Australian Water Resources Assessment 2010

Australian Government
Bureau of Meteorology

Published by the Bureau of Meteorology
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ISBN: 978 0 642 70619 5

Cover image: Lake Eildon, Victoria. Photograph courtesy of Alison Pouliot.

Contents

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.

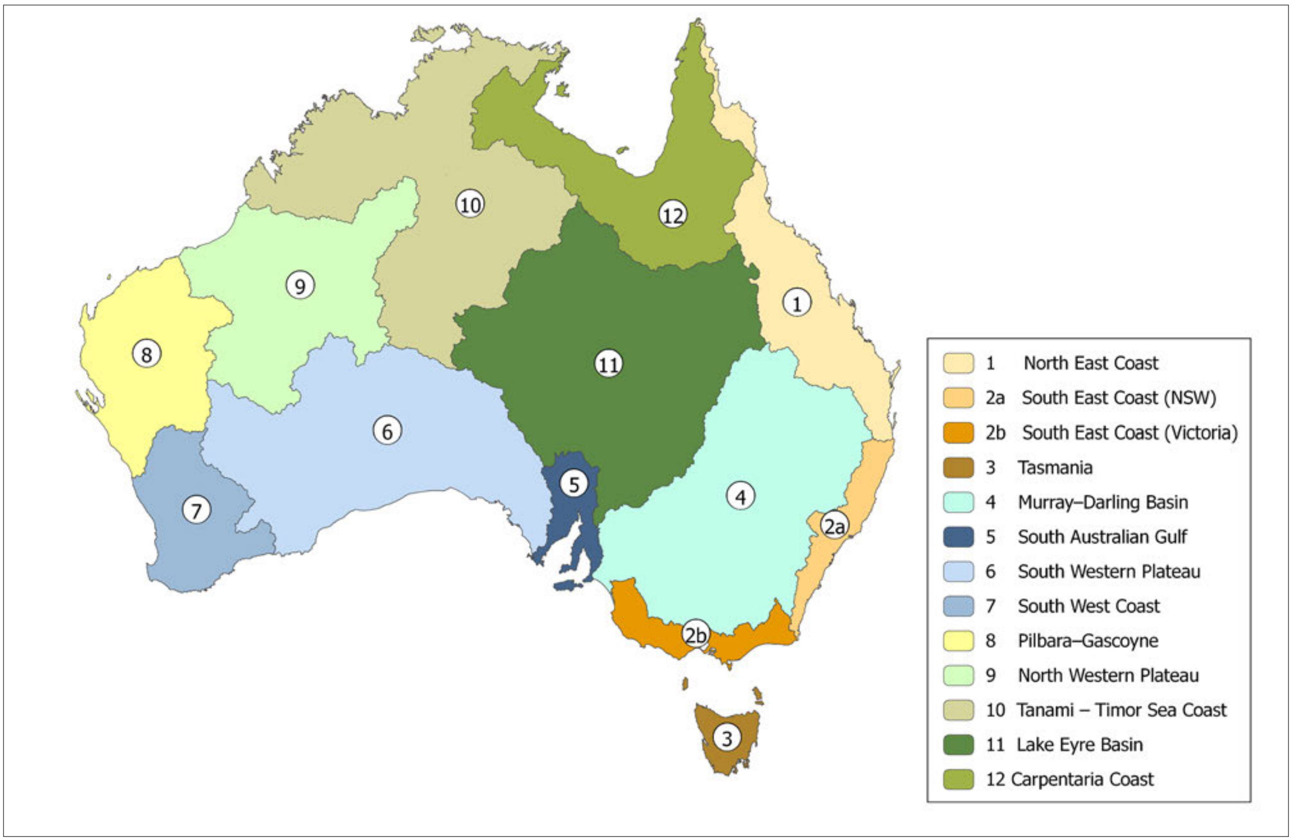


Figure 1-1. 2010 Assessment reporting regions and region numbers

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).

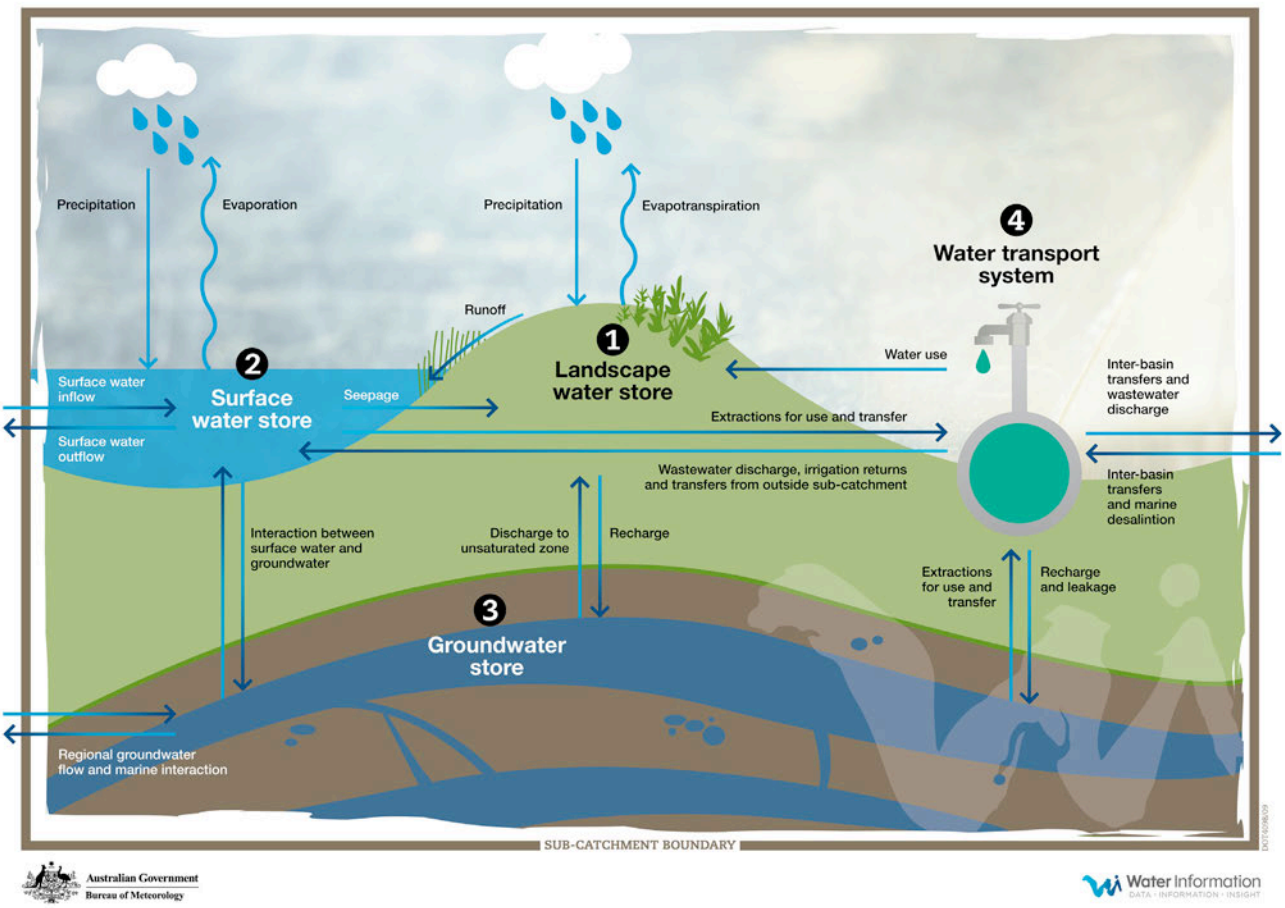


Figure 1-2. Primary water flows and water stores used in Australian water resources reporting by the Bureau

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.

1.4.5 National landscape water balance modelling (continued)

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.

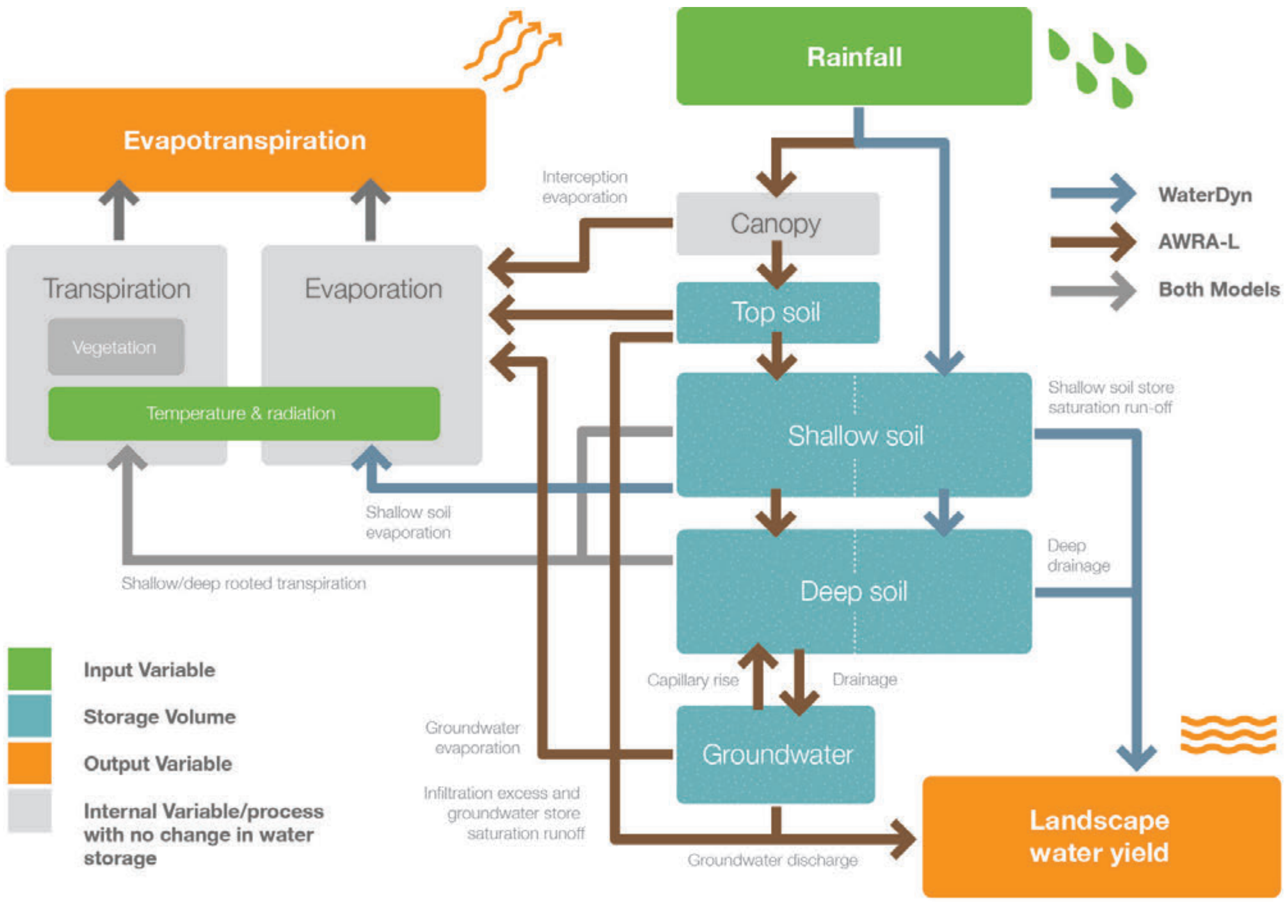


Figure 1-3. Schematic representation of inputs, outputs, flows and stores in the two landscape water balance models used in the 2010 Assessment

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

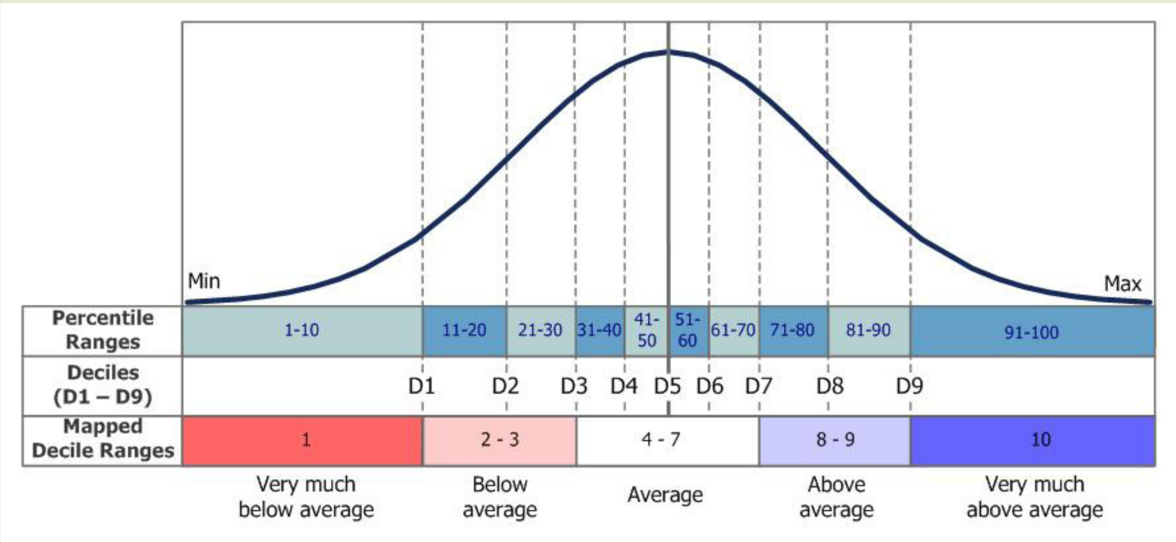
Deciles and percentiles are forms of descriptive statistics widely used in physical sciences to provide an easily interpretable and standardised summary of the position, or scale, of a value, measurement or observation relative to the full distribution of the data set.

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.

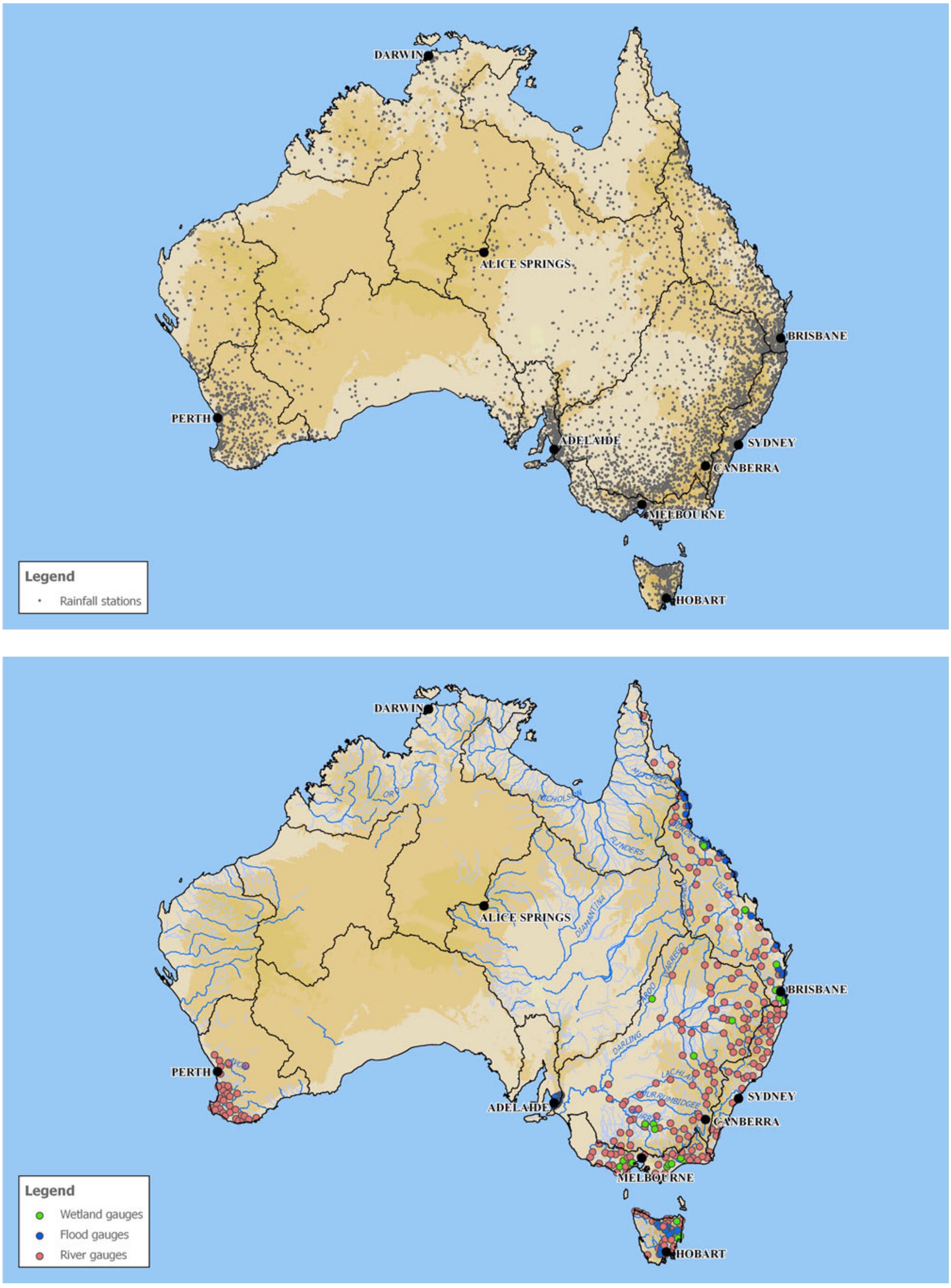


Figure 1-4. Location of rainfall stations (top) and stream gauges (bottom) selected for analysis in this report

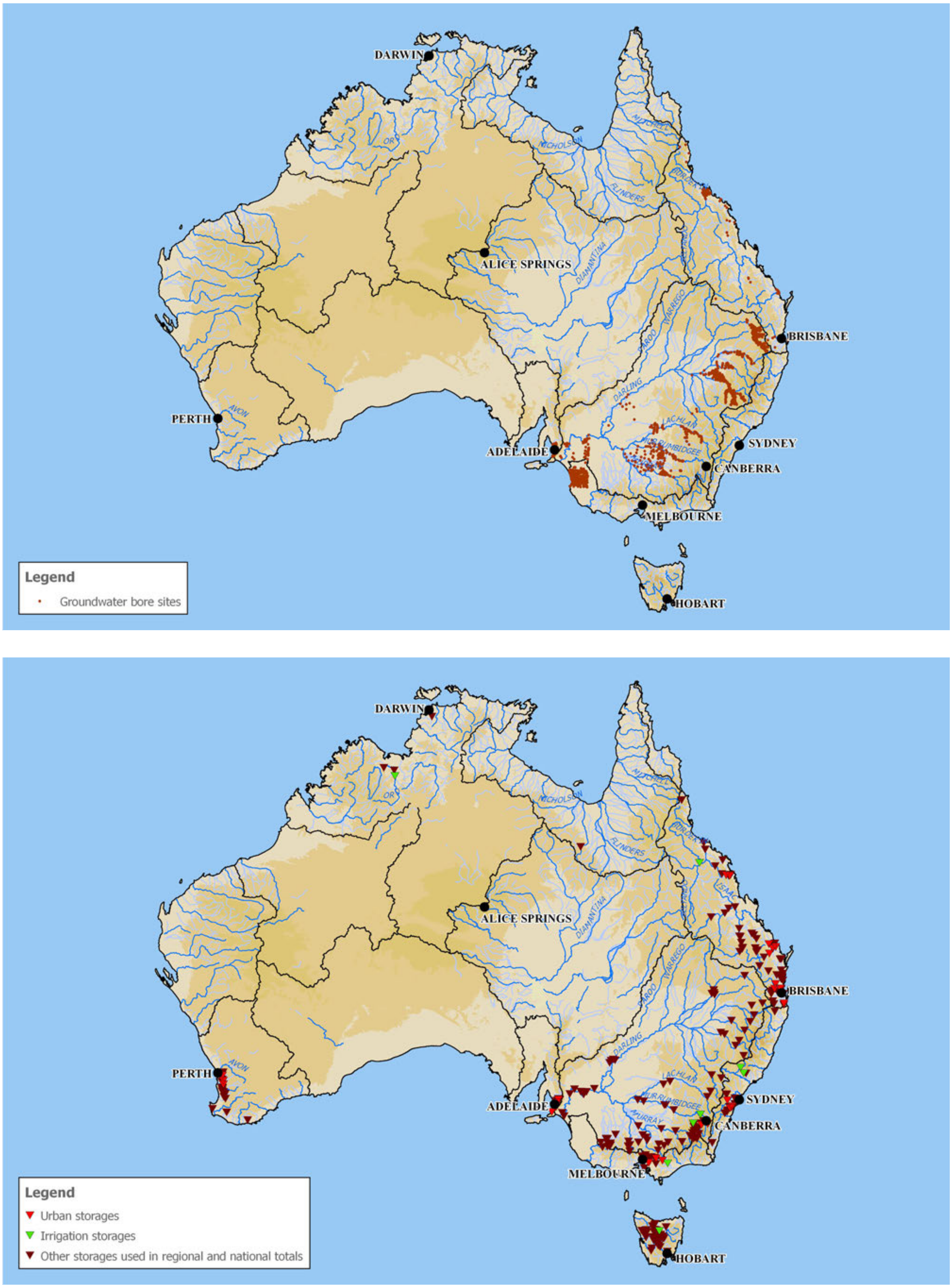


Figure 1-5. Location of groundwater bores (top) and surface water storages (bottom) selected for analysis in this report

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.