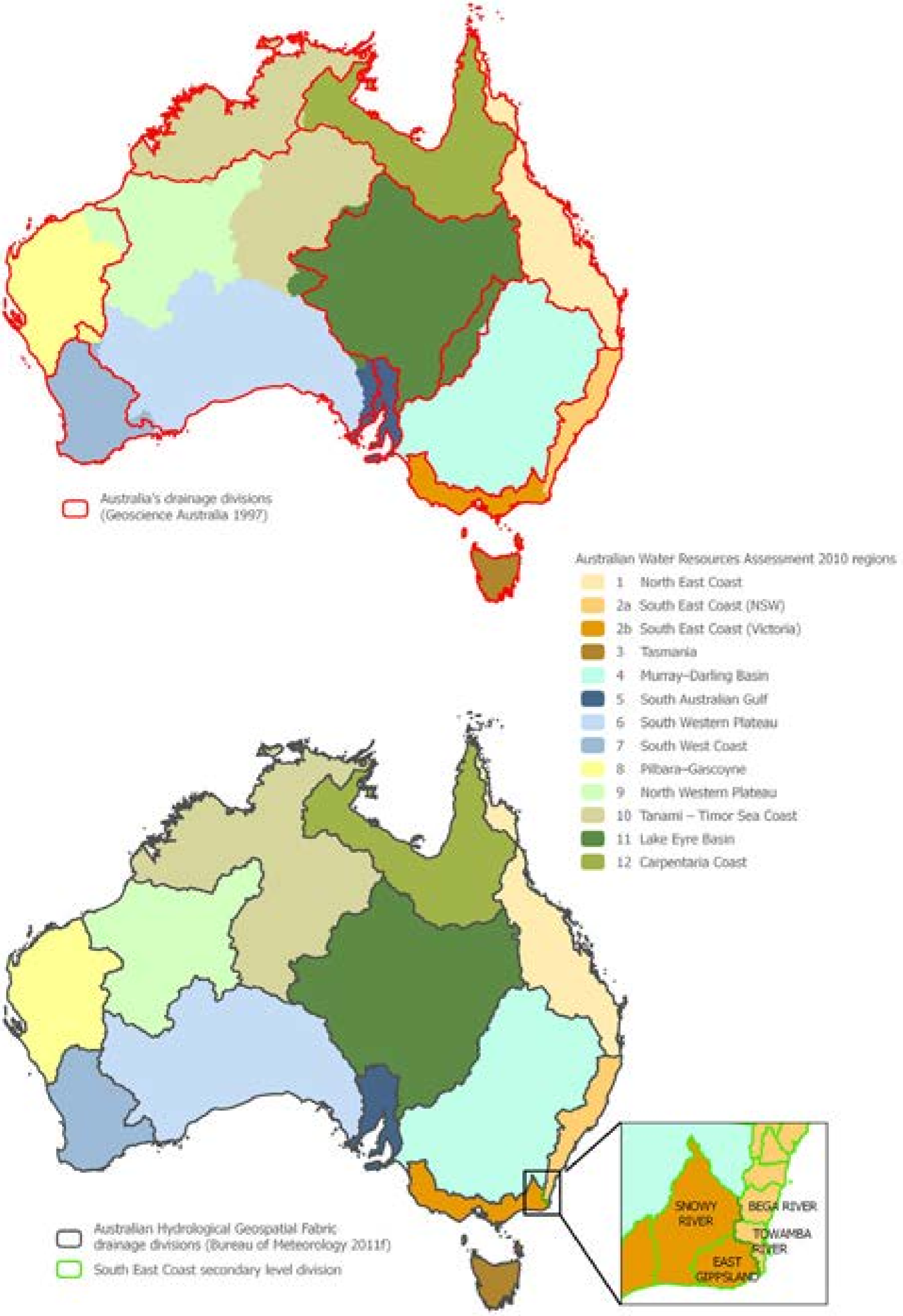


Figure 1-1. Comparison of drainage division boundaries of Geoscience Australia (1997) and the Australian Water Resources Assessment 2010 regions.

1.3 Jurisdictional water reporting products

There are many existing water information products already in the public domain in Australia. Links to key websites for these products are summarised in Table 1-1 and Table 1-2.

Table 1-1. Links to key Australian Government water reporting products

Organisation	Report name	Report link
Australian Bureau of Agricultural and Resource Economics and Sciences	Water Balance Reporting Tool	http://adl.brs.gov.au/water2010/water_balance_month/index.phtml
Australian Bureau of Statistics	ABS Water Accounts	www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4610.02004-05?OpenDocument
Australian Bureau of Statistics	Water Use on Australian Farms	www.abs.gov.au/AUSSTATS/abs@.nsf/mf/4618.0
Australian Bureau of Statistics	Water and the Murray–Darling Basin	www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.007
Commonwealth Scientific and Industrial Research Organisation	Sustainable Yields Projects	www.csiro.au/partnerships/SYP.html
Murray–Darling Basin Authority	Water Audit Monitoring Report	www.mdba.gov.au/services/publications/more-information?publicationid=88
National Water Commission	Australian Water Resources 2005	http://water.gov.au/IntroductiontoAWR2005/index.aspx?Menu=Level1_2
National Water Commission	National Performance Reports	www.nwc.gov.au/
National Water Commission	Biennial Assessment Report	www.nwc.gov.au/www/html/147-introduction---2009-biennial-assessments.asp?intSiteID=1

Table 1-2. Links to key State and Territory water reporting products

Jurisdiction	Organisation	Report name	Report link
Australian Capital Territory	Department of the Environment, Climate Change, Energy and Water	Water Report	www.environment.act.gov.au/__data/assets/pdf_file/0003/175206/DECCEW_Water_Report_FINAL_FINAL.pdf
New South Wales	New South Wales Office of Water	Water supply and sewerage performance monitoring	www.water.nsw.gov.au/Urban-water/Country-Towns-Program/Best-practice-management/Performance-monitoring/Performance-monitoring/default.aspx
Northern Territory	Natural Resources, Environment, The Arts and Sport	Water Allocation Plans	www.nt.gov.au/nreta/water/manage/water_allocation.html
Queensland	Department of Environment and Resource Management	Water Resources Planning Annual Catchment Reports	www.derm.qld.gov.au/wrp/annual_reports.html
Tasmania	Department of Primary Industries, Parks, Water and Environment	Waterway Monitoring Report and Water Management Plans	www.dpiw.tas.gov.au/inter.nsf/WebPages/JMUY-6BV8GJ?open
South Australia	South Australia Water	Annual Report, Drinking Water Quality and Water Sustainability Reports	www.sawater.com.au/sawater/whatsnew/publications/annual+reports.htm
Victoria	Department of Sustainability and Environment	Victorian Water Accounts	www.water.vic.gov.au/monitoring/accounts
Western Australia	Department of Water	Allocation Plans	www.water.wa.gov.au/Managing+water/Allocation+planning/default.aspx

The following sections provide explanations of major jurisdictional products.

1.3 Jurisdictional water reporting products (continued)

1.3.1 Australian Bureau of Agricultural and Resource Economics and Sciences

The 'Rural Water' website of the Australian Bureau of Agricultural and Resource Economics and Sciences contains landscape water balance reports for every river basin and drainage division in Australia (average annual and for some historical months). Data were drawn from a large range of information sources, including: CSIRO, Bureau of Meteorology, Australian Bureau of Statistics, Geoscience Australia, the National Land and Water Resources Audit, the Australian National Committee on Large Dams, the Australian National Committee – International Commission on Irrigation and Drainage, the Murray–Darling Basin Commission, State Agencies and the Australian Water Resource Council.

1.3.2 Australian Bureau of Statistics

Water Account Australia

The Australian Bureau of Statistics Water Account Australia integrates annual data from different sources, including Australian Bureau of Statistics surveys, into a consolidated data-set. The account links physical water data to economic data, such as that in Australia's National Accounts. The 2004–05 Water Account Australia was partly funded by the National Water Commission and is a component of the Australian Water Resources 2005 project. Earlier Water Accounts were created for 1993–94 to 1996–97 and 2000–01.

Water Use on Australian Farms

The *Water Use on Australian Farms* publications provide estimates of agricultural water use, irrigated pastures and crops, water sources for agricultural use, irrigation water management and financial data relating to irrigation. Estimates are presented for Australia, State and Territories and regions, as well as for the Murray–Darling Basin. These estimates are compiled from data collected as part of the agricultural census, which is conducted every five years with sample agricultural surveys carried out during the inter-census years.

Water and the Murray–Darling Basin

This publication provides environmental, economic and social information for the Murray–Darling Basin, which is presented in five chapters. Chapter 3 describes water use in the Murray–Darling Basin including:

- water consumption
- irrigation application rates
- area irrigated
- water storage.

1.3.3 Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Projects to investigate likely sustainable water yields in the Murray–Darling Basin, Tasmania, northern Australia and in southwest Western Australia were commissioned in response to shortages, and potential development opportunities in water resources. Policy-makers are the primary audience for Sustainable Yields projects. The findings will be used in the development of water sharing plans as specified in the Commonwealth *Water Act 2007*.

The Sustainable Yields projects assessed the current and future availability of water resources. Four scenarios of climate and water resource development were considered:

- Scenario A – current development and historic climate
- Scenario B – current development and recent climate
- Scenario C – current development and future climate
- Scenario D – future development and future climate.

Scenario A used 1895–2006 rainfall data while Scenario B was based on rainfall for the ten years between 1997 and 2006. Scenarios C and D used the 2030 climate predictions from global climate models in the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. In terms of water resource development, Scenarios A, B and C replicated the conditions specified in current water sharing plans, whereas Scenario D considered the expansion of farm dams, plantation forestry and groundwater extraction.

Eighteen new reporting units were developed for the Murray–Darling Basin Sustainable Yields projects. The new units were based on a combination of surface hydrology and river system models. They differ from previous spatial units, such as surface water management areas, river basins and Murray–Darling Basin Cap regions.

The results from the Sustainable Yields projects are presented in a series of regional and summary reports, which can be accessed from the CSIRO website. Regional reports generally contain the following water information:

- contextual information (hydrology, hydrogeology and water management)
- climate and drought assessment
- modelled run-off
- modelled groundwater recharge
- water balance (from river systems modelling)
- groundwater balance (from groundwater modelling)
- water accounts (based on measurement and estimation)
- environmental assessments.

1.3 Jurisdictional water reporting products (continued)

1.3.4 National Water Commission

Australian Water Resources 2005

The primary purpose of Australian Water Resources 2005 was to provide a baseline assessment of water resources and management prior to national water reforms. Baseline information on water availability, water use and river/wetland health was assembled for future comparisons measuring the success of the National Water Initiative reform process.

Under the National Water Initiative, the National Water Commission is required to: 'undertake a baseline assessment of the water resource and governance arrangements, based on existing work by the Parties and undertaking further work only where required.' (National Water Commission 2011c)

Regional water resources assessments were undertaken for surface water management areas and groundwater management units. Depending on the region, these assessments can include:

- contextual information
- water resources
- water balance
- water use
- assessment of river and wetland health
- management indicators.

National Performance reports

Urban and rural performance benchmarking reports for the most significant water suppliers have been published by the National Water Commission since 2005. Three annual reports were completed for 88 urban water utilities and two annual reports were done for the 13 rural water service providers. Indicators for both reports were developed, covering:

- water resources
- system characteristics
- customer service
- environment
- health
- asset management
- finance and pricing.

Australian Water Markets report

The National Water Commission released its inaugural water markets report in December 2008. The report provides a range of data relating to entitlements, allocations, trading and economic activity occurring in each State and Territory. Data are presented by regulated and unregulated management areas.

Biennial Assessment report

Biennial Assessments by the National Water Commission report on all aspects of progress with respect to the objectives and outcomes of the National Water Initiative. This includes reporting on progress with respect to:

- the level of understanding of our water resources and their use
- ensuring the health of river and groundwater systems
- increasing the productivity and efficiency of water use
- dealing with challenges for rural and urban communities.

One of the means by which the Biennial Assessments achieve this is to report against performance indicators approved by the Natural Resource Management Ministerial Council, including indicators such as:

- water application rates for irrigated agriculture
- gross value of irrigated agricultural production by State per unit volume
- household water use per annum
- percentage of water supplied to users by source
- percentage of water losses in distribution systems
- proportion of water use for consumptive and non-consumptive purposes.

1.3 Jurisdictional water reporting products (continued)

1.3.5 Murray–Darling Basin Authority

The Murray–Darling Basin Authority took over many of the responsibilities of the former Murray–Darling Basin Commission. Their functions under the Commonwealth *Water Act 2007* include:

- establishment of a Basin Plan
- measuring, monitoring and recording the quality and quantity of water resources in the Murray–Darling Basin
- management of Murray–Darling water resources
- operation of a Murray–Darling Basin Water Rights Information Service.

Water Audit Monitoring report

Water Audit Monitoring reports are produced annually by the Murray–Darling Basin Authority. They report on compliance with diversion limits as well as water and climate conditions for the year including:

- diversions
- water trading
- environmental flows
- storages and streamflow
- allocation
- losses
- groundwater use.

Most data are annual and presented in tables and graphs.

1.3.6 Australian Capital Territory (ACT)

The key water publication in the ACT is the annual *ACT Water Report* published by the Environment Protection Authority. This report is environmentally driven and focuses on the waterways of the ACT with the exception of Lake Burley Griffin, which is a federal responsibility. These reports have been produced yearly since 1996–97 with the most recent being the 2007–08 report (Australian Capital Territory Government 2008). Values recorded throughout the reporting year (for example, streamflow or water quality indicators) are compared to the long-term averages.

Recent reports are divided into three sections: (i) Water Resources; (ii) Water Quality and Condition; and (iii) Research and Community Activities.

The Water Resources section relates to the volume of water available for use within the ACT and provides an overview of water allocation and water availability. Water allocation is tabulated as total water volume and number of surface, groundwater and surface plus groundwater licences from 14 water management areas. Water availability is graphed as the previous year's rainfall and inflow against long-term averages.

The Water Quality and Condition section relates to water quality measured in water courses throughout and near the ACT during the year.

The Research and Community Activities section outlines research programs and community activities that were conducted during the reporting year. Groundwater levels are monitored at 14 bore sites in the ACT. Research and monitoring of groundwater are reported in Section 3 of the *ACT Water Report*.

The annual report of the State-owned water company, ACTEW, is the only other annual publication currently produced in the ACT that contains water information. The ACTEW Annual Report is published as a requirement under section 6(1) of the ACT *Annual Reports (Government Agencies) Act 2004* and contains a review of drinking water consumption in the ACT and treated wastewater effluent discharge into the Murrumbidgee system. This report makes a brief statement as to whether environmental flow guidelines were met for the year.

1.3 Jurisdictional water reporting products (continued)

1.3.7 New South Wales (NSW)

A dedicated annual water report covering a broad range of water related issues and statistics across all of NSW is not currently published. However, individual organisations responsible for different jurisdictions do produce water information products (e.g. annual reports) covering a range of issues.

The NSW Office of Water produces the Water Supply and Sewerage Performance Monitoring Report. This report provides a broad range of data for 107 non-metropolitan and four metropolitan water utilities with annual information for comparison over the previous six years. Information relating to utility characteristics, health, water resources and usage, pricing and economics, and effluent management is presented.

The Sydney Catchment Authority Annual Report provides several water information products. Bulk water supplied over the past five years to customers (Sydney Water, Wingecarribee Shire Council, Shoalhaven City Council, direct users and others) is reported as a table and bulk water stored over the past ten years is reported graphically. The annual report also details releases from storages in the Sydney catchment for the previous year. Releases are categorised as being for customer, the environment or other purposes. The annual report also contains rainfall data.

1.3.8 Northern Territory

There is no annual, high profile public report on the status of water resources in the Northern Territory. Water Allocation Plans are gradually being developed for various priority catchments across the Northern Territory where the need for more intensive management of water resources is identified.

The Water Allocation Plans were developed to maintain environmental flow in areas where groundwaters are seasonally recharged and drawn down. There is generally high recharge, but also high discharge rates which can be monitored each year, allowing for an adaptive management approach. There is no standard template for a Plan. The level of detail is based upon the population, the importance of the resource to the community and the complexity of the hydrological system. The objectives of the plans can be summarised as:

- to manage water resources in a way that balances social and environmental protection with economic growth
- to provide an understanding of the water resources and water demands
- define water allocations and establish mechanisms for community involvement in water resource management
- set a strategic work plan for management of water resources for the next ten years.

1.3 Jurisdictional water reporting products (continued)

1.3.9 Queensland

In Queensland, a Water Resource Plan establishes a framework for sustainable water resource management for domestic, irrigation and industrial purposes, and environmental water requirements. It specifies the outcomes that must be met under sustainable water management arrangements in the plan area, and how they will be achieved. It is typically implemented through a resource operations plan, which establishes the operating rules for water supply systems to meet the Water Resource Plan's objectives.

Under section 53 of the Queensland *Water Act 2000*, the minister must report periodically on the implementation of each plan. The Water Resource Plan Annual Report 2009–10 provides the annual flow conditions and realised extractions, which vary year to year. The Annual Report contains one chapter for each plan. It covers the period from 1 July 2009 to 30 June 2010 for 19 catchments (Barron, Border, Boyne, Burdekin, Burnett, Calliope, Condamine and Balonne, Cooper Creek, Fitzroy, Georgina and Diamantina, Gold Coast, Great Artesian Basin, Gulf, Logan, Mitchell, Moonie, Moreton, Pioneer Valley and Warrego–Paroo–Bulloo–Nebine).

Generally this report provides information for each catchment under the following headings:

- overview
- background on plan area
- hydrologic year in review
- plan implementation
- plan outcomes
- water allocation and use
- water sharing rules and critical water supply arrangements
- water trading
- water service provider operations and monitoring
- impact monitoring
- ecological monitoring
- planning processes and changes to the plan.

1.3.10 Tasmania

While there are a number of water data and information products developed for Tasmania, no annual, high profile public report on the status of water resources in the State is undertaken. The Department of Primary Industries, Parks, Water and Environment is the major custodian for Government water information and hydrological water assessment in Tasmania. Water Information Systems of Tasmania provides public access to streamflow, groundwater, water quality, water licence and river health data for the State's catchments.

Between 2004 and 2008, Waterway Monitoring Reports were produced on an annual basis for 40 of the State's 48 catchments. These annual reports provided streamflow and water allocation information and interpretations on the status of water quality and river health in each catchment. Prior to this, more detailed State of Rivers Reports were completed for 13 catchments in agriculturally developed areas of the State.

More detailed water resource assessments are undertaken to support the development of catchment water management plans. Information on catchment hydrological characteristics, the current status of water allocation and water availability on a sub-catchment basis is provided through hydrological reports. This information is used with environmental and socio-economic information to develop the water management plan. To date, six water management plans have been formally adopted with a further seven plans in various stages of development.

Hydro Tasmania undertakes water management reviews as a mechanism to review environmental performance and water management practices. The process is undertaken on a catchment by catchment basis. Various scientific studies support the review including hydrological assessments.

1.3 Jurisdictional water reporting products (continued)

1.3.11 South Australia (SA)

There is no annual, publicly available, comprehensive water publication or water balance for South Australia. The State's major water utility, South Australia Water, produces several regular reports based on its jurisdiction. Its Annual Report provides:

- annual water consumption statistics (e.g. total volume supplied, average household consumption, highest daily consumption)
- water source derivation (i.e. River Murray, surface water, groundwater)
- wastewater figures and a comparison of these values over the previous five years.

South Australia Water also produces a Drinking Water Quality Report and a Water Sustainability Report, the latter of which has been incorporated into the Annual Report since 2008.

Under the National Water Initiative, South Australia Water is required to provide statistical data on water use for metropolitan Adelaide and South Australian regional centres (Mount Gambier, Whyalla, Murray Bridge, Port Augusta, Port Lincoln and Port Pirie). This is compiled by the National Water Commission in production of its National Performance Report.

1.3.12 Victoria

The State Water Report presents accounts of water in each of Victoria's 29 river basins for the financial year. Information presented for each basin includes:

- a seasonal overview, factors influencing water availability, comparison with the previous years data
- a map of the river basin
- current water resources summary
- surface water (water balance, small catchment dams, entitlement transfers, diversions)
- groundwater
- seasonal allocations and restrictions on water use, diversions and extractions
- recycled water
- water for the environment (environmental water reserve, entitlements, passing flow compliance requirements, streamflow management plans, water leaving the basin).

A methodology for calculating water balances is detailed in this report. In summary:

- The spatial unit for water accounts is the river basin as defined by the Australian Water Resource Council.
- Groundwater information is reported within a river basin to give an indication of total resource use.
- The accounts detail diversions and extractions rather than use.
- Diversion types include urban, irrigation district, regulated licensed, environmental water and small catchment dams.
- Diversion figures are recorded at the off-take and therefore include all transmission losses prior to water reaching the user.

1.3 Jurisdictional water reporting products (continued)

1.3.13 Western Australia (WA)

There are a number of water data and information products generated by various organisations in Western Australia. The Department of Water has published several reports outlining water resources across the State including allocation plans which are available on their website. Published water balance studies by the Water Corporation focus mainly on groundwater resources.

Helping underpin the sustainable planning and management of this State's water resources is the South West Sustainable Yields project undertaken by the Department of Water and CSIRO. This project involves an assessment of the water yield of 13 catchments and 24 groundwater areas in the southwest, particularly in irrigation areas, under a changing climate.

2. Landscape water balance methods

2.1 Introduction

A major component of the Australian Water Resources Assessment 2010 report is the estimation of the dominant landscape water flows and stores on a national scale. These are not directly measured across all parts of Australia. Spatial interpolation techniques and modelling simulations were used to generate this information.

This chapter explains the reasoning for the choice of the WaterDyn and AWRA-L as the models for simulating the spatial and temporal variability of the non-measured water balance components. These include actual evapotranspiration, soil moisture and landscape water yield (run-off and groundwater discharge).

2.2 Considerations for choice of methods

The Bureau's Water Information Services Branch was formed in 2008 to produce various retrospective water reporting products. Since then, Bureau and CSIRO staff have been working on establishing systems and methods to support this new role. Two new major information products will be regularly produced. These are the Australian Water Resources Assessment report and the National Water Account (www.bom.gov.au/water/nwa). The National Water Account contains water accounting reports for nationally significant regions. It provides information on water stores and flows, water rights and water use.

Both products require continental scale water balance estimation, according to the conceptual water balance framework defined by Barratt (2008) as illustrated in Figure 2-1. As observations are not available for all of these stores and flows at sufficient frequency and resolution across the continent, various models or methods are required to estimate the required values.

The methods for estimating components of the water balance for the 2010 Assessment and the National Water Account 2010 were chosen according to the following considerations:

- **consistency**: the methods could be applied consistently to both products
- **timeliness**: the methods could be implemented in time for both product deadlines subject to available Bureau resources
- **robustness**: the methods are demonstrably robust compared with other available methods.

The choice of methods for rainfall, actual evapotranspiration, landscape water yield and soil moisture storage are discussed below.

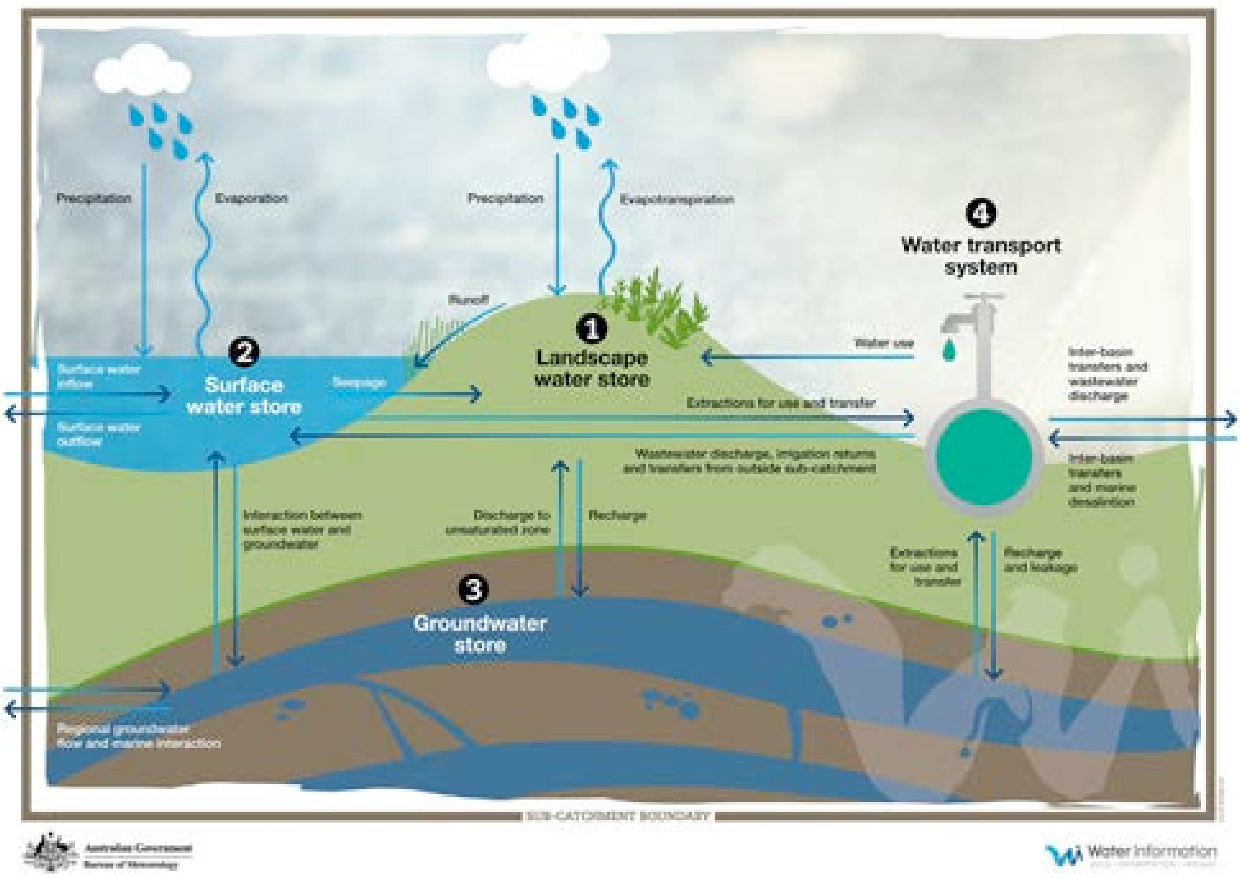


Figure 2-1. Conceptual water balance framework of Barratt (2008)

2.3 Modelling concepts

2.3.1 Input climate data requirements

Rainfall measurements are required for estimation of the rainfall term (Barratt 2008) and for input into water balance models. Gridded rainfall produced by the Bureau (Jones et al. 2009) was used. The data-set is derived from spatial interpolation of available daily rainfall readings collected by the Bureau.

Solar radiation and temperature serves as input for the models used in this report. Daily gridded estimates provided under the Australian Water Availability Project were used (see www.bom.gov.au/jsp/awap/).

Modelled landscape water balance estimates

The 2010 Assessment includes estimates of actual evapotranspiration, landscape water yield (run-off and groundwater discharge) and soil moisture storage. The AWRA-L model version 0.5 (Van Dijk 2010; Van Dijk & Warren 2010) and WaterDyn version 25M (Raupach et al. 2008) produce modelled estimates of all these components. Figure 2-2 shows a diagram of the conceptual processes contained in each of these models that were implemented within the Bureau.

Other methods exist that can be used to produce estimates of individual components of the water balance, but these have yet to be adopted by the Bureau. For example, the conceptual rainfall run-off models (e.g. as employed within the various Sustainable Yields projects; www.csiro.au/partnerships/SYP.html; Chiew et al. 2008) can be used to produce estimates of run-off. Furthermore, satellite empirical-based methods can be used to estimate actual evapotranspiration (e.g. the CSIRO Modis Reflectance Scaling ET (CMRSET) algorithm; Guerschman et al. 2009).

Comparisons of the various modelling methods available against observed streamflow (Viney 2010) and evapotranspiration (King et al. 2011) and relative to one another (Bacon et al. 2010) provide information about the accuracy of the estimates for the various model outputs.

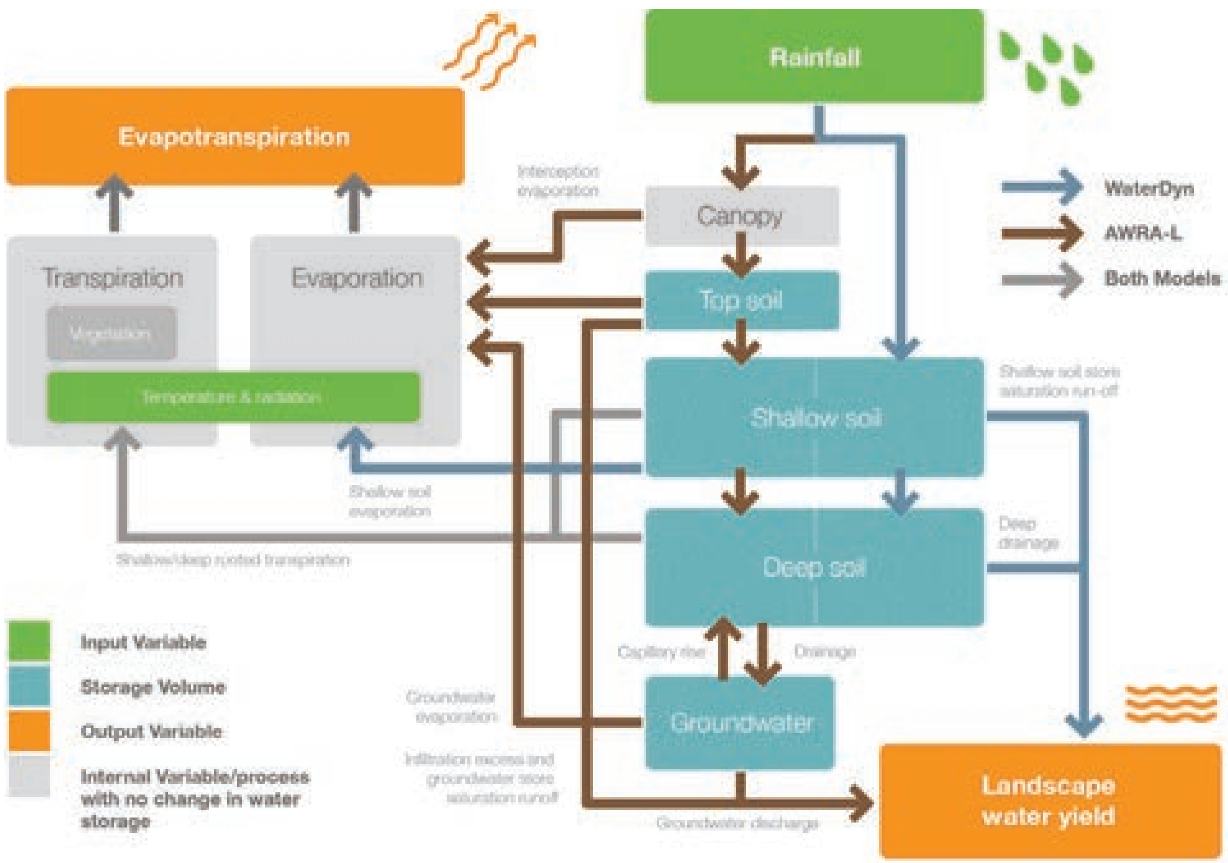


Figure 2 2. Conceptual diagram of AWRA-L and WaterDyn model processes

2.3 Modelling concepts (continued)

Landscape water yield

Rainfall run-off models calibrated to local streamflow tend to perform best. Furthermore, an ensemble of run-off estimates from the various models available tends to produce a better estimate overall. Also, the national gridded models AWRA-L and WaterDyn perform at a similar standard, although not as well as locally calibrated models. Model performances are of varying quality depending on location as illustrated in Figure 2-3 and Figure 2-4 by the annual bias and Nash-Sutcliffe efficiency values for the various regions used in the Sustainable Yields projects. In these graphs, the Australian Water Availability Project represents the WaterDyn model results.

Evapotranspiration

Evapotranspiration estimates provided from AWRA-L and WaterDyn are reasonable compared to other available methods in uplands areas. Satellite-based methods perform better in irrigation/inflow receiving areas, as the models do not currently allow for sources of water into a grid pixel other than rainfall (e.g. flooding, irrigation). The CMRSET algorithm was recommended for use in inflow receiving areas, with AWRA-L or WaterDyn recommended for upland areas. Application of such a quilted product was not possible in time for the Australian Water Resources Assessment 2010 report.

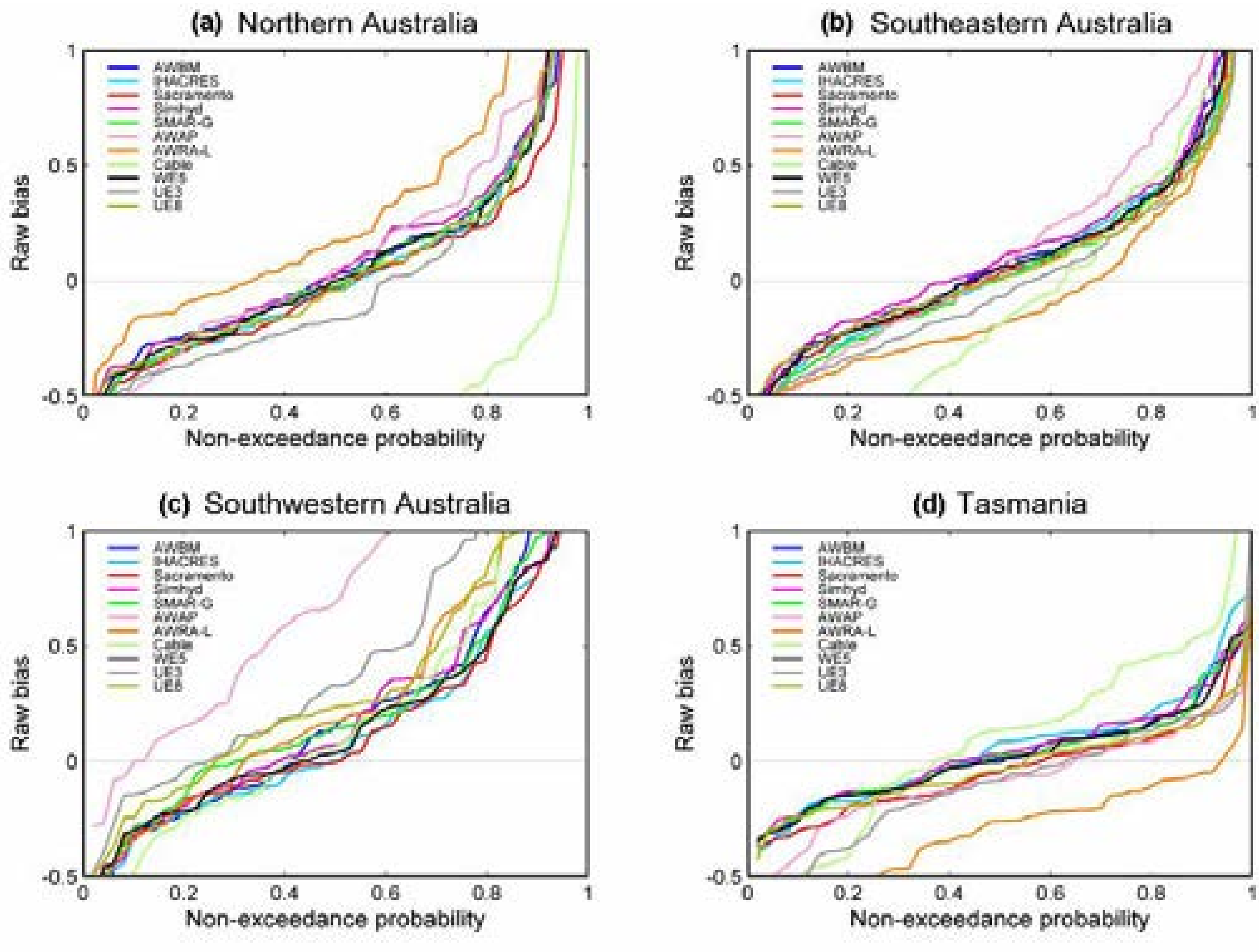


Figure 2-3. Cumulative distribution of raw average bias of annual streamflow predictions in validation mode for: (a) northern Australia, (b) south-eastern Australia, (c) south-western Australia and (d) Tasmania (Viney 2010)

2.3 Modelling concepts (continued)

Soil moisture storage

Soil moisture estimates derived from AWRA-L and WaterDyn differ greatly in magnitude when compared in absolute terms across the reporting regions (Figure 2-5). This difference is predominantly due to the differing assumptions in each of the models regarding upper and lower soil store capacity. WaterDyn uses available soil depth mapping to spatially vary the soil depth around Australia within the model. Spatially explicit soil properties for the two WaterDyn soil layers are based on the McKenzie and Hook (1992) and McKenzie et al. (2000) interpretations of the Digital Atlas of Australian Soils (Northcote et al. 1960–68). AWRA-L currently uses a constant soil storage capacity across Australia. Neither approach is perfect, as (a) for WaterDyn: the soil mapping will contain errors and (b) for AWRA-L: soil depth (and hence water holding capacity) varies spatially. Comparison of relative performance at reproducing observed field and satellite data is yet to be undertaken.

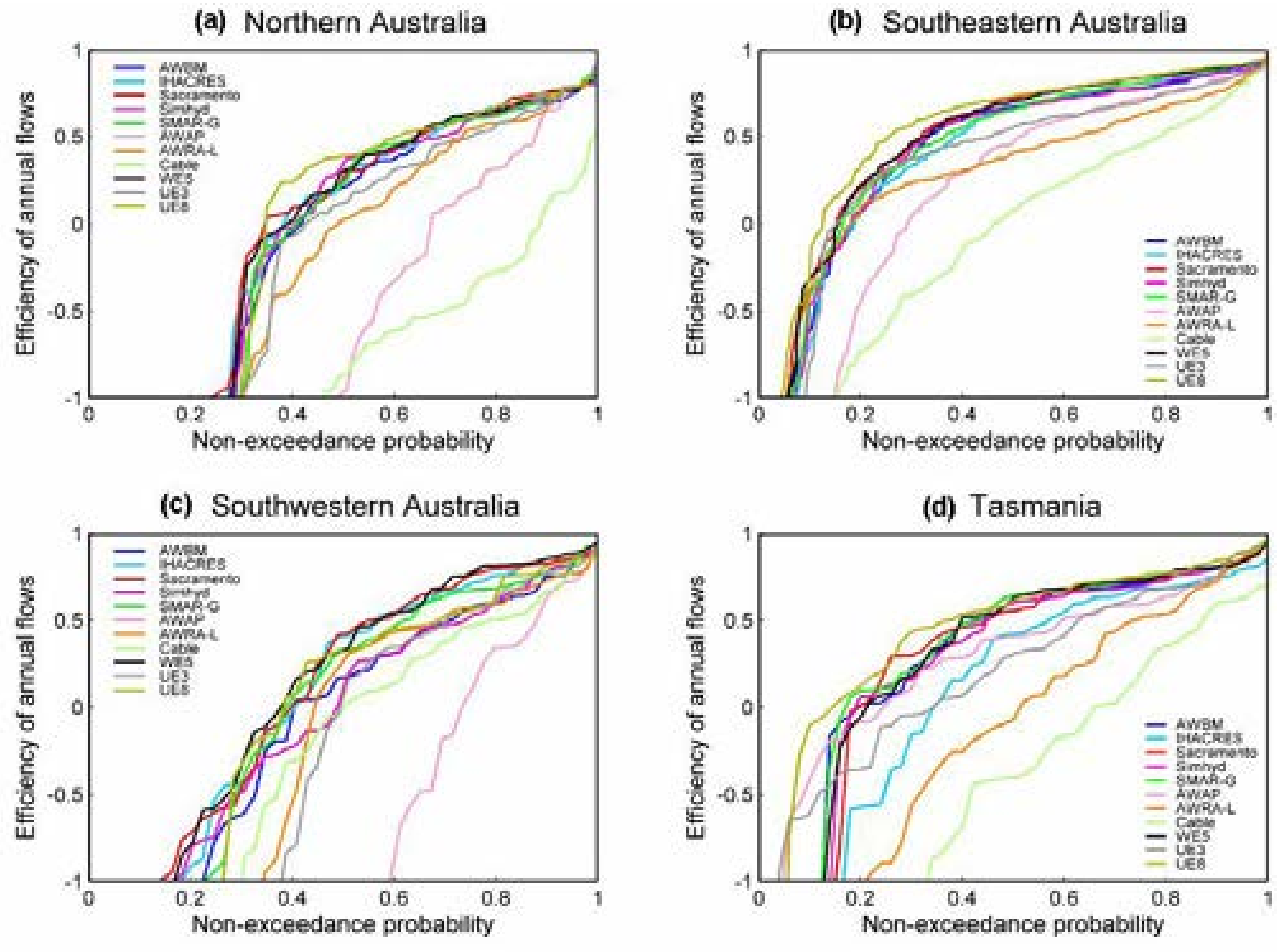


Figure 2-4. Cumulative distribution of Nash-Sutcliffe Efficiency of annual streamflow predictions in validation mode for (a) northern Australia, (b) south-eastern Australia, (c) south-western Australia and (d) Tasmania (Viney 2010)

2.3 Modelling concepts (continued)

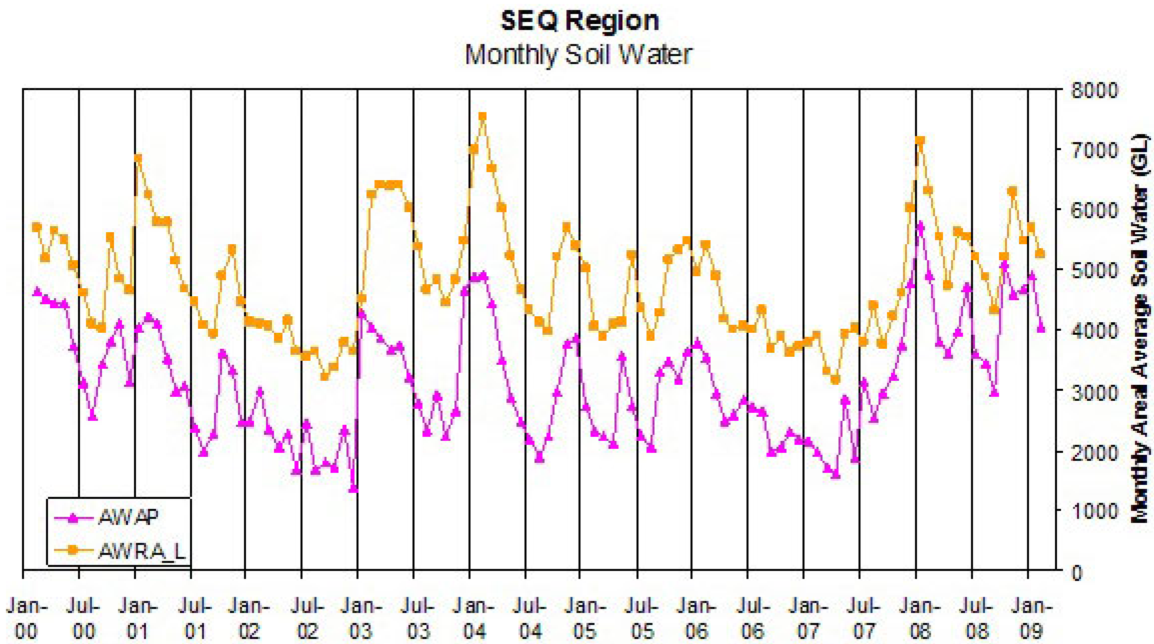


Figure 2-5. Monthly aggregated soil moisture for South East Queensland comparing WaterDyn (AWAP) and AWRA-L (Bacon et al. 2010)

2.4 Adopted approach

The following decisions were made as the most comprehensive approach to estimate the required water balance components for the 2010 Assessment.

Landscape water yield

As there was insufficient time for calibration/regionalisation of standard rainfall run-off models for use in the National Water Account 2010 and the Australian Water Resources Assessment 2010, an average of WaterDyn and AWRA-L, defined below, was selected to generate estimates of modelled landscape water yield for this report. That estimate was shown by Bacon et al. (2010) to be better than either model alone when compared to available unimpaired catchment streamflow data.

$$LWY = (F_{WDis} + Q_{Tot}) / 2$$

Where:

- LWY is modelled landscape water yield
- F_{WDis} is modelled catchment discharge/outflow from WaterDyn [surface run-off (F_{WRun}) + deep drainage (F_{WLch2})]
- Q_{Tot} is modelled streamflow from AWRA-L (surface run-off + groundwater discharge).

Soil moisture storage

As the WaterDyn soil store varied according to available soil depth mapping (albeit flawed due to mapping errors), the WaterDyn model was chosen for calculation of soil moisture storage. Averaging of soil store estimates (as used for streamflow) was not considered appropriate, as the conceptual structure and capacity of AWRA-L and WaterDyn soil and groundwater storages are different.

Actual evapotranspiration

As the satellite-based algorithms, compared by King et al. (2011), were not available to the Bureau for the Australian Water Resources Assessment 2010, and as WaterDyn was used for soil moisture storage, WaterDyn was also used for evapotranspiration calculation.

It should be noted that, as an AWRA-L and WaterDyn average was used for landscape water yield in the Australian Water Resources Assessment 2010, and WaterDyn was used for evapotranspiration and soil moisture storage, a mass balance is not maintained.

2.5 Current development: the AWRA modelling system

As part of the Water Information Research and Development Alliance (WIRADA) between the Bureau and CSIRO, the AWRA modelling system (Van Dijk et al. 2011; see Figure 2-6) is the preferred model for use in future editions of this report. It is under development to support the Bureau's National Water Account and Australian Water Resources Assessment reporting requirements. This development will improve the robustness of the estimation methods and will facilitate timely reporting by the Bureau.

The AWRA modelling system includes the following components:

- A holistic **water balance model** (AWRA-LRG): this consists of landscape, river and groundwater balance components, also allowing dynamic linkages between them. Development has focused on the landscape component to date (Van Dijk & Warren 2010). AWRA-LRG will provide a consistent water balance estimation system.
- A **model-data fusion system** to update and constrain model estimates according to observations where appropriate. Model-data fusion includes calibration/parameterisation of model components (e.g. calibration of a rainfall run-off model according to streamflow data), assimilation of observations to update model states/parameters (updating model soil store states according to satellite observations) and other blending methods (e.g. averaging differing model estimates of run-off).
- A **benchmarking system** to test that the model and input data are accurately reflecting observations. The benchmarking system refers to a set of (partly or wholly automated) tests designed to assess how well the simulations from a modified system version (in comparison to a previous system version) reproduce a standard set of observations following a standard set of criteria. This also needs to include ongoing evaluation of system forcing data where possible.

Other components are under development as well, which is further described by Stenson et al. (2011). It is expected that through this research and development, over the remainder of the WIRADA (ending June 2013), estimates provided within Australian Water Resources Assessment reports will significantly improve.

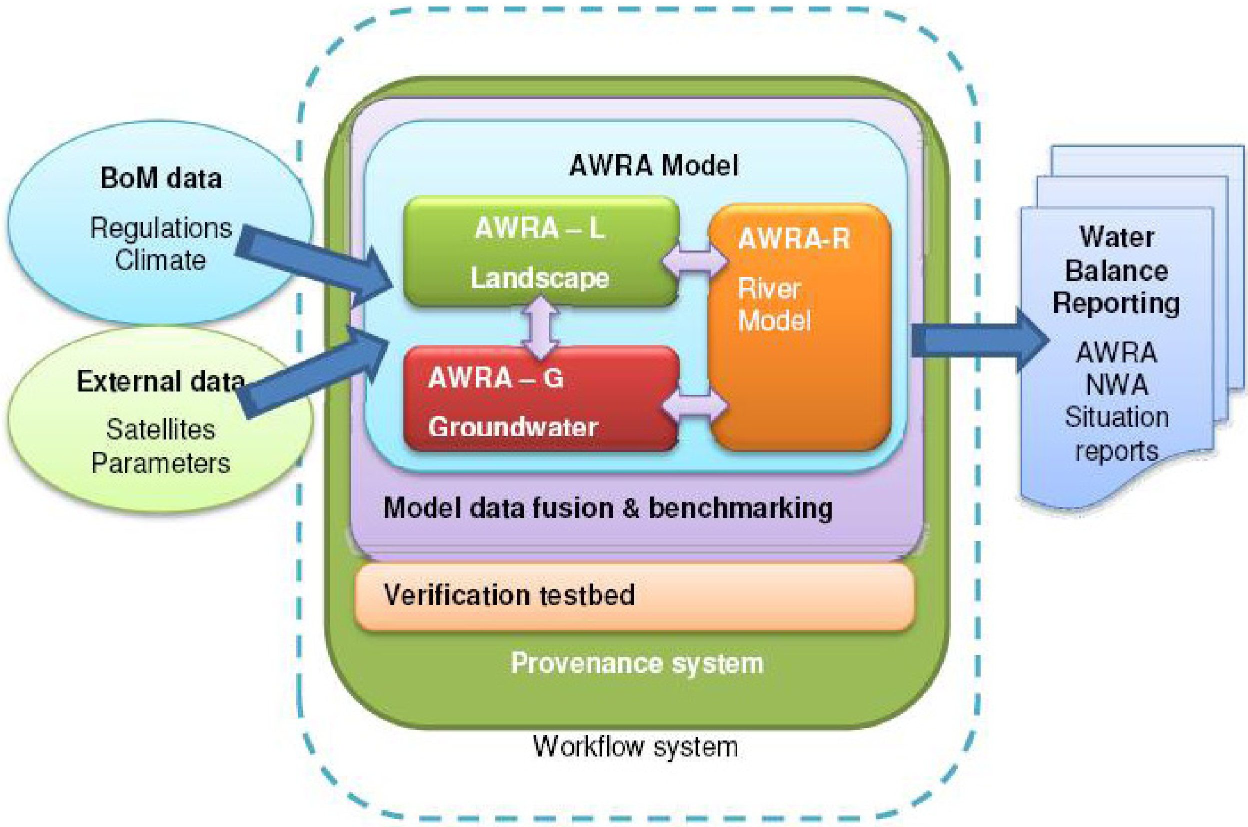


Figure 2-6. AWRA modelling system conceptual diagram

3. Methods review summary

The 2010 Assessment includes many different analysis methods, most of them specifically focusing on particular components of the water resources (i.e. groundwater, storages or streamflow). These methods were selected with care, based on a sound investigation of similar assessments previously performed in Australia and overseas.

This summary is to provide a list of references and peer reviews of the analysis methods used in this report, to demonstrate the validity of the methods.

For each method used in the report, the consequent tables provide the following information:

- a reference to the section in which the method is used
- a short description of the input data for the analysis
- a short description of the applied method
- the resolution (temporal and spatial) of the output data
- references to other work in which the method was applied
- an example illustration of the output.

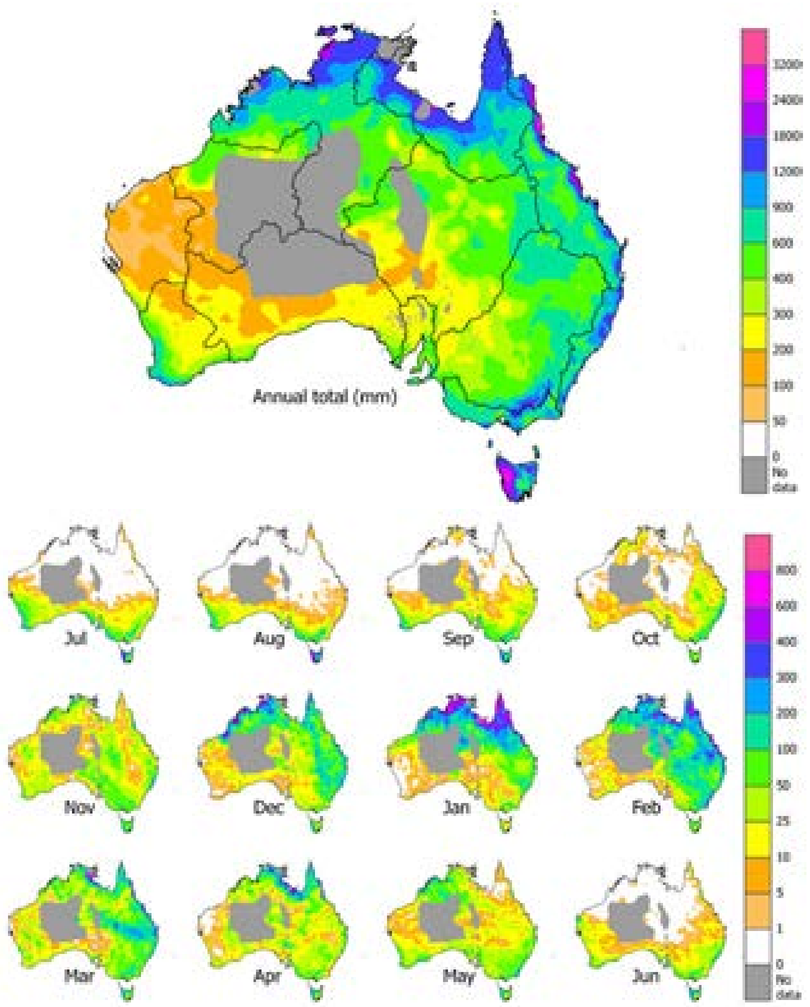
More information on each individual report figure can be found in the metadata for the figure in question. This is provided on the Australian Water Resources Assessment 2010 website.

For further details of Categories of Water Information defined in the Methods review summary, please refer to the following webpages:

- Categories of water information www.bom.gov.au/water/regulations/categoriesWaterAuxNav.shtml
- Sub-categories of water information www.bom.gov.au/water/regulations/subCategoriesWaterAuxNav.shtml

Analysis	Data	Method	Reference/peer review
Annual and monthly national rainfall surfaces National Overview/ Landscape water flows in 2009–10 (Section 2.3)	**Description** 5 x 5 km rainfall grid data derived using an anomaly-based approach applying the Barnes successive correction method and smoothing spline approach. **Source** Bureau (National Climate Centre)	**Description** Bureau standard spatial climate data presentation method. Monthly and annual total rainfall grids (July–June) presented. Monthly data summed to generate annual rainfall grid. **Resolution (Output)** **Temporal** – Annual/Monthly **Spatial** – 5 x 5 km grid (National coverage)	Bureau of Meteorology 2010, Annual Climate Summary 2009, www.bom.gov.au/climate/annual_sum/2009/AnClimSum09_HR1.1.pdf Bureau of Meteorology 2011, Annual Climate Summary 2010, www.bom.gov.au/climate/annual_sum/2010/AnClimSum10_HR1.0.pdf Jones, DA, Wang, W and Fawcett, R 2009, 'High-quality spatial climate data-sets for Australia', *Australian Meteorological and Oceanographic Journal*, vol. 58, pp. 233–248.

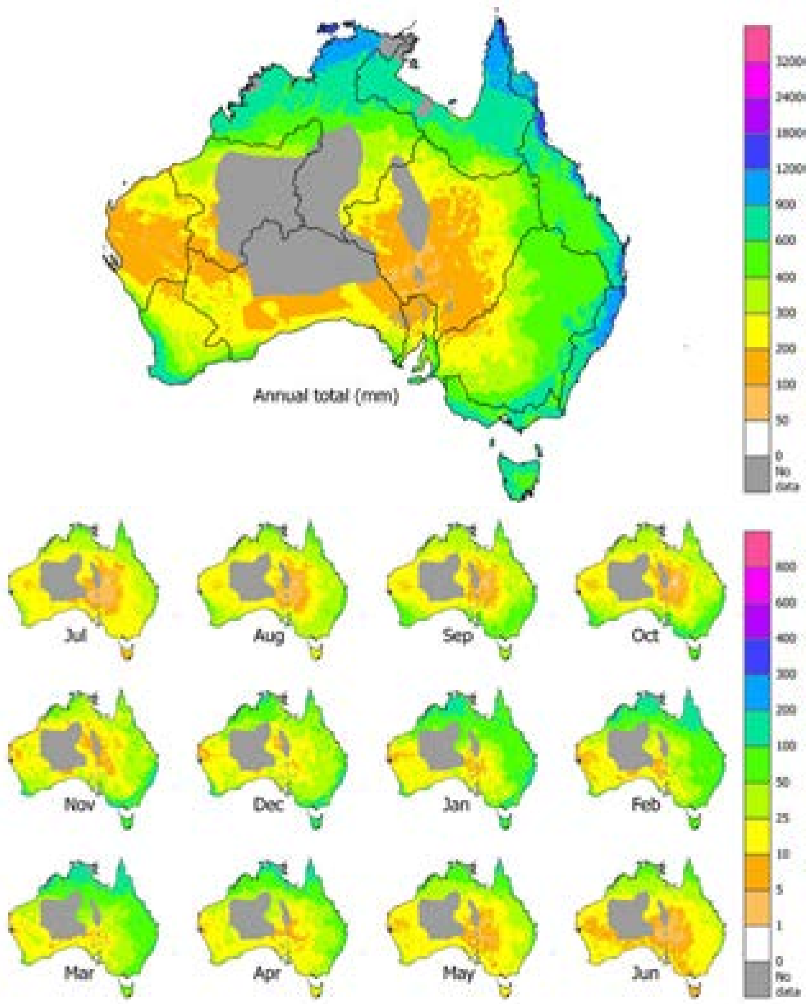
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Annual and monthly national modelled actual evapotranspiration surfaces National Overview/ Landscape water flows in 2009–10 (Section 2.3)	**Description** 25 x 5 km actual evapotranspiration grid data from national water balance model (WaterDyn). Based on the Priestly-Taylor equation. **Source** CSIRO (WaterDyn V26)	**Description** Bureau standard spatial climate data presentation method. Monthly and annual total modelled actual evapotranspiration grids (July–June) presented. Monthly data summed to generate annual evapotranspiration grid. **Resolution (Output)** **Temporal** – Annual/Monthly **Spatial** – 5 x 5 km grid (National coverage)	Raupach, MR, Briggs, PR, Haverd, V, King, EA, Paget, M and Trudinger, M 2009, *Australian Water Availability Project: CSIRO Marine and Atmospheric Research Component: Final Report for Phase 3*, CAWCR Technical Report No. 013, Centre for Australian Weather and Climate Research, Australia.

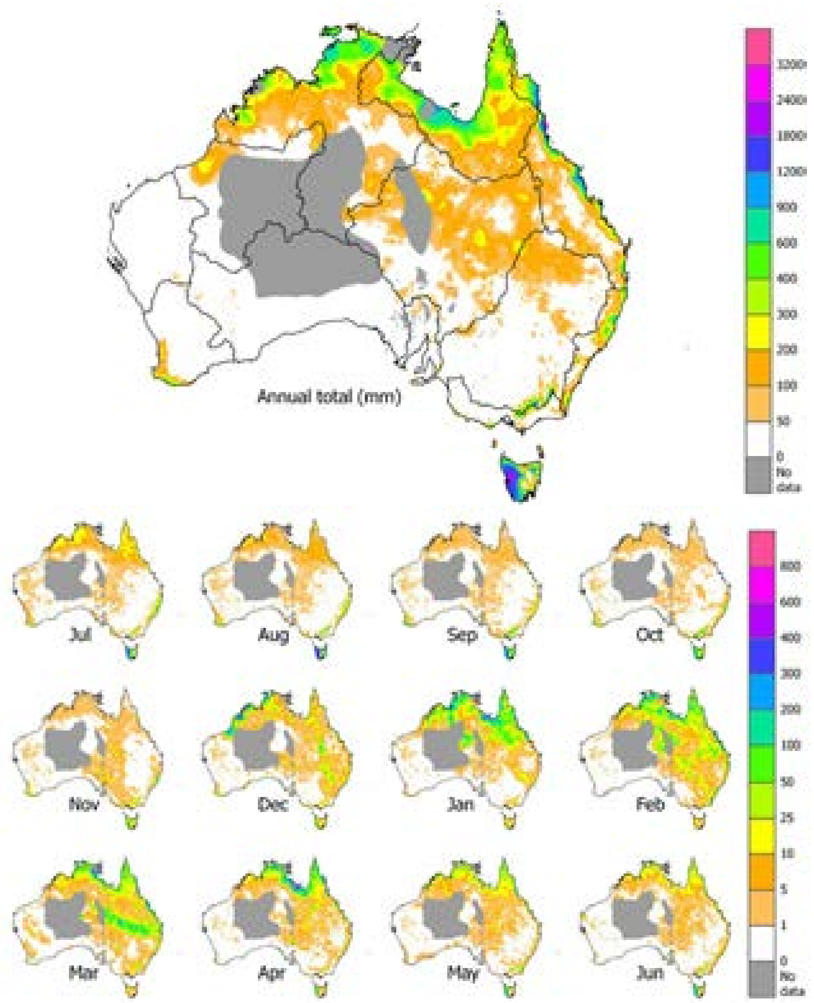
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Annual and monthly national modelled landscape water yield surfaces National Overview/ Landscape water flows in 2009–10 (Section 2.3)	**Description** 5 x 5 km modelled landscape water yield grid data derived from average of model generated outputs from two national water balance models (WaterDyn and AWRA-L). **Source** CSIRO (WaterDyn V26/AWRA-L)	**Description** Bureau standard spatial climate data presentation method. Monthly and annual total modelled landscape water yield grids (July–June) presented. Monthly data summed to generate annual landscape water yield grid. **Resolution (Output)** **Temporal** – Annual/Monthly **Spatial** – 5 x 5 km grid (National coverage)	Raupach, MR, Briggs, PR, Haverd, V, King, EA, Paget, M and Trudinger, M 2009, *Australian Water Availability Project: CSIRO Marine and Atmospheric Research Component: Final Report for Phase 3*, CAWCR Technical Report No. 013, Centre for Australian Weather and Climate Research, Australia. Van Dijk, A 2010, *The Australian Water Resources Assessment System: Technical Report 3; Landscape Model (version 0.5), Technical Description*, CSIRO National Research Flagships: Water for Healthy Country, Canberra. Viney, NR 2010, *A comparison of modelling approaches for continental stream flow prediction*, CSIRO National Research Flagships: Water for Healthy Country, Canberra.

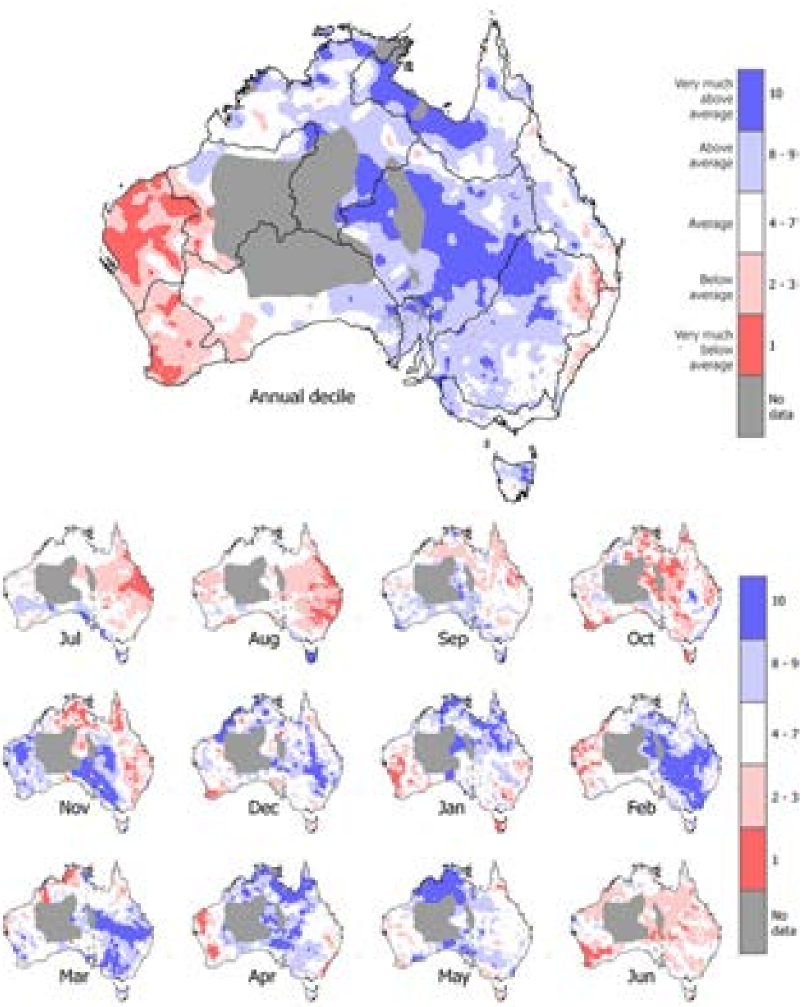
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Annual and monthly national deciles (rainfall, evapotranspiration and landscape water yield) National Overview/ Landscape water flows in 2009–10 (Section 2.3)	**Description** 5 x 5 km annual and monthly deciles grid data generated for each of the landscape water flows. Deciles calculated from long-term gridded data (July 1911 to June 2010) from two national water balance models (WaterDyn and AWRA-L). **Source** Bureau (National Climate Centre) CSIRO (WaterDyn V26/AWRA-L)	**Description** Bureau standard spatial climate data analysis and presentation method. Monthly and annual deciles grids (July–June) presented based on the long-term record (July 1911 to June 2010). **Resolution (Output)** **Temporal** – Annual/Monthly **Spatial** – 5 x 5 km grid (National coverage)	Bureau of Meteorology 2011, Annual Climate Summary 2010, www.bom.gov.au/climate/annual_sum/2010/AnClimSum10_HR1.0.pdf Bureau of Meteorology 2010, Annual Climate Summary 2009, www.bom.gov.au/climate/annual_sum/2009/AnClimSum09_HR1.1.pdf Bureau Climate Statements www.bom.gov.au/climate/current/statements/scs22.pdf www.cawcr.gov.au/publications/researchletters/CAWCR_Research_Letters_2.pdf

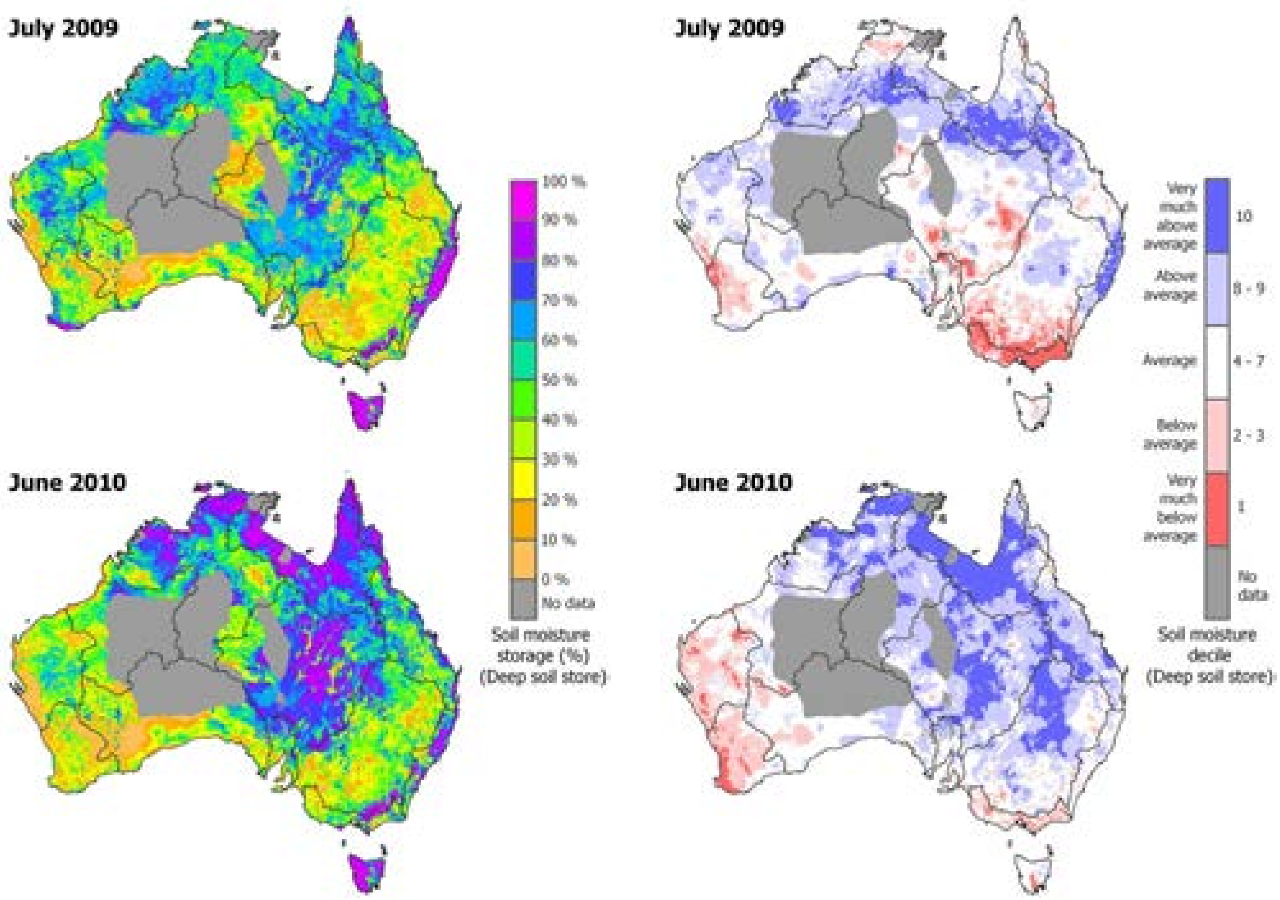
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Annual variation in national soil moisture surfaces National Overview/ Soil Moisture Store in 2009–10 (Section 2.4)	**Description** 5 x 5 km gridded monthly soil moisture index data from national water balance model (WaterDyn). Deciles calculated from long-term gridded data (July 1911 to June 2010). **Source** CSIRO (WaterDyn V26)	**Description** Spatial soil moisture data analysis and presentation method for WaterDyn model outputs. Monthly deep soil store moisture storage (0–100%) – based on soil moisture index (0–1) – and deciles presented for the beginning and end of the reporting year (July 2009 to June 2010). Deciles classes are derived from the relevant monthly values from the long-term (July 1911 to June 2010) record. **Resolution (Output)** **Temporal** – Monthly **Spatial** – 5 x 5 km grid (National coverage)	Australian Water Availability Project www.csiro.au/awap/cgi/awap2.pl?ser=Australia_run26c_monthly Raupach, MR, Briggs, PR, Haverd, V, King, EA, Paget, M and Trudinger, M 2009, *Australian Water Availability Project: CSIRO Marine and Atmospheric Research Component: Final Report for Phase 3*, CAWCR Technical Report No. 013, Centre for Australian Weather and Climate Research, Australia.

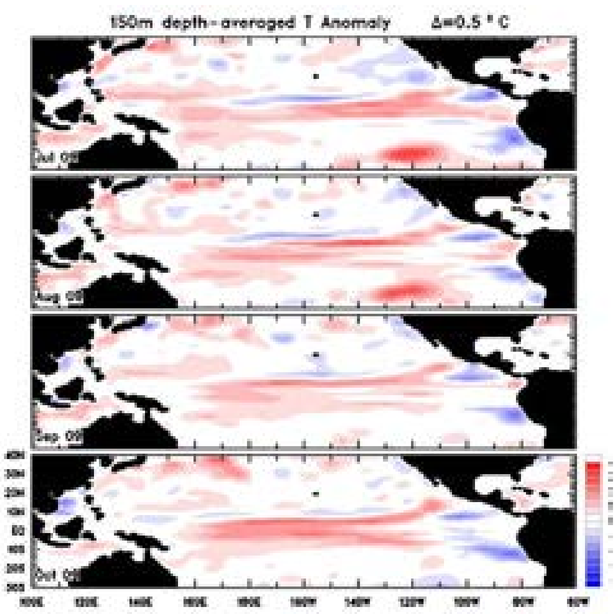
Example figures

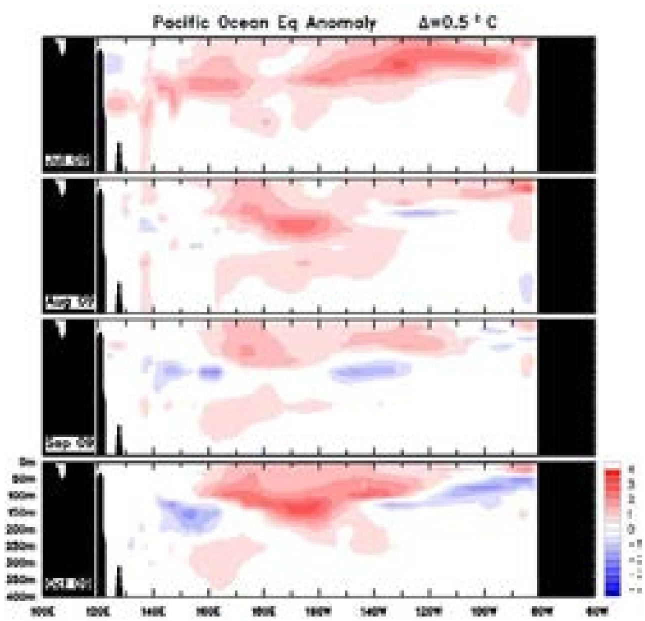


3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Monthly Pacific Ocean temperature maps and profiles National Overview/ Australian climate drivers in 2009–10 (Section 2.8)	**Description** Pacific Ocean 150 m depth-averaged temperature anomalies and monthly vertical temperature anomaly at the equator. Data presented as four-month sequences covering July 2009 to June 2010. **Source** Bureau (National Meteorological and Oceanographic Centre)	**Description** Standard Bureau and International presentation of surface and sub-surface Pacific Ocean temperature anomalies for the assessment and analysis of Pacific Ocean ENSO conditions. **Resolution (Output)** **Temporal** – Monthly sequence for 2009–10 **Spatial** – Pacific Ocean	Bureau of Meteorology Seasonal Outlooks – El Niño/La Niña www.bom.gov.au/climate/enso/ Temperature anomaly sequences http://reg.bom.gov.au/cgi-bin/wrap_fwo.pl?IDYOC006.gif http://reg.bom.gov.au/cgi-bin/wrap_fwo.pl?IDYOC007.gif

Example figures

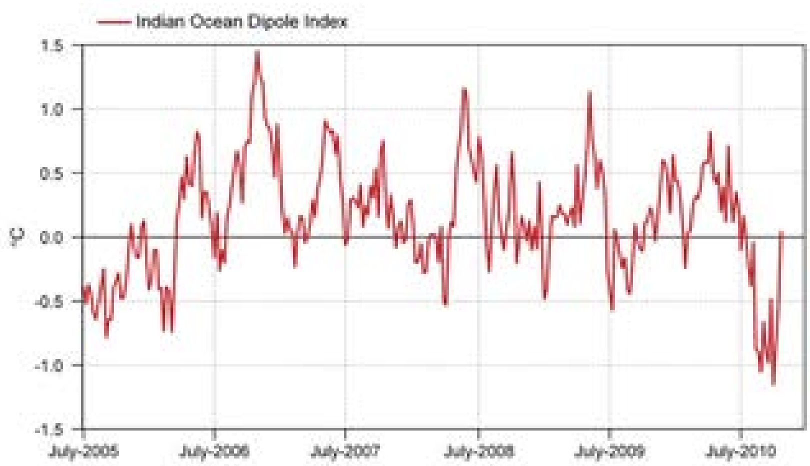




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Southern Oscillation Index (SOI) and Indian Ocean Dipole (IOD) Time-series National Overview/ Australian climate drivers in 2009–10 (Section 2.8)	**Description** Monthly Southern Oscillation Index (SOI) time-series data (July 2005 to October 2010). Weekly Indian Ocean Dipole (IOD) time-series data (July 2005 to October 2010). **Source** Bureau (National Climate Centre)	**Description** Standard presentation of historic SOI and IOD time-series data. SOI data presented at monthly resolution with a five-month binomial weighted mean. The five-month mean for month x = $(SOI_{x-2} + 4SOI_{x-1} + 6SOI_{x} + 4SOI_{x+1} + SOI_{x+2}) / 16$ IOD Index data presented at weekly resolution. **Resolution (Output)** **Temporal** – Monthly (SOI) and weekly (IOD)	Bureau of Meteorology Seasonal Outlooks – El Niño/La Niña www.bom.gov.au/climate/enso/ SOI and IOD time-series www.bom.gov.au/climate/current/soi2.shtml www.bom.gov.au/climate/enso/indices.shtml Troup, AJ 1965, 'The Southern Oscillation', *Quarterly Journal of Royal Meteorological Society*, vol. 91, pp. 490–506. Saji, NH, Goswami, BN, Vinayachandran, PN and Yamagata, T 1999, 'A dipole mode in the tropical Indian Ocean', *Nature*, vol. 401, pp. 360–363.

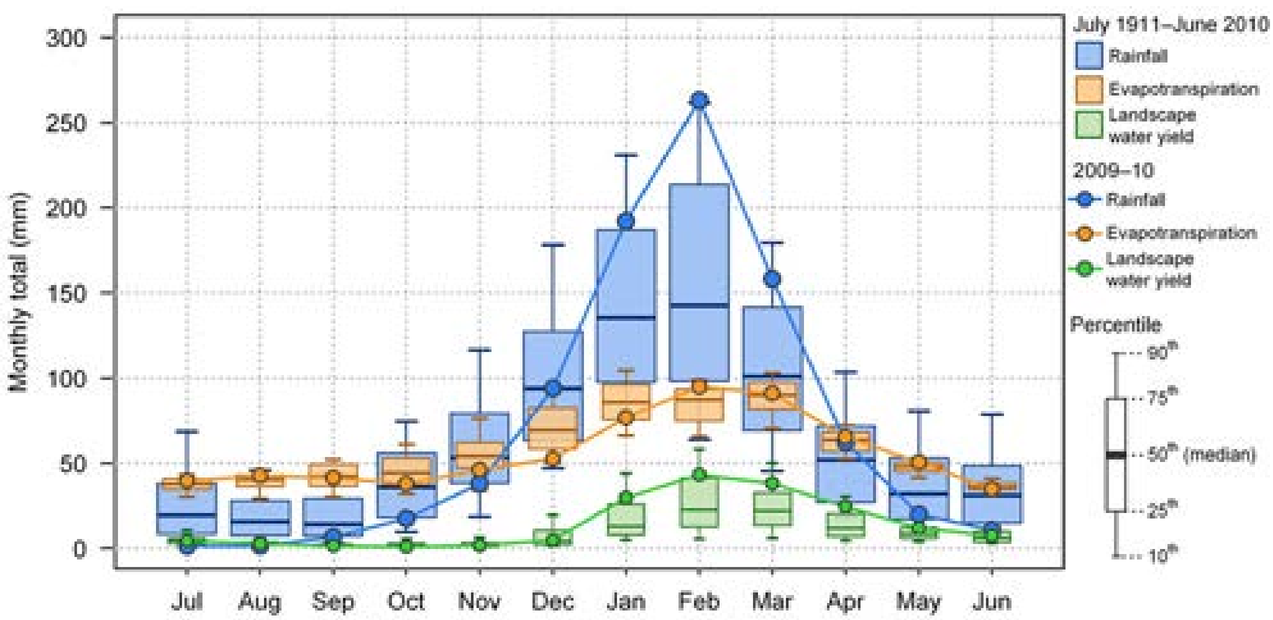
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Monthly box plots of regional landscape water balance model flows Regional water resources assessments/Recent patterns in landscape water flows (Section 4 of the regional chapters)	**Description** Regionally averaged monthly landscape water flow data from national landscape water balance models (WaterDyn and AWRA-L). Data presented are rainfall, evapotranspiration and landscape water yield. **Source** Bureau (National Climate Centre) CSIRO (WaterDyn V26/AWRA-L)	**Description** Monthly data for the current year (2009–10) are presented relative to long-term record. Monthly distributions (box and whiskers) are calculated from long-term model run data (July 1911 to June 2010). Landscape water flow variables presented are: 1) rainfall 2) actual evapotranspiration 3) landscape water yield. **Resolution (Output)** **Temporal** – Monthly **Spatial** – Australian Water Resources Assessment reporting region (spatially averaged)	Example for the interpretation of the Bureau's Streamflow Forecasts www.bom.gov.au/water/ssf/forecasts.shtml#drainage=murray_darling&basin=upper_murray&catchment=Q_HUME_TOT&productType=DT_1&productGroup=data

Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Regional summary of annual landscape water flows (mapped annual totals and deciles) Regional water resources assessments/Recent patterns in landscape water flows (Section 4 of the regional chapters)	**Description** 5 x 5 km gridded annual landscape water flows data (July–June) from national landscape water balance models (WaterDyn and AWRA-L). Deciles calculated from long-term gridded data (July 1911 to June 2010) The underlying data are the same as presented for the national water flow surfaces in Section 2.3. **Source** Bureau (National Climate Centre) CSIRO (WaterDyn V26/AWRA-L)	**Description** Bureau standard spatial climate data presentation method. Annual total and annual deciles landscape water flow grids (July–June) presented. Annual deciles grids (July–June) calculated based on the long-term record (July 1911 to June 2010). Landscape water flow variables presented are: 1) rainfall 2) actual evapotranspiration 3) landscape water yield. **Resolution (Output)** **Temporal** – Annual **Spatial** – 5 x 5 km grid for each Australian Water Resources Assessment reporting region	Bureau of Meteorology 2011, Annual Climate Summary 2010, www.bom.gov.au/climate/annual_sum/2010/AnClimSum10_HR1.0.pdf Bureau of Meteorology 2010, Annual Climate Summary 2009, www.bom.gov.au/climate/annual_sum/2009/AnClimSum09_HR1.1.pdf Raupach, MR, Briggs, PR, Haverd, V, King, EA, Paget, M and Trudinger, M 2009, *Australian Water Availability Project: CSIRO Marine and Atmospheric Research Component: Final Report for Phase 3*, CAWCR Technical Report No. 013, Centre for Australian Weather and Climate Research, Australia

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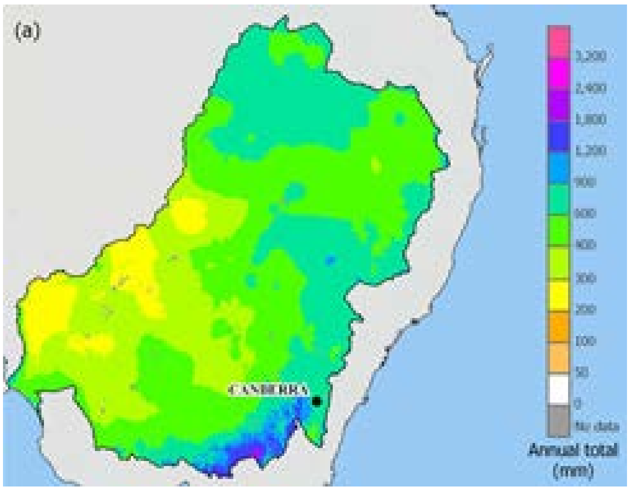
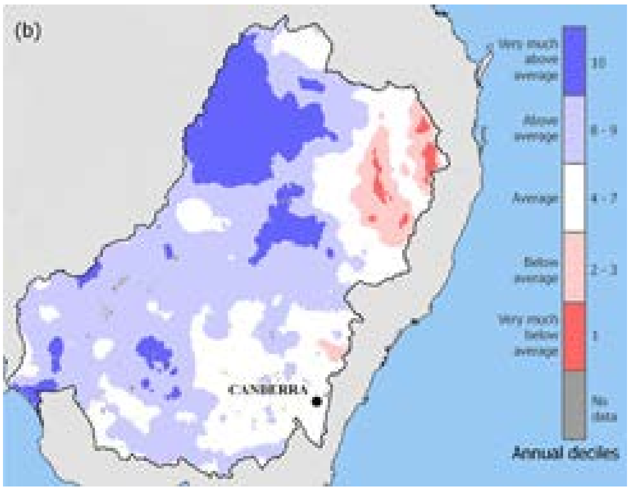
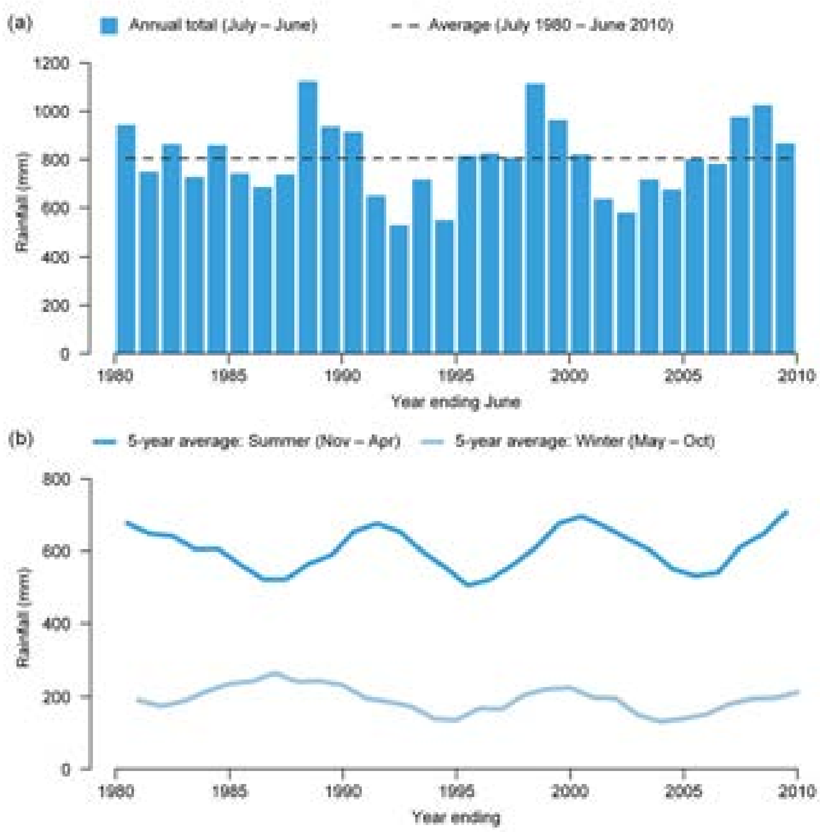




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Time-series of landscape water flows over the past 30 years (annual and seasonal) Regional water resources assessments/Recent patterns in landscape water flows (Section 4 of the regional chapters)	**Description** Spatially averaged monthly and annual landscape water flow data (July–June) from national landscape water balance models (WaterDyn and AWRA-L). Summer (November–April) and winter (May–October) season totals calculated from monthly model output data. **Source** Bureau (National Climate Centre) CSIRO (WaterDyn V26/AWRA-L)	**Description** Simple time-series plot of annual data presented for past 30 years (July 1980 to June 2010). Simple time-series plot of seasonal five-year moving averages (backward looking) data presented for past 30 years (November 1980 to October 2010). Landscape water flow variables presented are: 1) rainfall 2) actual evapotranspiration 3) landscape water yield. **Resolution (Output)** **Temporal** – Annual (July–June) and six-month seasons (November–April and May–October) Spatial – Australian Water Resources Assessment reporting region (spatially averaged)	Example of the Bureau's climate variability and change time-series: **Annual plot** www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=rain&area=aus&season=0112&ave_yr=A **Seasonal plot** www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=rain&area=aus&season=0411&ave_yr=5 Jones, DA, Wang, W and Fawcett, R 2009, 'High-quality spatial climate data-sets for Australia', *Australian Meteorological and Oceanographic Journal*, vol. 58, pp. 233–248.

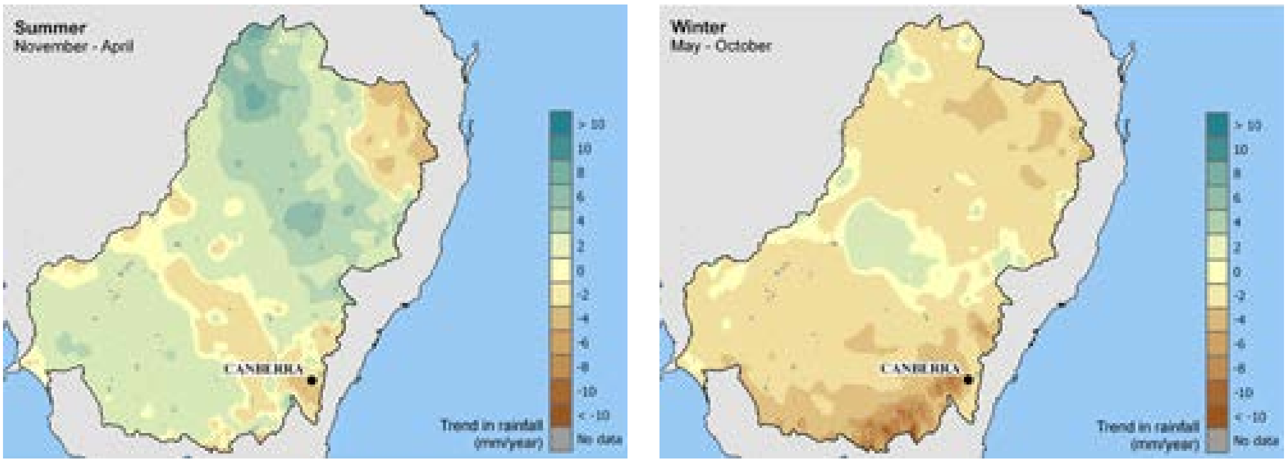
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Regional maps trends in seasonal landscape water flows over the past 30 years (seasonal) Regional water resources assessments/Recent patterns in landscape water flows (Section 4 of the regional chapters)	**Description** 5 x 5 km gridded landscape water flow data from national landscape water balance models (WaterDyn and AWRA-L). Trend analysis applied to summer (November–April) and winter (May–October) season totals. Analysis applied to the past 30 seasonal periods (November 1980 to October 2010). **Source** Bureau (National Climate Centre) CSIRO (WaterDyn V26/AWRA-L)	**Description** Simple linear regression trend calculated for summer and winter totals at each 5 x 5 km grid cell over the past 30 years (November 1980 to October 2010). Slope of linear regression line (mm/year) presented to reflect the strength and direction of potential trends. The statistical significance (regression analysis p-values) was calculated (see Section 4.3.1 of the Technical supplement). **Resolution (Output)** **Temporal** – six-month seasons (November–April and May–October) **Spatial** – 5 x 5 km grid for each Australian Water Resources Assessment reporting region	Example of the Bureau's climate variability and change trend analysis www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi?map=rain&area=aus&season=1202&period=1970 Kundzewicz, ZW and Robson, AJ 2004, 'Change detection in hydrological records – a review of the methodology', *Hydrological Sciences Journal/Journal des Sciences Hydrologiques*, vol. 49, no. 1.

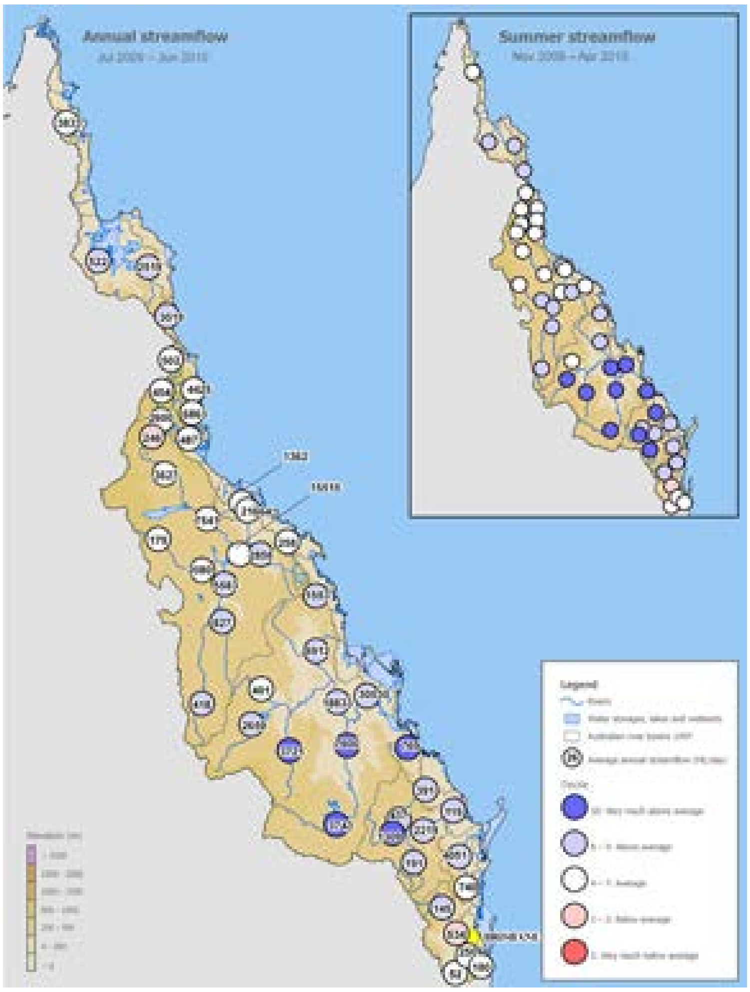
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based seasonal streamflow anomaly analyses Regional water resources assessments/Rivers, wetlands and groundwater (Section 5 of some regional chapters)	**Description** Measured streamflow discharge (ML/day). Data collated for currently operational reference streamflow gauges with records available for at least the past 30 years (July 1980–June 2010). **Source** Bureau (Hydstra database)	**Description** Decile ranking of annual discharge for the reporting year (July 2009 to June 2010) compared to long-term (July 1980 to June 2010) annual time-series. Decile ranking of summer discharge for the reporting year (November 2009–April 2010) compared to long-term (November 1980–April 2010) seasonal time-series. **Resolution (Output)** **Temporal** – Annual/Summer season (November–April) **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Marsh, T and Sanderson, F 2009, *UK Hydrological Review 2008*, NERC/Centre for Ecology and Hydrology, United Kingdom. http://nora.nerc.ac.uk/10839/1/UK_Hydrological_Review_2008.pdf

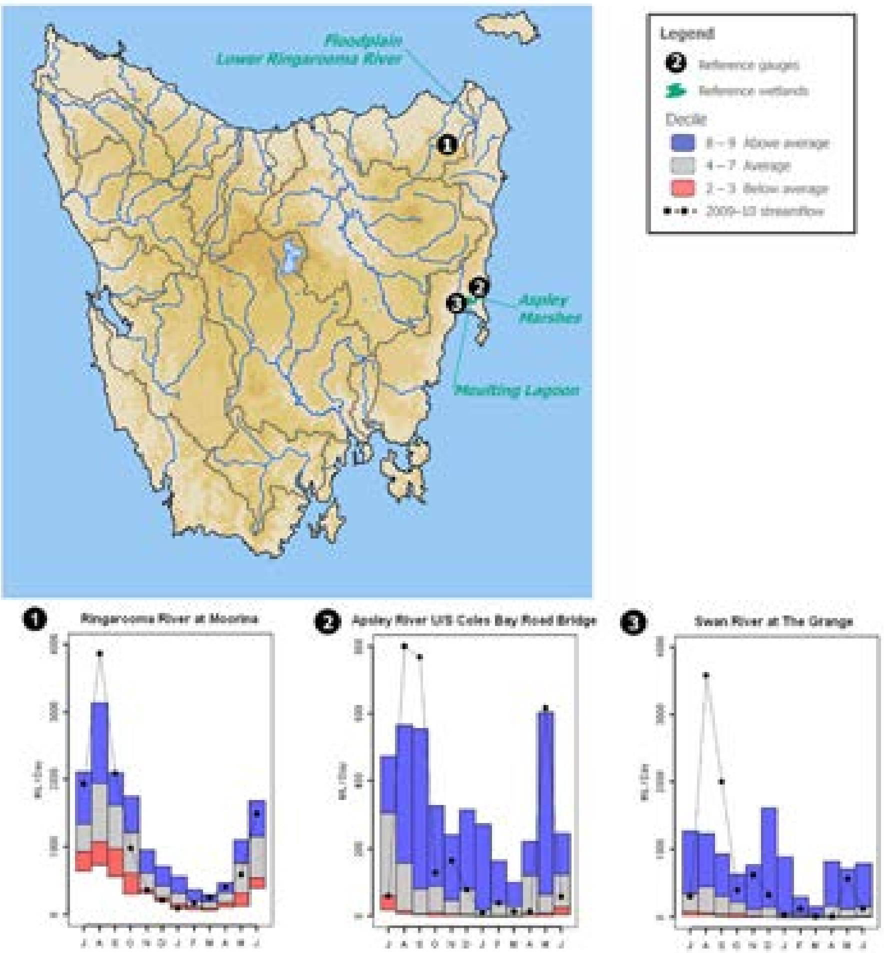
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of monthly streamflow Regional water resources assessments/Rivers, wetlands and groundwater (Section 5 of some regional chapters)	**Description** Measured streamflow discharge (ML/day). Data collated for currently operational reference streamflow gauges with records available for at least the past 30 years (July 1980 to June 2010). **Source** Bureau (Hydstra database)	**Description** Graphical presentation of measured monthly streamflow for 2009–10 plotted against derived monthly decile ranges (2–3, 4–7 and 8–9). Decile ranges calculated from 30-year (July 1980 to June 2010) record. Plots are presented on a map of the reporting region linked to the location of reference streamflow gauges. **Resolution (Output)** **Temporal** – Monthly **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Standard graphical presentation of hydrological information Reference not required

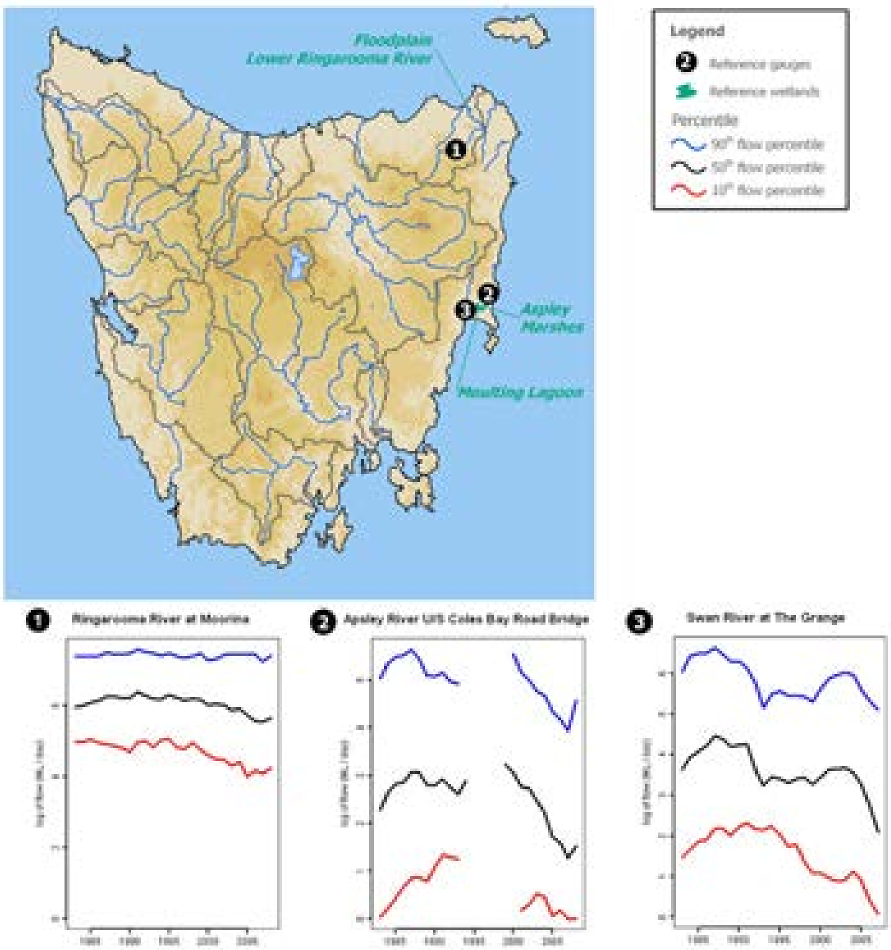
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of changes in streamflow over the past 30 years Regional water resources assessments/Rivers, wetlands and groundwater (Section 5 of some regional chapters)	**Description** Measured streamflow discharge (ML/day). Data collated for currently operational reference streamflow gauges with records available for at least the past 30 years (July 1980 to June 2010). **Source** Bureau (Hydstra database)	**Description** Graphical presentation of measured daily streamflow percentiles (10 per cent, 50 per cent and 90 per cent) based on a five-year moving window for the available 30-year record. Plots are presented on a map of the reporting region linked to the location of the reference streamflow gauges. **Resolution (Output)** **Temporal** – Annual **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Standard analysis and presentation of hydrological information Reference not required

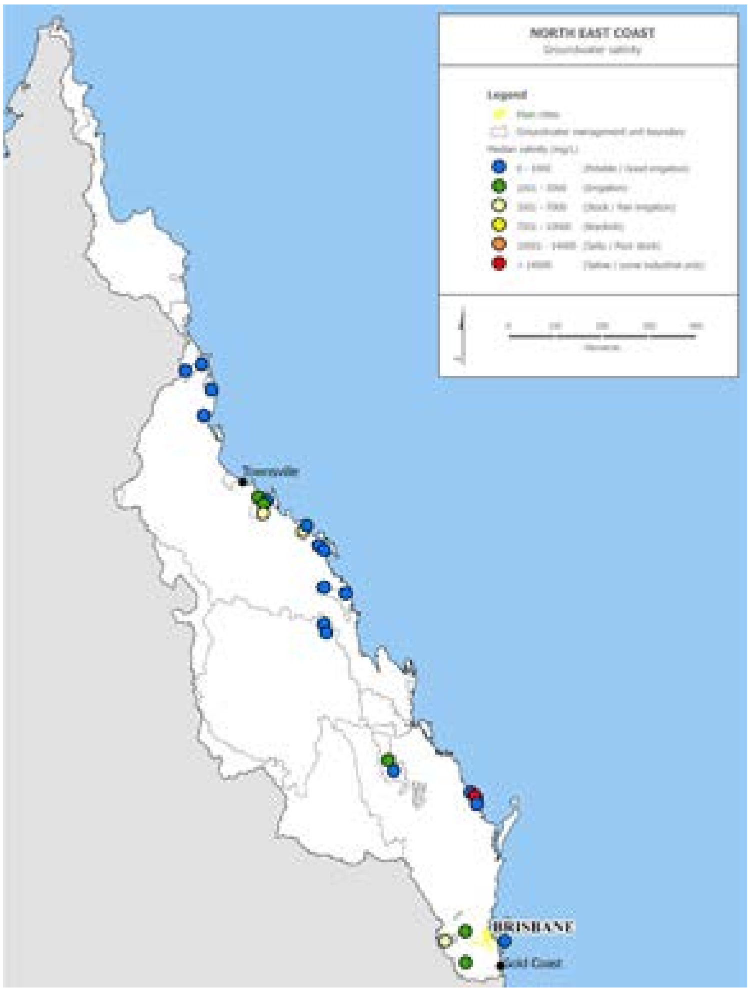
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based summary of groundwater salinity Regional water resources assessments/Rivers, wetlands and groundwater (Section 5 of some regional chapters)	**Description** Electrical conductivity of a groundwater sample (µS/cm). Data collated for currently operational monitoring bores for the past 20 years (July 1990 to June 2010). **Source** Bureau (Groundwater database)	**Description** Standard map presentation of calculated median salinity (mg/L) over the 20-year period (July 1990 to June 2010). Median values classified based on quality and potential use. Empirical equation (below) used to convert units of Electrical Conductivity (EC) (µS/cm) to Total Dissolved Solids (TDS) (mg/L). TDS (mg/L) = EC(µS/cm at 25°C) x 0.6 **Resolution (Output)** **Temporal** – Median of period (20 years) **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Victorian Resources Online: Victoria's Groundwater Resource www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/water-ground-res

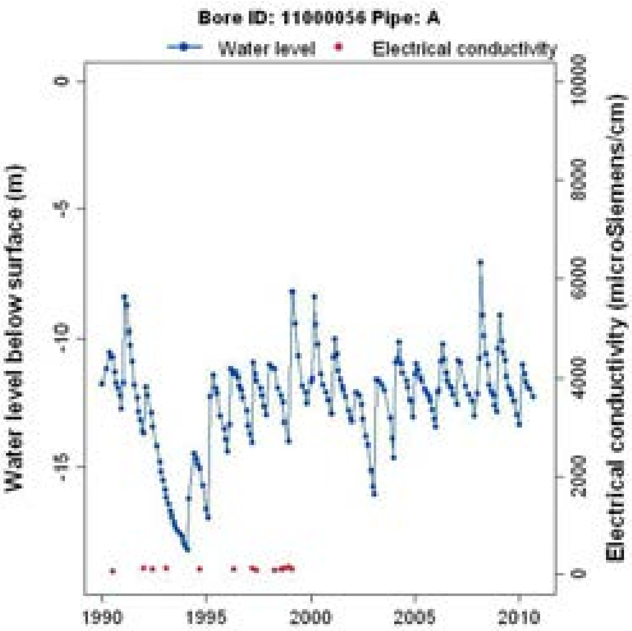
Example figures

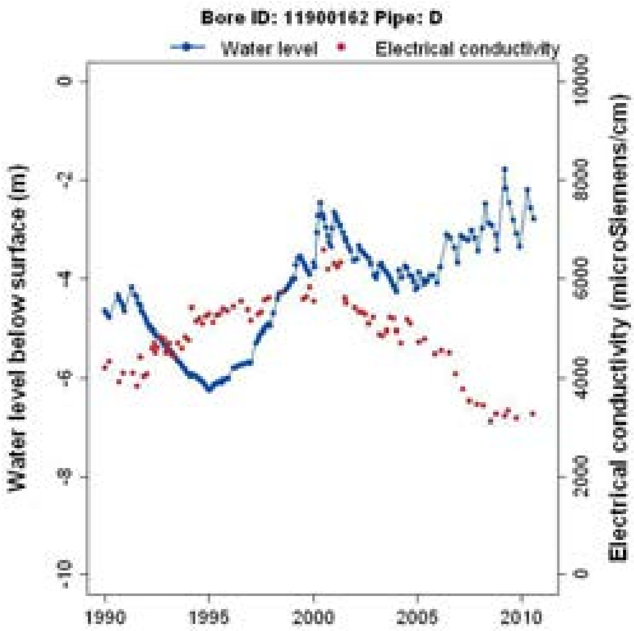


3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of changes in groundwater levels and salinity Regional water resources assessments/Rivers, wetlands and groundwater (Section 3.5)	**Description** Groundwater level of a bore (relative to datum) and electrical conductivity of a groundwater sample (µS/cm). Data collated for currently operational monitoring bores for the past 20 years (July 1990 to June 2010). **Source** Bureau (Groundwater database)	**Description** Graphical presentation of variations and changes in groundwater level (and quality) over the 20-year period (July 1990 to June 2010) Empirical equation (below) used to convert units of Electrical Conductivity (EC) (µS/cm) to Total Dissolved Solids (TDS) (mg/L). TDS (mg/L) = EC(µS/cm at 25°C) x 0.6 **Resolution (Output)** **Temporal** – Variable (dependent upon frequency of measurement) **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Murray–Darling Basin Commission 2008, *Groundwater Status Report 2000-2005; Technical Report*, Murray–Darling Basin Commission, Canberra. Victorian Resources Online: Victoria's Groundwater Resource www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/water-ground-res

Example figures

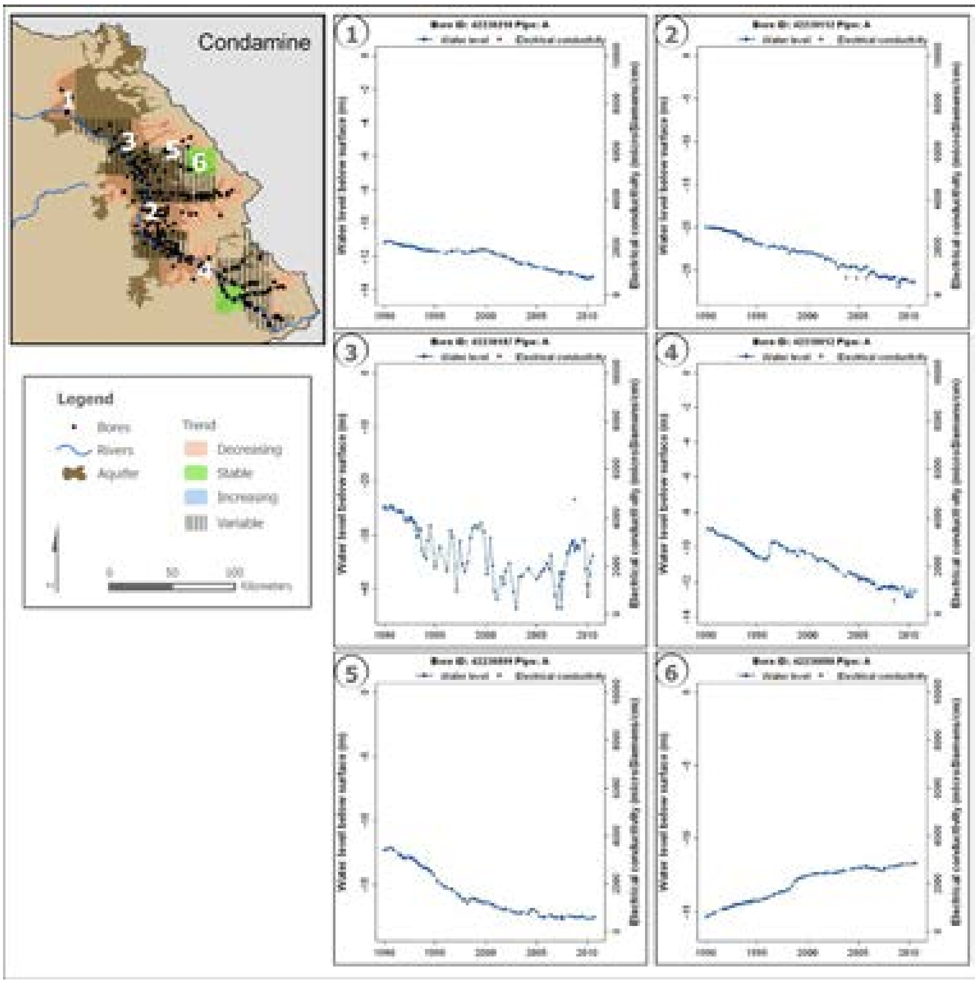




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Trends in groundwater levels Regional water resources assessments/Rivers, wetlands and groundwater (Sections 7.5 and 8.5)	**Description** Groundwater level of a bore (relative to datum). Data collated for currently operational monitoring bores for the past 20 years (July 1990 to June 2010). **Source** Bureau (Groundwater database)	**Description** Standard map presentation of trends in groundwater levels over the period 2005 to 2010 using 20 x 20 km grids across selected aquifers. The linear trend in groundwater levels for a 20 x 20 km grid is assessed as decreasing, stable, increasing or variable. **Resolution (Output)** **Temporal** – Variable (dependent upon frequency of measurement) **Spatial** – 20 x 20 km grids for selected aquifer(s)	Murray–Darling Basin Commission 2008, *Groundwater Status Report 2000-2005; Technical Report*, Murray–Darling Basin Commission, Canberra.

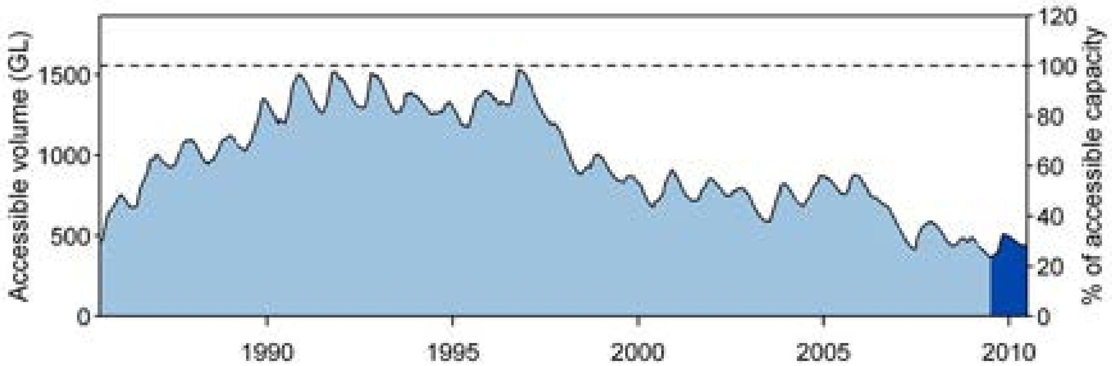
Example figures

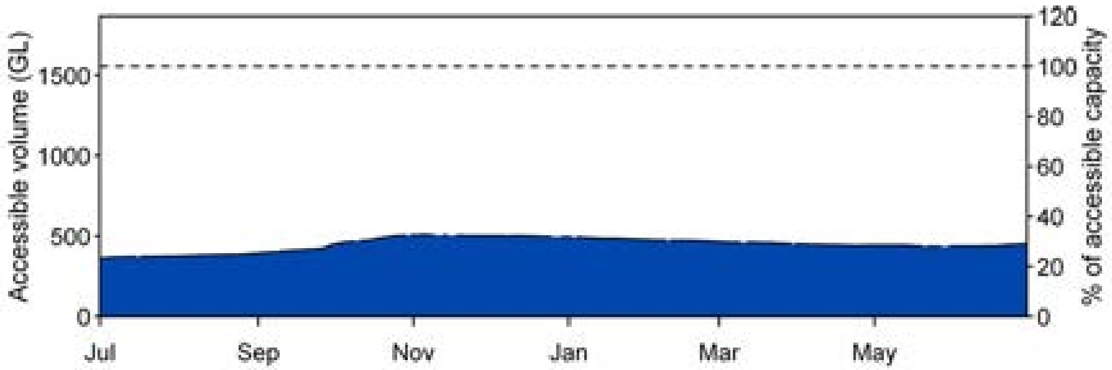


3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of changes in surface water storage (urban/ irrigation) Regional water resources assessments/Water for cities and towns (Section 6 of some regional chapters) Regional water resources assessments/Water for agriculture (Section 7 of some regional chapters)	**Description** Volume of water held in a major storage (GL). **Source** Bureau (AWRIS)	**Description** Graphical presentation of observed long-term and reporting year storage data (2009–10). Graphical axes represent data as both storage volume (GL) and per cent full (per cent of maximum capacity). **Resolution (Output)** **Temporal** – Daily **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Standard presentation of water storage information http://water.bom.gov.au/waterstorage/awris/index.html www.bom.gov.au/water/about/publications/document/factsheet_waterstorage.pdf

Example figures

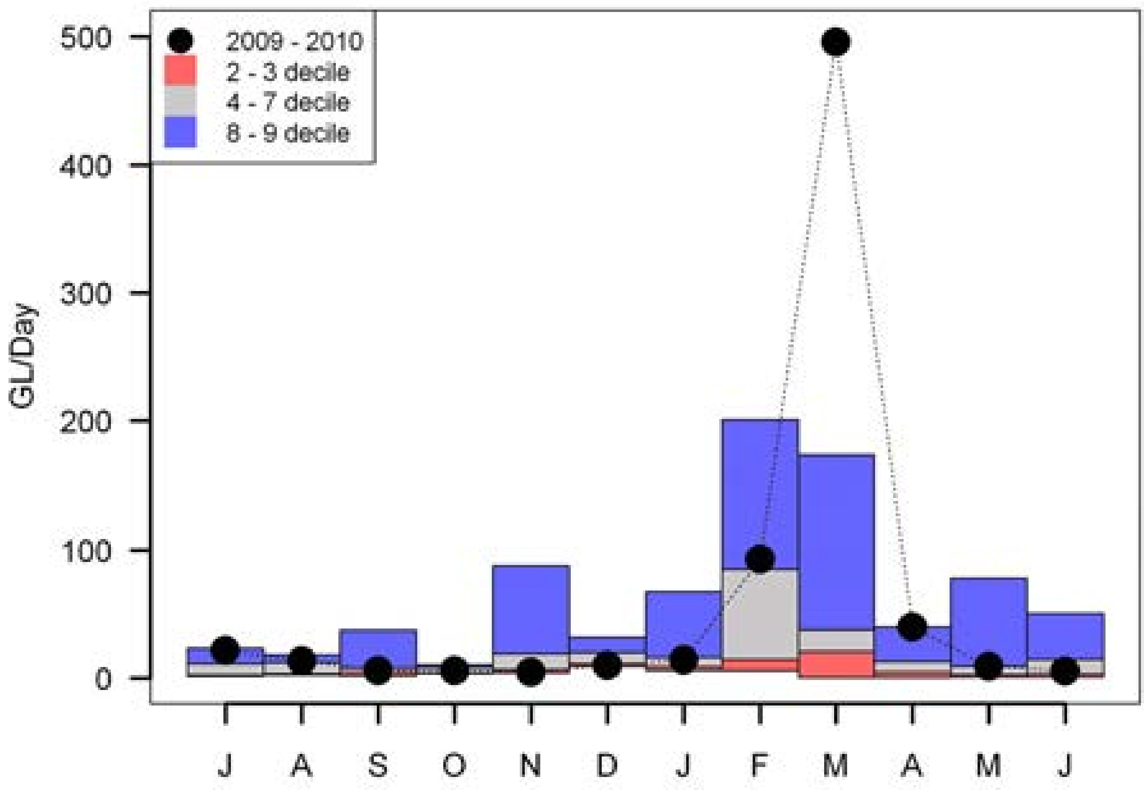




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of monthly inflows into selected storages (urban/irrigation) Regional water resources assessments/Water for cities and towns (Section 6 of some regional chapters) Regional water resources assessments/Water for agriculture (Section 7 of some regional chapters)	**Description** Measured streamflow discharge (ML/day). Data collated for currently operational reference streamflow gauges with records available for at least the past 30 years (July 1980 to June 2010). **Source** Bureau (Hydstra database)	**Description** Graphical presentation of measured monthly streamflow for 2009–10 plotted against derived monthly percentile classes (10–30, 30–70 and 70–90). Percentiles calculated from 30-year (July 1980 to June 2010) record. **Resolution (Output)** **Temporal** – Monthly **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Standard graphical presentation of hydrological information Reference not required

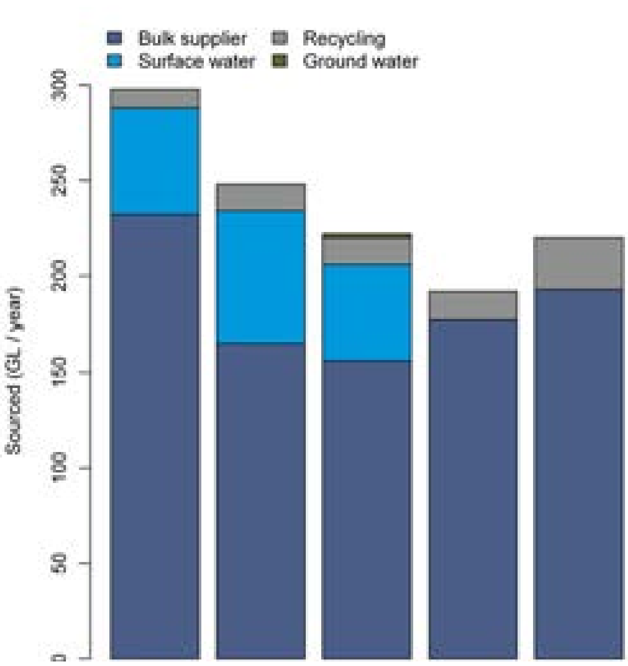
Example figures

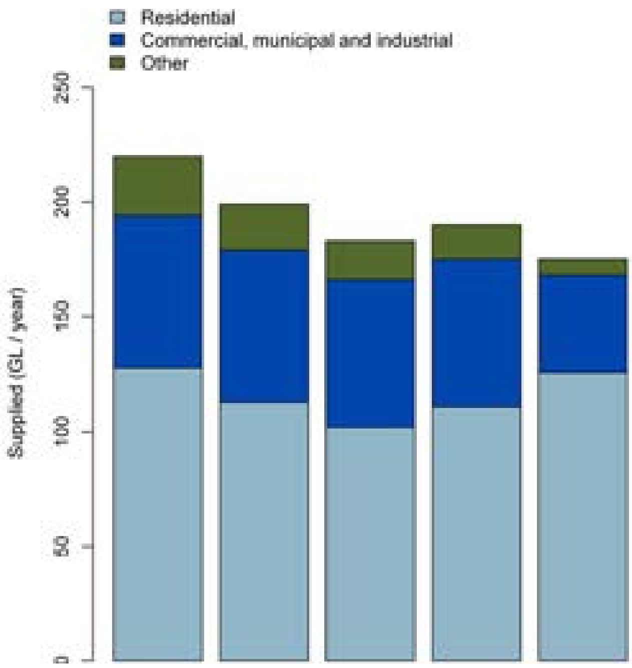


3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Time-series of annual urban water supply by source Regional water resources assessments/Water for cities and towns (Section 6 of some regional chapters)	**Description** Information about Urban Water Management. For more details refer to Definitions of Sub-Categories of Water Information: www.bom.gov.au/water/regulations/subCategoriesWaterAuxNav.shtml#urbanWater **Source** Bureau (Hydstra database)	**Description** Plot of total annual water volume sourced and description of sources (e.g. surface water, groundwater, recycled, desalinated). Also water volume delivered to different groups of users. **Resolution (Output)** **Temporal** – Annual (July to June) **Spatial** – Urban water supply area within relevant Australian Water Resources Assessment reporting region	Standard graphical presentation of hydrological information Reference not required

Example figures

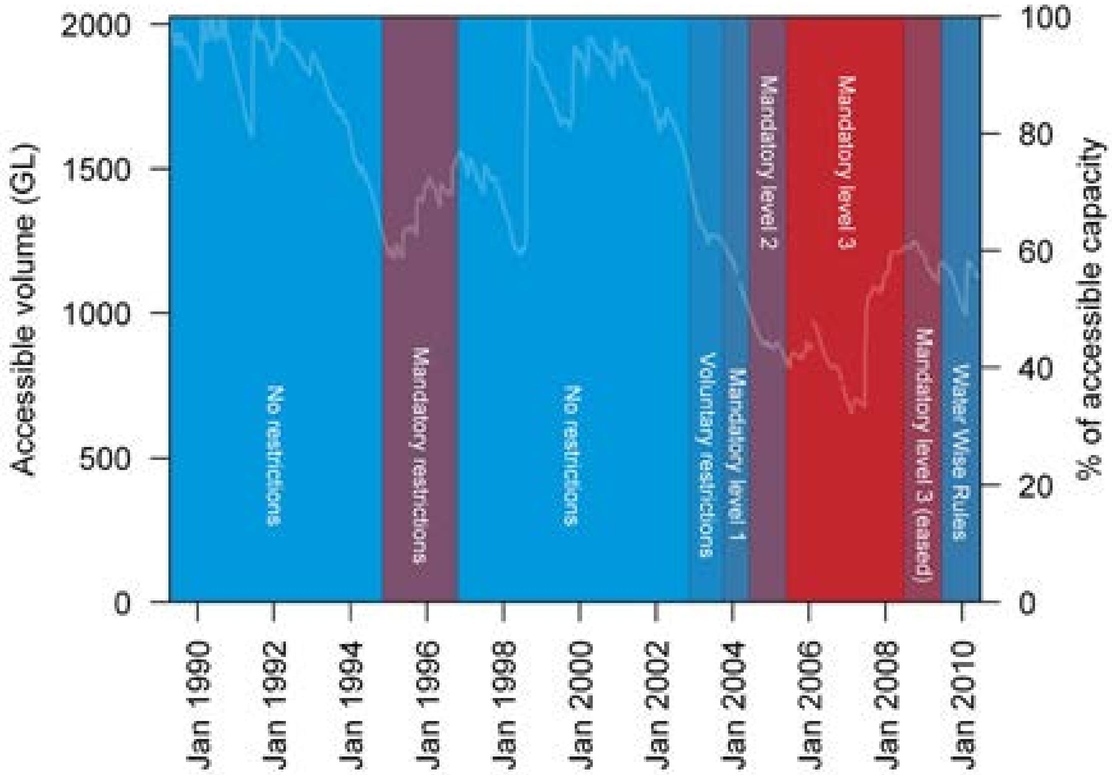




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Changes in urban water restrictions over time Regional water resources assessments/Water for cities and towns (Section 6 of some regional chapters)	**Description** Water use restriction announcements indicating level, commencement and termination dates, a description of water restriction levels and where they apply. **Source** Bureau (Hydstra database)	**Description** Graphical representation of water restriction levels over time plotted against a relevant measure of water availability, i.e. reservoir storage. Only applied where restrictions may be defined relative to a defined storage level or other resource availability variable. **Resolution (Output)** **Temporal** – Variable – dependent on announcements of changes to restriction levels **Spatial** – Water supply area within relevant Australian Water Resources Assessment reporting region	Standard graphical presentation of hydrological information Reference not required

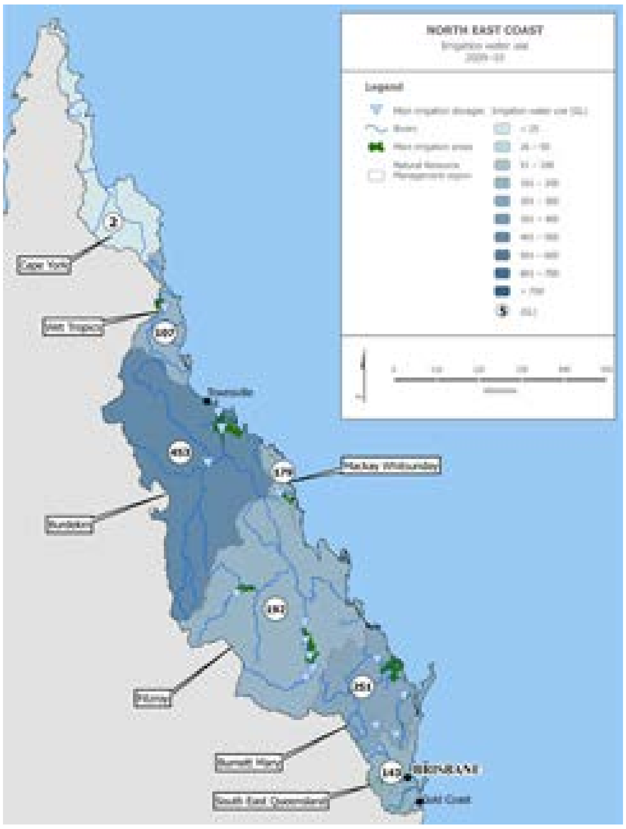
Example figures

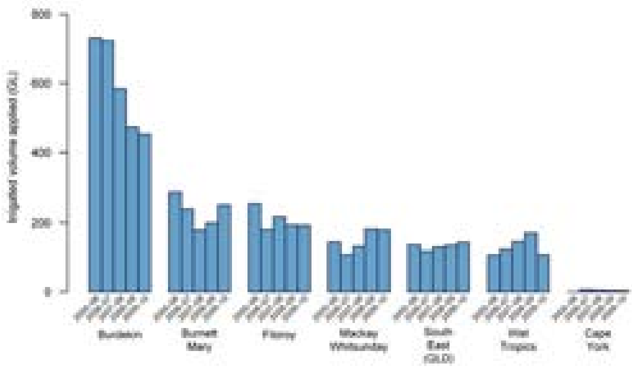


3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Patterns in annual irrigation water use Regional water resources assessments/Water for agriculture (Section 7 of some regional chapters)	**Description** Annual (July–June) irrigation water use data from ABS *Water Use on Australian Farms* reports. Data are summarised at a national resource management (NRM) level for the four years between 2005–06 and 2008–09. Data for 2009–10 were not available at the time of publication. **Source** Australian Bureau of Statistics (ABS) – *Water Use on Australian Farms* reports	**Description** Mapped and graphical representation of annual irrigation water use for each NRM region within the reporting region. **Resolution (Output)** **Temporal** – Annual **Spatial** – NRM regions within relevant Australian Water Resources Assessment reporting region	Australian Bureau of Statistics (ABS) 2010a, *Water Use on Australian Farms* 2009-10, ABS, Canberra, www.abs.gov.au/ausstats/abs@.nsf/mf/4618.0

Example figures

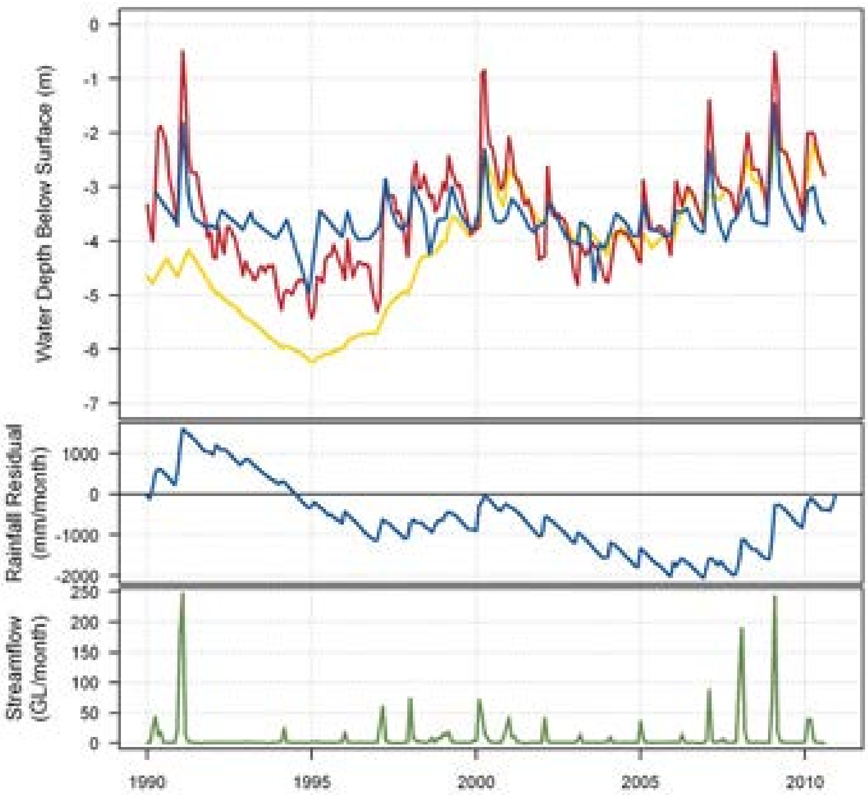




3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based time-series of variations in shallow groundwater levels, residual rainfall and streamflow Regional water resources assessments/Water for agriculture (Sections 3.7, 7.7 and 8.7)	**Description** Groundwater level of a bore (relative to datum) and measured streamflow discharge (ML/day). Data collated for currently operational monitoring bores for the past 20 years (July 1990 to June 2010). **Source** Bureau (Groundwater database) Bureau (Hydstra database) Bureau (Climate data online)	**Description** Graphical presentation of the relationship between monthly variations in shallow groundwater levels (m), local residual rainfall (mm/month) and measured streamflow (GL/month). The rainfall residual mass curve is based on the following equation. Rainfall residual mass for month(x) = (Actual rainfall for month(x) – average rainfall for month(x) + (the cumulative sum of (Actual rainfall for month – average rainfall for month) for all previous months). **Resolution (Output)** **Temporal** – Monthly **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Modified from: Murray–Darling Basin Commission 2008, *Groundwater Status Report* 2000–2005: Technical Report, ed. Murray–Darling Basin Commission, Canberra.

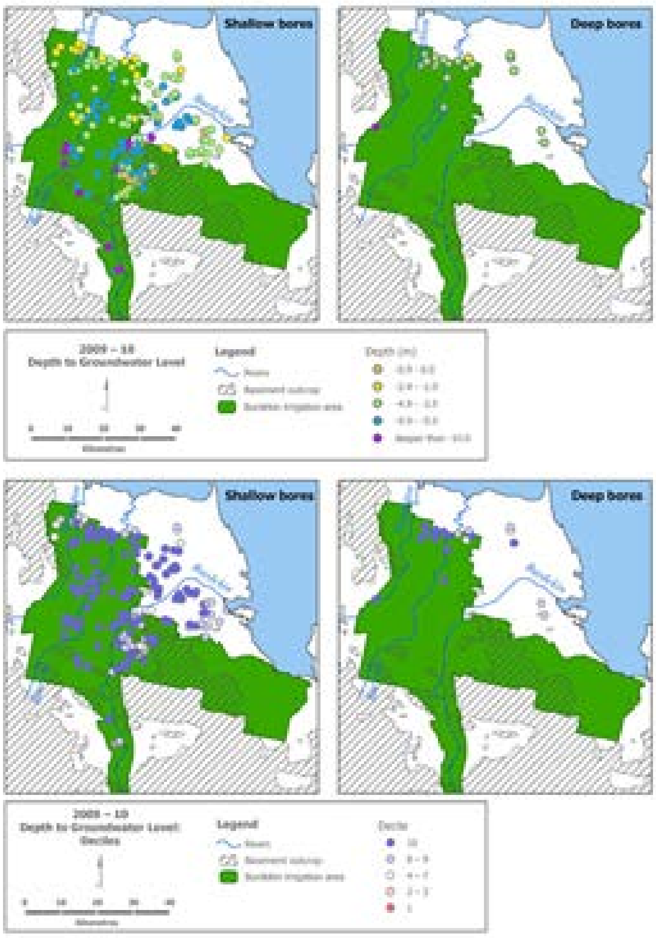
Example figures



3. Methods review summary (continued)

Analysis	Data	Method	Reference/peer review
Site-based analysis of groundwater depth Regional water resources assessments/Water for agriculture (Sections 3.7, 7.7 and 8.7)	**Description** Groundwater level of a bore (relative to datum). Data collated for currently operational monitoring bores for the past 20 years (July 1990 to June 2010). **Source** Bureau (Groundwater database)	**Description** Standard map presentation of calculated median depth to groundwater (m) for the reporting year (July 2009 to June 2010). Decile ranking of median depth to groundwater (m) for the reporting year (July 2009 to June 2010) compared to long-term (July 1980 to June 2010) levels. **Resolution (Output)** **Temporal** – Annual (median level and decile rank) **Spatial** – Sites within relevant Australian Water Resources Assessment reporting region	Reference not required

Example figures



4. Data and analysis

4.1 Introduction

The Bureau's Australian Water Resources Assessment reporting is a work in progress with regards to the methods used and results presented. Data sourcing and methods will improve over time. This section gives background information on data sources, methods applied to produce the figures in the report and the data available for download from the website.

4.2 Data selection procedures

A number of different selection procedures were employed to identify the most suited data for the 2010 Assessment. At the time of writing, suitable quality controlled and assured data from the Australian Water Resources Information System (Bureau of Meteorology 2011a) were not available. To overcome this, other sources of information were used. The following sections give an overview of the selection of information sources.

4.2.1 Estimated flows 'No Data' areas

The Australian landscape water balance modelling uses gridded daily rainfall data as a primary model input variable along with a number of gridded meteorological data-sets for the calculation of potential and actual evapotranspiration, i.e. maximum and minimum temperature, humidity and incoming solar radiation.

In order to run the model and perform the required analysis for the 99-year period (July 1911 to June 2010) a review of the reliability and quality of model input data was required, particularly for rainfall data that exhibit high levels of spatial variability.

The effects of the expansion of the rain-gauge network between 1990 and 2006 on the reliability of the interpolated rainfall surfaces were assessed to identify areas of poor quality data. Interpolation failures are generated as a result of sparse gauge networks and are particularly prominent in the central and western deserts. The analysis produced surfaces of rainfall interpolation reliability ranging from 100 per cent unreliable (data show consistent interpolation failure) to zero per cent unreliable, where data are defined to be reliable throughout the record within the constraints of the interpolation scheme (Jones, Wang & Fawcett 2009).

Australian Water Resources Assessment 2010 areas identified to be greater than 20 per cent unreliable (or less than 80 per cent reliable) were excluded from the landscape water balance modelling. The extent of areas of unreliable data (blue) are shown in Figure 4-1. The map also indicates additional areas (grey) that are not modelled due to absent parameter data, including oceans, salt lakes, salt pans, inland water, and some coastal features. All modelled areas (white) are reported in the landscape water flows analysis sections of the 2010 Assessment.

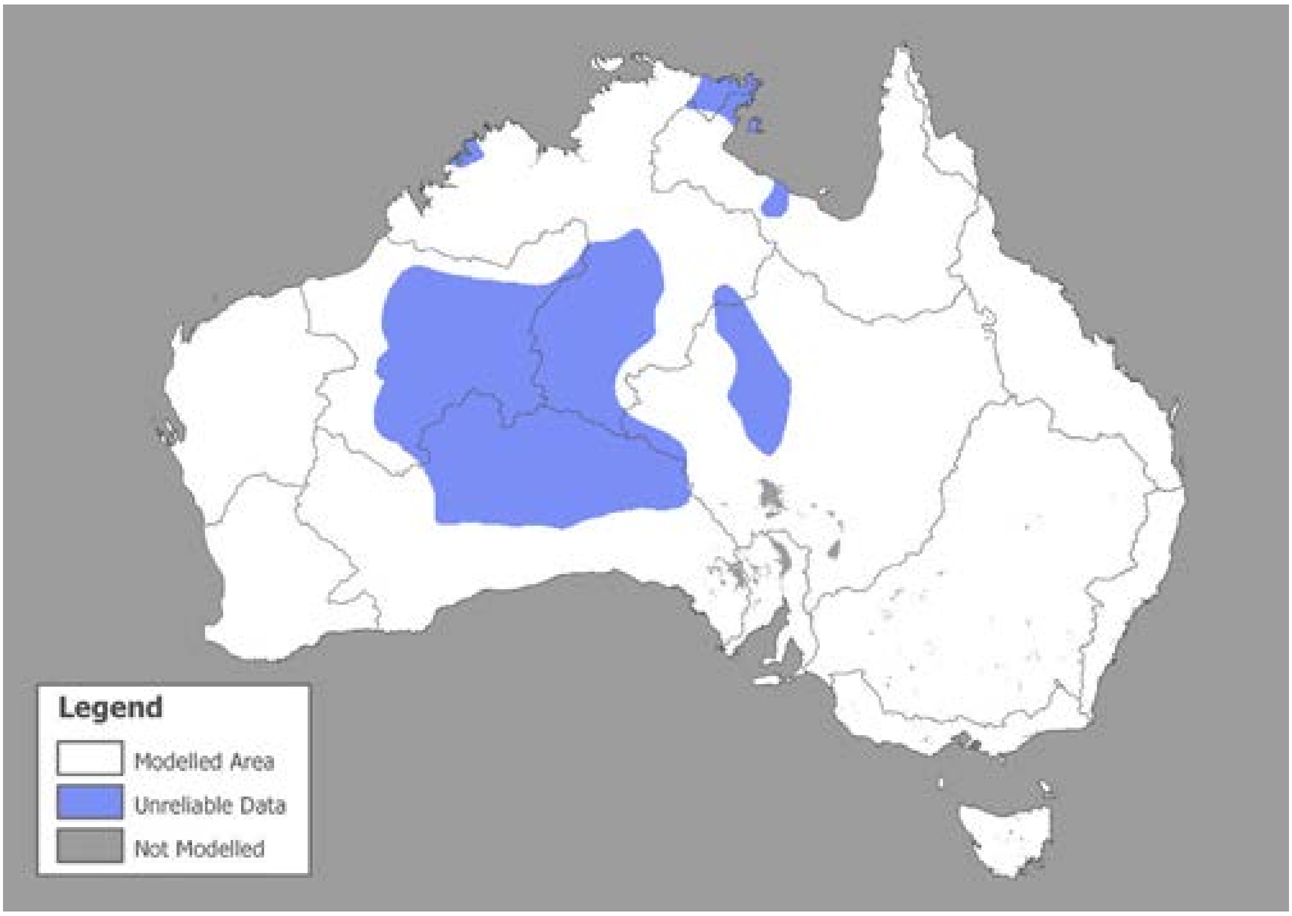


Figure 4 1. Map of areas included in the 2010 Assessment landscape water balance modelling and areas excluded from the model due to unreliable data and absent parameter data

4.2.2 Streamflow gauge selection

Gauges were selected for all relevant river basins to represent the lower reaches of each basin (i.e. to approximate total basin outflow). In the case of larger basins, additional gauges were selected to represent the major 'middle' and 'upper' basin tributaries to enable a monitoring of the varying status of river flow as water passes from the upper catchment tributaries to the downstream part of the basin. The reference gauges selected are provided in the data files accompanying the report chapters.

Gauges were selected which:

- were in ongoing operation in 2010
- possessed greater than or equal to 30 years of data record
- have data records available within the Bureau of Meteorology's data archives.

In selecting gauges for the wetland sections, these needed to be geographically close to the upstream side of the wetland (so as to represent variability in river inflow to the wetland site).

A visual quality check was performed on the run-off hydrographs to exclude unsuitable data from the analysis. The data were scanned for outliers and unusual patterns in the long-term discharge. Where long gaps exist in the data and unusual patterns were found, the site was excluded from the analysis for this report.

Since some distinct patterns can be caused by human actions (e.g. construction of new weirs/dams or deviation of river beds), not all unusual patterns are the result of data errors. The datasets will, therefore, be re-examined for potential use in future reports.

4.2 Data selection procedures (continued)

4.2.3 Flood information

Flood tables – site selection

A set of generic criteria were used in the selection and reporting of flood warning monitoring sites for the production of regional flood table summaries for the 2009–10 year. The selection criteria were adopted for each of the regions where flood summary tables are reported. Sites were selected:

- from the Bureau's Australian Integrated Forecast System database
- to give a maximum of 20 sites per Australian Water Resources Assessment reporting region
- to provide good spatial coverage across the reporting region
- based on reasonable data coverage and quality for the 2009–10 period
- based primarily on proximity to population centres (large cities/towns) where possible/relevant
- where the Bureau provides a quantitative flood forecast as part of the flood warning responsibilities that were prioritised (these sites usually correspond with populated centres and better quality data)
- where possible, to give approximately two sites per catchment (upper and lower catchments).

4.2.4 Selection of water storages

Water storages were selected based on their representation of the total system storage and system behaviour, and upon suitable data availability for 2009–10.

4.2.5 Selection of groundwater bores

The sources of groundwater data used for analyses carried out for this report were obtained from the main government agencies responsible for data collection within the different States. These agencies are the Department of Environment and Resource Management in Queensland, the NSW Office of Water and the Department for Water in South Australia. Other States were not considered in this report as, at the time of writing, suitable quality controlled data were not available from the Bureau's data stores.

The relevant aquifers for bores located within NSW and within the Murray–Darling Basin were identified based on the Geographical Information System data connected with the Groundwater Status Report 2000–2005 (Murray–Darling Basin Commission 2008). The aquifer information for bores located within the States of Queensland and South Australia were obtained either from the relevant databases or reports.

4.2.6 National Resource Management regions and irrigation water use

There are 56 natural resource management (NRM) regions identified for Australia, based on catchments and bioregions. The boundaries were established in agreements between the Commonwealth, State and Territory Governments between December 2002 and June 2004 (www.nrm.gov.au/nrm/region.html).

The irrigation water use figures available from the Australian Bureau of Statistics and used in this publication are summarised according to natural resource management regions.

These boundaries do not coincide with those of the Australian Water Resources Assessment 2010 reporting region boundaries. In areas close to the boundaries, population densities are relatively low and the use of these natural resource management regions provides a fair approximation to the situation in the Australian Water Resources Assessment 2010 regions. The areas used are shown in Figure 4-2 against a backdrop of the reporting regions.

The Wimmera natural resource management region, for example, spans both the South East Coast (Victoria) and Murray–Darling Basin reporting regions. For the purposes of this publication, the same irrigation water use amount per natural resource management region was allocated to both reporting regions, with no partitioning attempted.

4.2 Data selection procedures (continued)

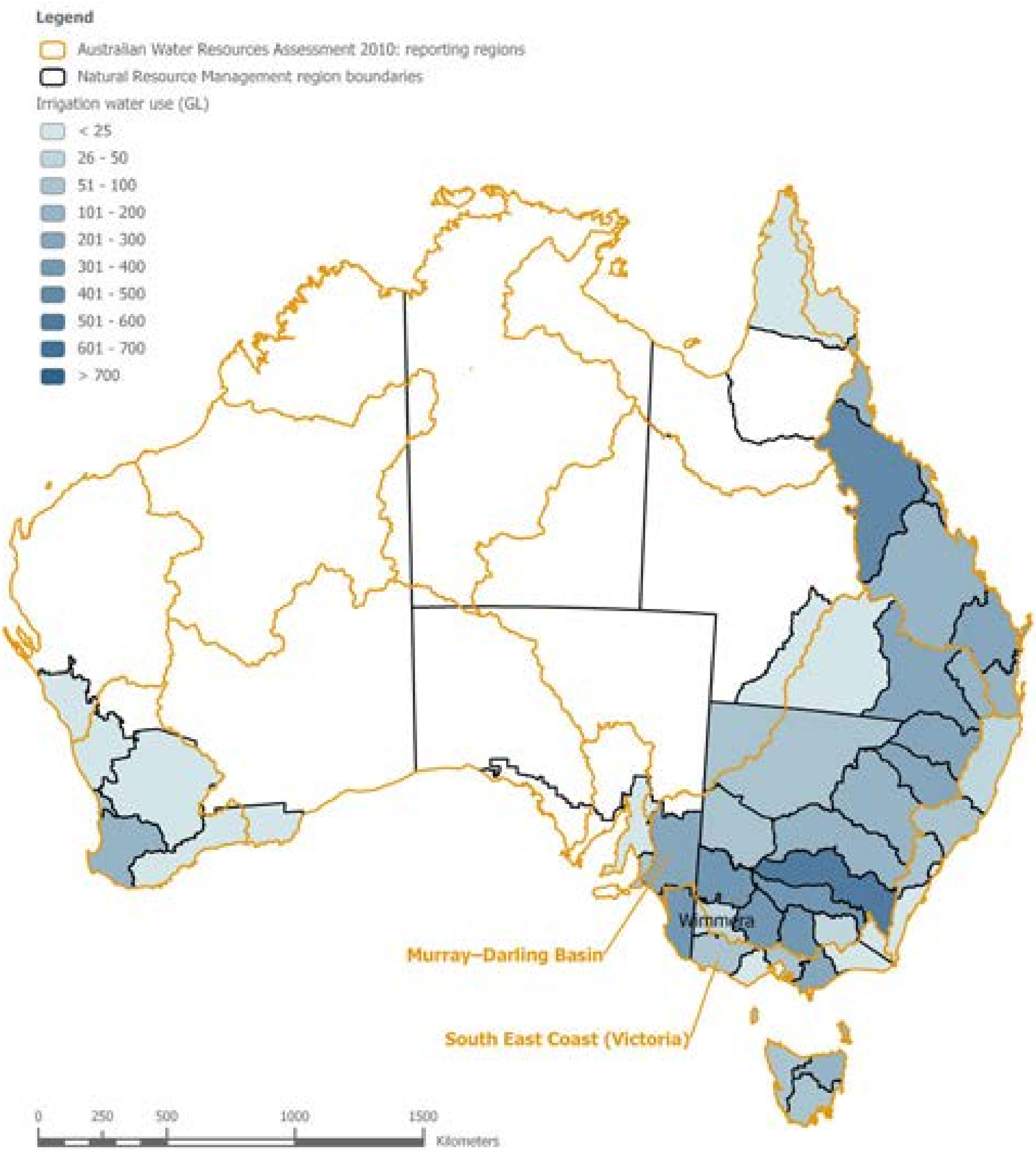


Figure 4-2. The Australian Water Resources Assessment 2010 reporting region and natural resource management region boundaries

4.3 Data analysis procedures

4.3.1 Guide to landscape flows trend analysis results

A simple analysis of trends in landscape water flow time-series was performed in order to provide an assessment of potential long-term movement and changes in modelled variables over time. As noted by Radziejewski and Kundzewicz (2004), many statistical trend and change tests are not able to detect a weak trend or a change which is not sufficiently long, but this cannot be interpreted as a demonstration of the absence of change.

The test statistic for simple linear regression was used to estimate trends across Australia applying the ordinary least squares estimator to fit a straight line between the n points (n = 30). The analysis provides an estimate of whether water flow variables increased or decreased over the defined time period (30 years) by calculating the gradient of the best fit regression line.

Data

The simple trend analysis was applied to the following national level landscape flows:

- rainfall
- modelled evapotranspiration
- modelled landscape water yield.

These data represent modelled inputs or outputs associated with the landscape water balance models applied. The data are generated as a monthly time-series for each 5 x 5 km model grid cell giving almost full coverage of Australia. Each data-set was aggregated to seasonal totals for the summer (November to April) and winter (May to October) periods, providing seasonal totals for the 30 years from November 1980 to October 2010. Regression trends are also presented for annual data (July to June) in this section, but are not presented in the regional chapters.

Simple linear regression

Simple linear regression fits a straight line through the set of n points in such a way that minimises the sum of square of residuals. The residuals are the vertical distances between the modelled points and the fitted line. The objective of the analysis is to determine the equation of the straight line (given below) that would provide the 'best' fit for the data.

$$Y = B_0 + B_1X$$

B_0 is a constant, B_1 is the slope (also called the regression coefficient), X is the value of the independent variable, and Y is the value of the dependent variable.

For the purpose of the Australian Water Resources Assessment report, the slope coefficient (B_1) was calculated for both the summer (November–April) and winter (May–October) season at each grid cell for all three flow variables. Figure 4-3 provides a summary of regression analysis for rainfall, evapotranspiration and landscape water yield for selected grid cell locations in the Murray–Darling Basin and Tanami – Timor Sea Coast regions.

Significance of estimated regression trend

An assessment of the significance of seasonal trends was also carried out as part of the statistical trend analysis process, although the results of the significance tests were not included in the regional chapters. The trend analysis was carried out to illustrate the potential directional trends in landscape water flows over the past 30 years, i.e. has seasonal rainfall tended to increase or decrease over the 30-year period, rather than to explicitly determine whether these changes are statistically significant.

If there is a significant linear relationship between the independent variable X and the dependent variable Y, the slope will not equal zero. Therefore, the null hypothesis (H_0) states that the slope of the linear regression is equal to zero, and the alternative hypothesis (H_a) states that the slope is not equal to zero.

$$H_0: B_1 = 0$$

$$H_a: B_1 \neq 0$$

Significance levels of five per cent and ten per cent were chosen for the presentation of results. A five per cent significance level means that an error will be made, on average, for five per cent of the time, i.e. if the null hypothesis was true then one in 20 test results will be significant and incorrect. It should be noted that any level of significance can be chosen between zero and 100 per cent, although the significance levels chosen here are widely used in statistics.

A linear regression t-test was applied to determine whether the slope of the regression line differs significantly from zero. The test statistic is a t-score (t) defined by the following equation:

$$t = b_1 / SE$$

where b_1 is the slope of the sample regression line, and SE is the standard error of the slope.

4.3.1 Guide to landscape flows trend analysis results (continued)

The P-value is the probability of observing a sample statistic as extreme as the test statistic and can be used to assess whether the statistical test satisfies the test hypotheses based on the defined levels of significance. The test statistic is based on the t-score and the t-distribution is used to assess the probability associated with the test statistic. The degrees of freedom (DF) associated with the test statistic is equal to:

$$DF = n - 2$$

where n is the number of observations in the sample.

If the test indicates a significant trend in a data series, based on the calculated P-value, the null hypothesis (H_0), (i.e. there is no linear trend identified in the slope of the regression line ($B_1 = 0$)), is rejected.

National maps of the calculated linear regression slopes (in mm/year) and statistical significance are presented for seasonal rainfall, evapotranspiration and landscape water yield in Figure 4-4, Figure 4-5 and Figure 4-6. Trend gradients are also presented on an annual basis (July to June).

Assumptions and limitations

The analysis of national trends in seasonal and annual rainfall, evapotranspiration and landscape water yields presented in this report include a number of assumptions and limitations. The analysis provides only a simplified assessment of (linear) trends in landscape model variables and should, therefore, only be interpreted as providing an indication of the directional tendencies in these variables over the past 30 years. The strength and magnitudes of these trends should only really be taken to be indicative as a consequence of the simple nature of the statistical test and the inherent variability, spatially and temporally, of the underlying data.

Some (not all) of the relevant assumptions and limitations of the statistical analysis are identified below.

Assumptions

- Trends in seasonal and annual rainfall, modelled evapotranspiration and landscape water yield are assumed to be linear over the past 30 years.
- The data points are assumed to be independent with no serial correlation, i.e. no short-term correlation between samples.
- The measurement and calculation of the data is assumed to be consistent over space and time, i.e. the method used for the generation of rainfall surfaces is the same over the 30-year period.
- The data are assumed to be normally distributed. Data transformations to compensate for undesirable data properties, i.e. high skewness or strong departure from normality, were not applied.

Limitations

- Only very limited exploratory data analysis and visual assessment was applied to the data and therefore the depth of understanding of the underlying data is also limited. The large volume of data involved in the analysis and time and resource constraints proved highly prohibitive in the further analysis and understanding of the data and results of statistical analysis. It is acknowledged that without a rigorous exploratory data analysis process, the quality, robustness and reliability of the analysis and its interpretation will be weakened.
- The simple linear regression test does not effectively identify more complex characteristics of trends. For instance, this approach does not identify break points and step changes in the time-series or changes in trend direction or period trends within the data period.
- The 30-year time period was assumed to be sufficient for the analysis of statistical trends and represents a good standard period for analysis. The analysis of much longer term records, i.e. up to 100 years, may provide additional values and support to the results and interpretation of statistical trends and change over time.
- Potential implications of spatial statistics and spatial independence were not considered.

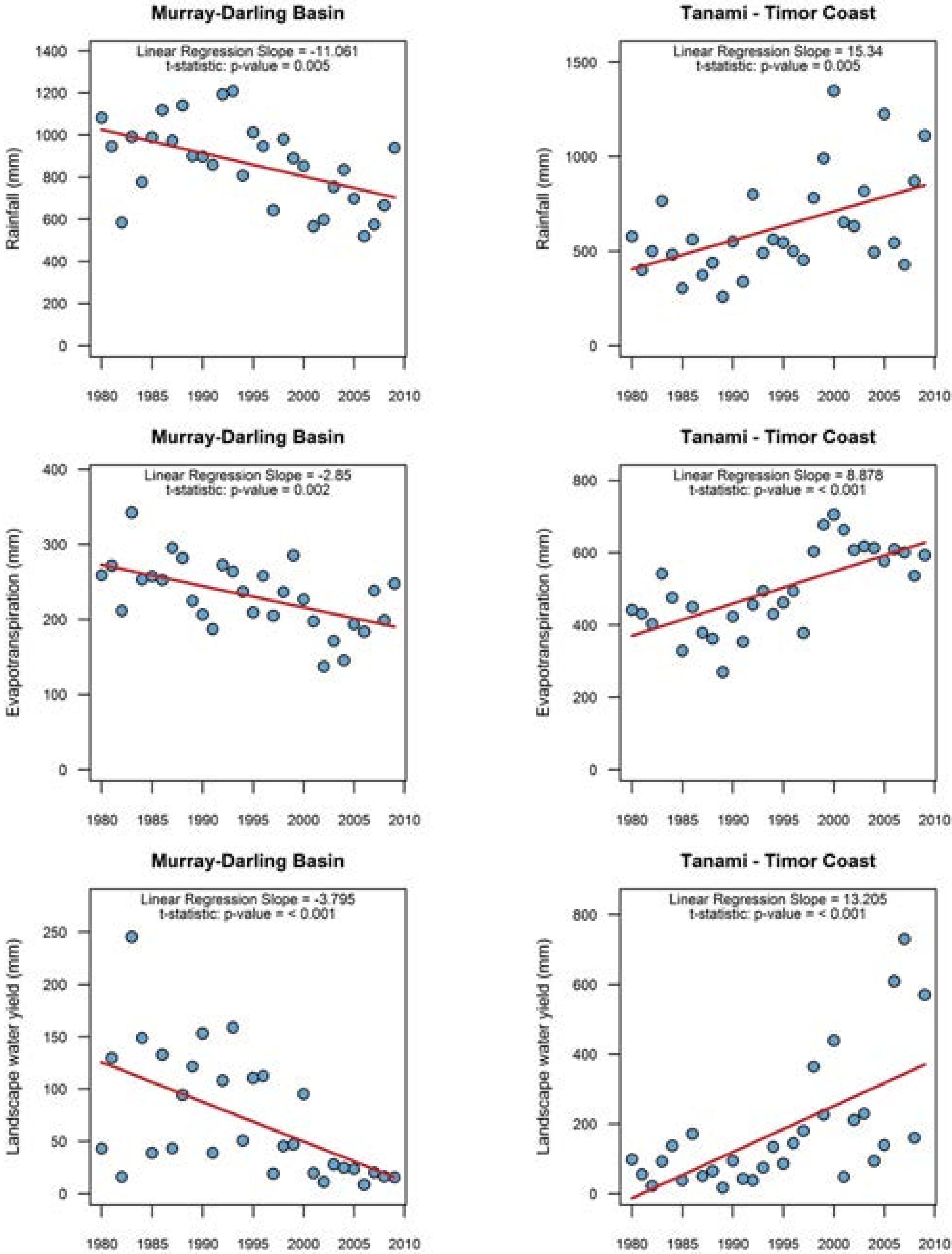


Figure 4-3. Regression analysis for selected grid cell locations in the Murray–Darling Basin and Tanami – Timor Sea Coast regions

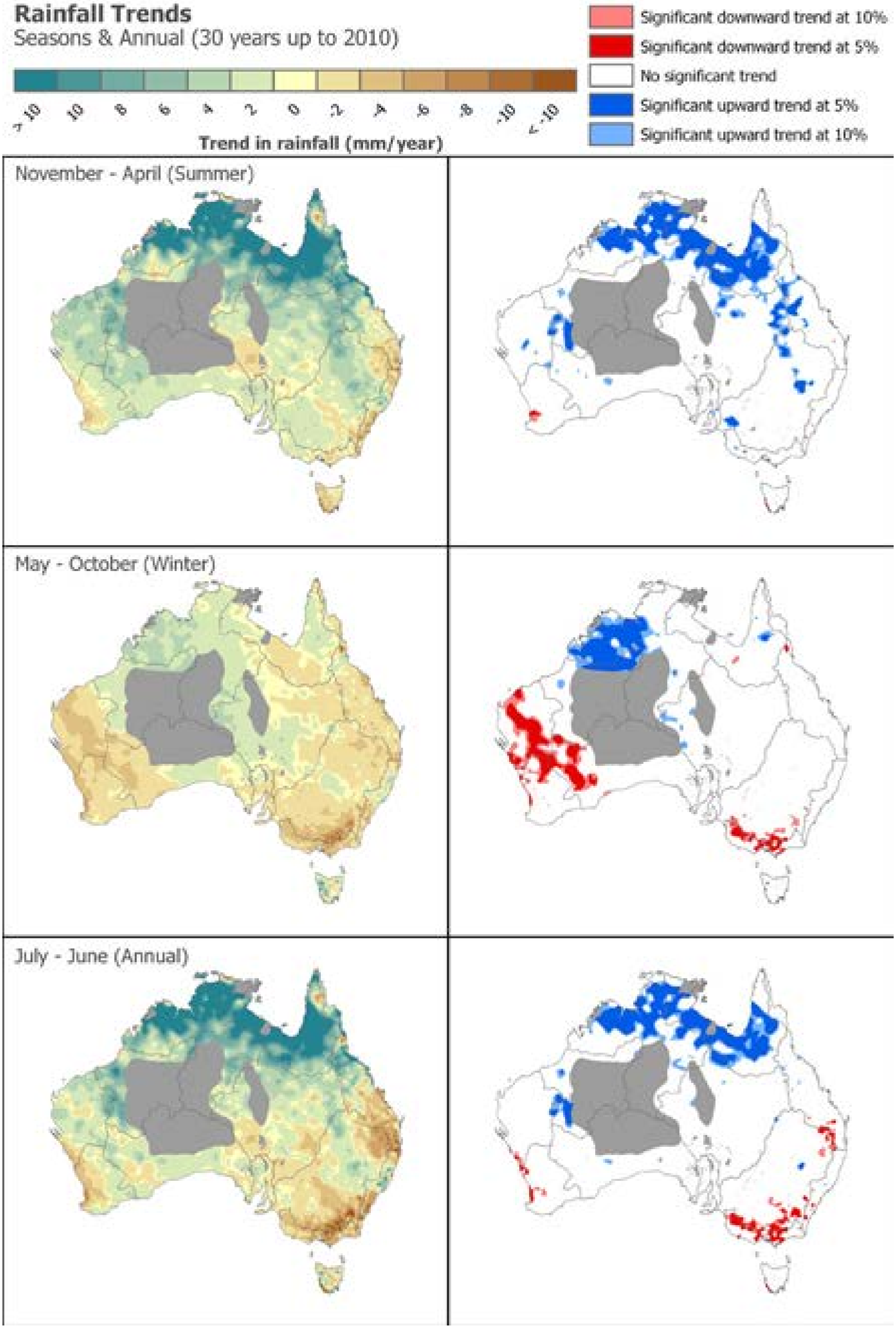


Figure 4-4. Maps of estimated trends in summer, winter and annual rainfall (for 30 years up to 2010) and associated levels of statistical significance (at 5% and 10% significance)

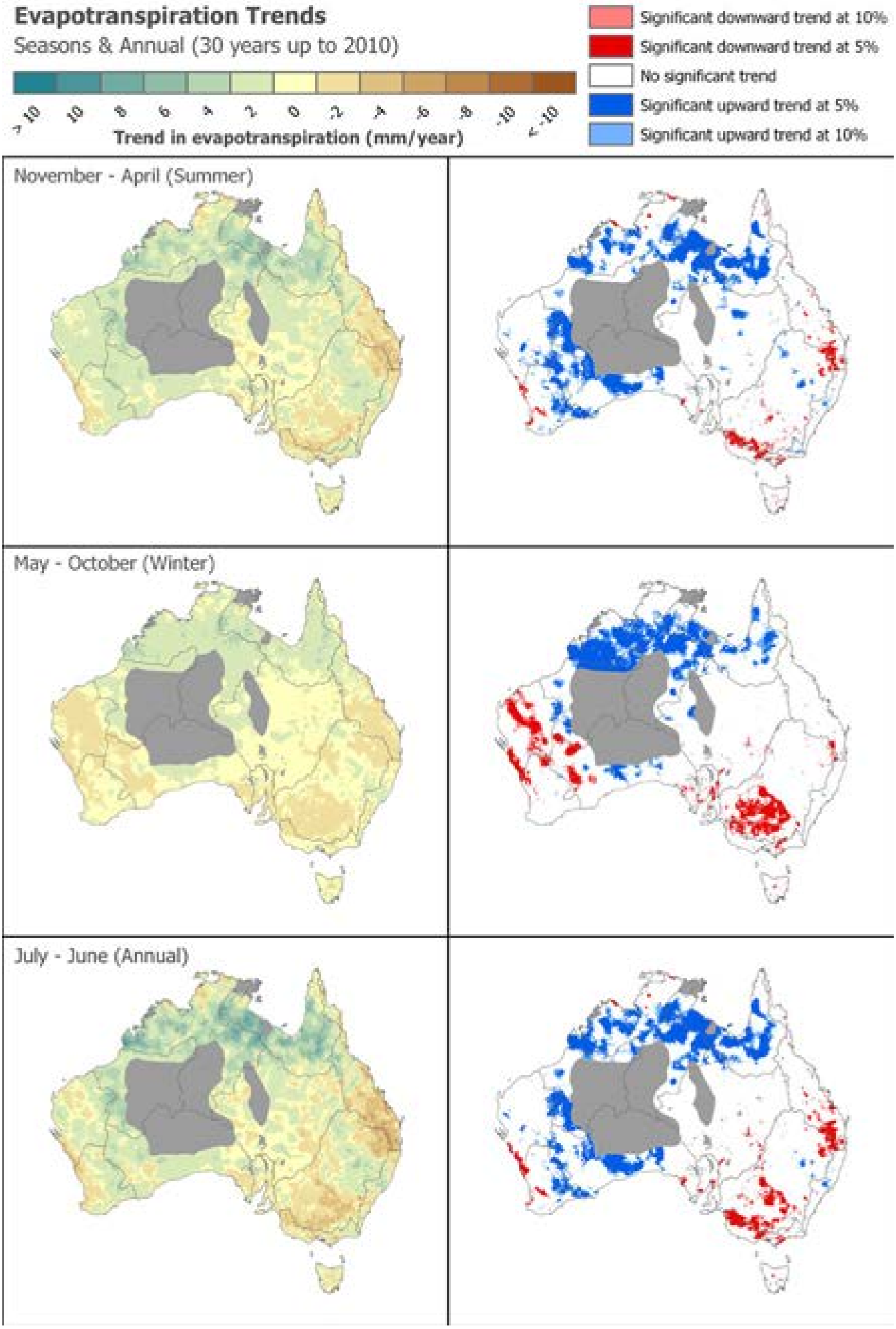


Figure 4-5. Maps of estimated trends in summer, winter and annual evapotranspiration (for 30 years up to 2010) and associated levels of statistical significance (at 5% and 10% significance)

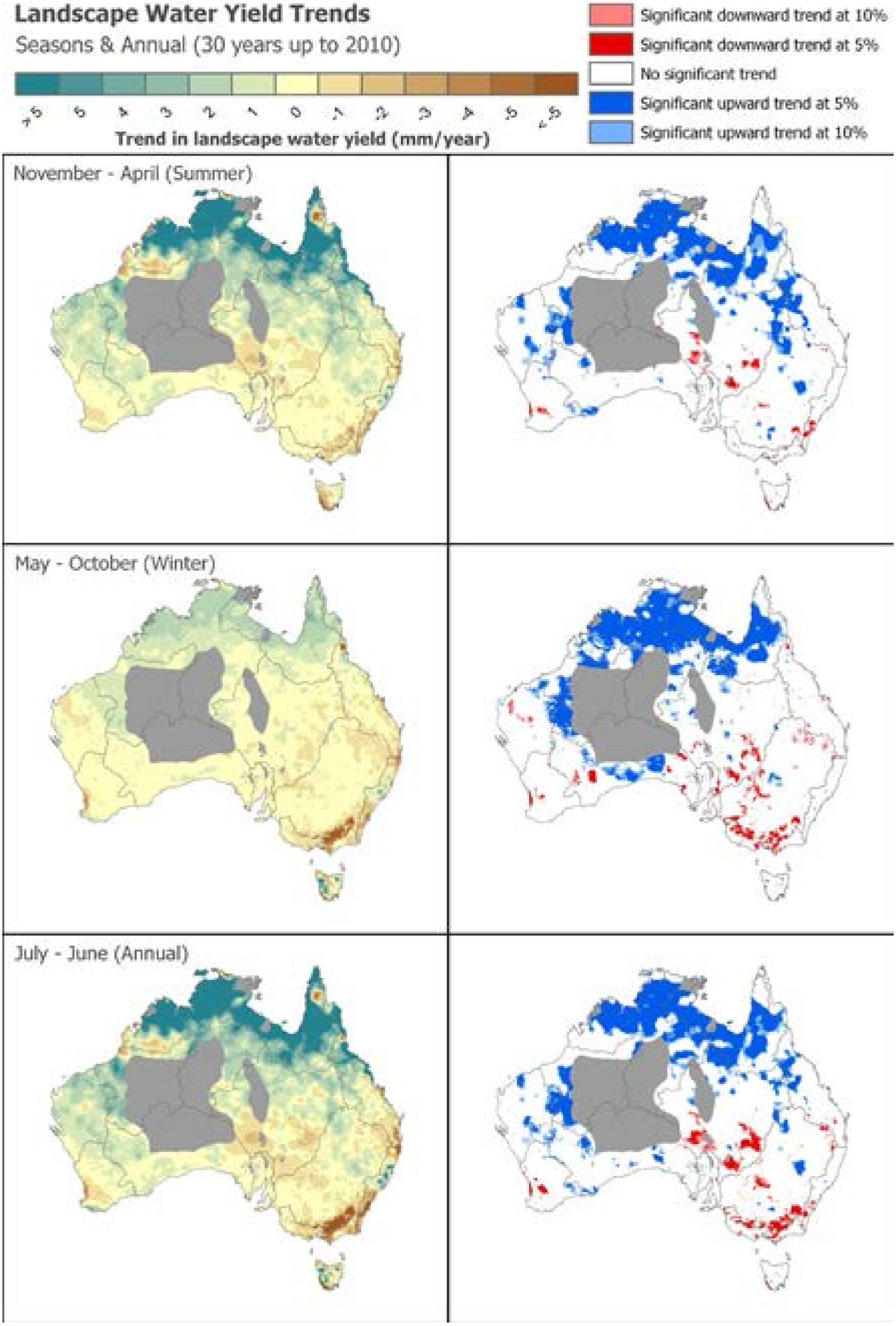


Figure 4-6. Maps of estimated trends in summer, winter and annual landscape water yield (for 30 years up to 2010) and associated levels of statistical significance (at 5% and 10% significance)

4.3.2 Guide to surface water storages information

This section provides information relating to the water storage figures presented in the Australian Water Resources Assessment report. This is general information regarding terminology, understanding storage graphs and data, copyright and data supply information and general data processing information. Storage specific information and data are available within the storage figures' metadata.

Water storage terminology

The following terms are used for the water storage volume figures and are visually explained by Figure 4-7:

- **per cent of accessible capacity** – the volume of water in storage as a percentage of accessible storage capacity. Note that the percentage full may exceed 100 per cent due to floods
- **accessible storage capacity** – the volume of water a storage can hold between the minimum supply level and full supply level; equal to total storage capacity excluding dead storage capacity. This is the capacity that is reported for all storages and the sum of this capacity that is reported for systems of storages
- **accessible storage volume** – the volume of water stored at a particular time and date. It excludes the dead storage volume and hence is the volume of water that can be accessed under normal circumstances without the installation of additional infrastructure
- **dead storage capacity** – the portion of a water storage's capacity that is equal to the volume of water below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.

Storage data graphs in the Australian Water Resources Assessment report give an indication of accessible storage, excluding dead storage.

The mean daily accessible storage for a storage or system of storages is shown by a black line, which may contain gaps where data of one or more storages are unavailable. There are no gaps in the blue shading as data were linearly interpolated over the gaps.

During periods of high river flow or flood, storages can hold more than 100 per cent of their rated capacity.

Percentages are calculated based on the accessible capacity of the storage as per 30 June 2010. Therefore, the storage volume in previous years may also exceed 100 per cent if the storage capacity decreased. Changes in storage capacity can occur for a variety of reasons including: sediment accumulation or changes to the height of the dam or outlet structures.

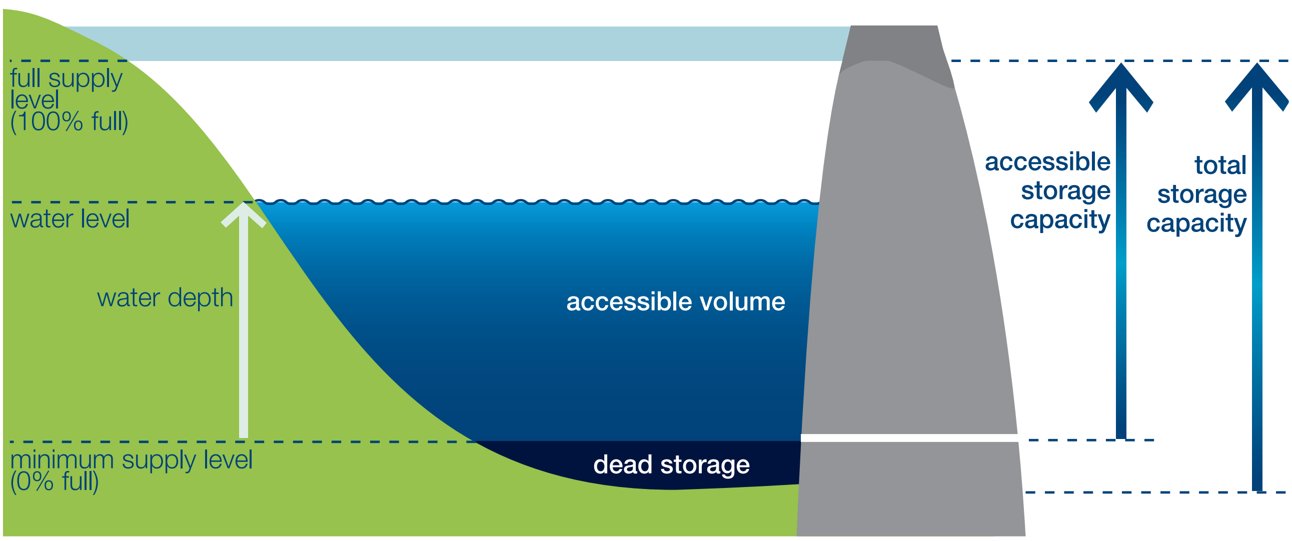


Figure 4-7. Conceptual representation of a water storage

4.3.2 Guide to surface water storages information (continued)

Data processing

Corresponding volume/level pairs are created using a capacity table, the established relation between water level and storage volume. Depending on the provided data and configuration of the storage, either level or volume will be specified as the primary data feed from which to calculate values.

Where historical capacity tables were not available, the capacity table as at 1 January 2009 was used to calculate storage volume for the period prior to this date.

Standardisation

All data that are received from a data provider for a storage is converted to the Bureau standard (e.g. meters above Australian Height Datum (mAHD) and Accessible Volume). Where required, the reference data as at 1 January 2009 were used to standardise data back to the beginning of the period of record.

Calculate mean daily values

Mean daily storage volume values were calculated in one of two ways:

- Simple average – mean daily volume values are calculated from sub-daily data by calculating the mean of all the measurements received for the day
- Time weighted average – mean daily volume values are calculated from sub-daily data by linearly interpolating between points and calculating the average volume over the entire day from midnight to midnight.

4.4 Data available with the report

Introduction

Data files will be available for download from the Bureau's website www.bom.gov.au/water/awra/2010/metadata.shtml for most of the figures contained in the report. Readily available background information (particularly for the maps) is referenced only, as are a few data-sets considered sensitive by the data providers.

Only information shown in the figures is included together with its associated metadata. The original data used to derive this information are described in the metadata. Information is grouped into zip files associated with each chapter. PDF metadata files are associated with the data for each figure. For ease of identification, a small JPG file of the figure is also included.

Spatial information

The raster data that are provided with the national overview chapter are not repeated in the regional chapters. A shapefile of regional boundaries is provided to enable selection of regional data subsets. Legend information is provided linking numerical ranges to associated colours used in the report. The raster data are provided in ASCII grid format.

All publicly available background information is available from the Bureau's Geofabric website (www.bom.gov.au/water/geofabric/index.shtml) and Geoscience Australia (www.ga.gov.au/products-services/data-applications.html). Spatial information on groundwater unit boundaries is not included but will be available in the near future from the Bureau's website.

Graphed information

The graphed information in the figures is provided in zip files associated with each of the individual chapters. Information is provided in CSV format.

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