3

Some basics about Earth's water

The water cycle

The water cycle, also known as the hydrological cycle, describes the continuous movement of water above, below and on the surface of the earth. The total amount of water the earth has does not change, but the water is constantly being changed between liquid water, water vapour and ice.

Energy from the sun causes water from the ocean, lakes and rivers to evaporate. When the water vapour so formed (which is invisible) is pushed by wind over hills and mountains, it cools as it rises and turns back into tiny droplets, forming clouds. When these tiny droplets combine in the process of condensation, they fall to the earth as precipitation – rain or hail or snow. Much of the precipitation soaks into the soil and some of this is taken up by vegetation and some finds its way into aquifers – porous rock through which water can move. The rest flows into lakes, rivers and the ocean, and the water cycle continues (Fig. 3.1).[1] It follows that water does not necessarily fall to the earth as rain or snow in the same place from which it evaporated, but overall, the total amount of water remains the same.

The total volume of the world's water has been estimated to be 1386 million km^3. Only 2.5 per cent (35 million km^3) of this is fresh water, most being salt water contained in the oceans, seas, saltwater lakes and in aquifers below the oceans. Of the fresh water, more than two-thirds is locked up in glaciers, ice, snow and permafrost. The remainder is theoretically 'available' for human use, though only a tiny proportion of it – 0.4 per cent – is found on the surface of the earth, as lakes, rivers, marshes and wetlands, soil moisture, air humidity, and in plants and animals. The rest is underground – that is, groundwater found in aquifers. Approximately one-fifth of the fresh water used in the world comes from aquifers, with ~800 km^3 being extracted from the ground each year, supporting 1.5 billion people.[2]

Groundwater is water located in saturated zones below the earth's surface, accumulating in tiny pores – spaces between the smallest soil and rock particles – or in narrow cracks in the rock itself. These geological structures are called *aquifers*. Water from aquifers eventually flows into streams, rivers and the ocean, or onto the surface of the land via springs. Some groundwater is fresh and suitable for drinking, whereas some is brackish or contains high levels of dissolved chemicals, and consequently is unsuitable for human consumption or livestock supplies. Some of these underground storages are replenished quite quickly as rainwater seeps through the soil, but others, especially in areas of low rainfall, are not renewed or are renewed only very slowly. Aquifers vary enormously in size, from very small to exceedingly large. The Great Artesian Basin in Central Australia is one of the largest groundwater storages in the world, covering 22 per cent of the continent.[3]

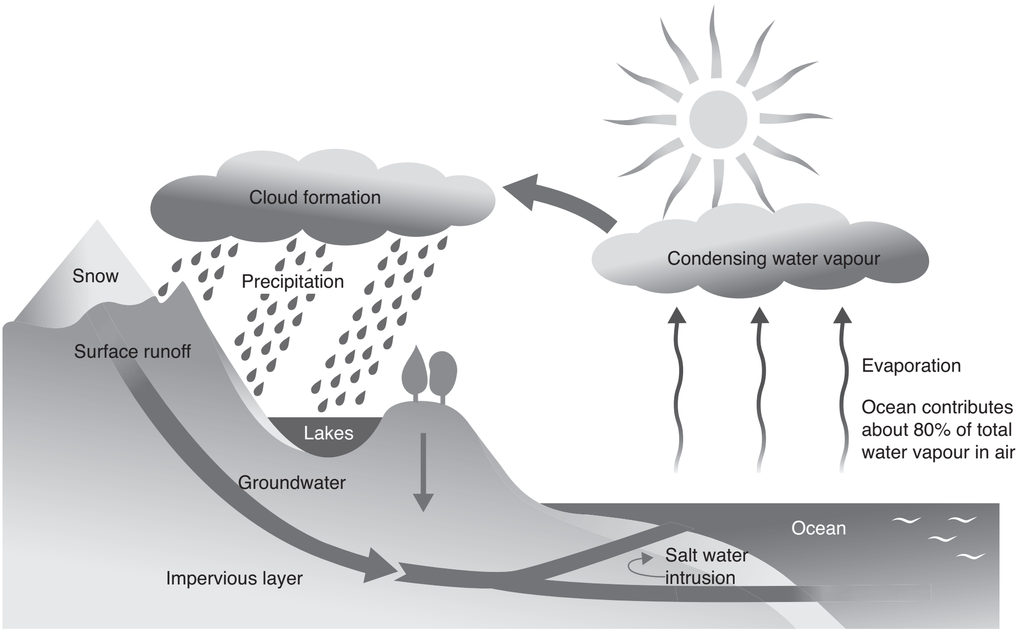

Fig. 3.1. The water cycle. Source: SA Water <https://www.sawater.com.au/community-and-environment/our-water-and-sewerage-systems/water-sources/the-water-cycle> (CC BY 3.0 AU).

In regions of the globe where rainfall is low, groundwater is a particularly important resource. Many cities rely to a substantial extent on groundwater for their supplies, for example, Beijing (China), Mexico City (Mexico) and Perth (Australia). Also, in many countries, huge quantities of groundwater are used for irrigation and industry (Chapter 8).

Climate change is having an impact on our freshwater resources and ecosystems, including melting ice sheets, glaciers and permafrost, and causing changes to rainfall patterns, though the total quantity of water available to the planet is not predicted to change.[2]

Evaporation and evapotranspiration

Evaporation is the process by which liquid water is turned to gas (water vapour). As a key component of the world's water cycle, it is responsible for the movement of enormous quantities of water. Most (~86 per cent) of the world's evaporation occurs from the ocean, as well as significant amounts from lakes and rivers. *Transpiration* is the process through which water is absorbed by plants through their roots and is ultimately released to the atmosphere through the leaves.

Evapotranspiration is the sum of evaporation and plant transpiration from the earth's land surface to the atmosphere, including soil (soil evaporation), and vegetation (transpiration). More than 10 per cent of global evaporation comes from the soil and vegetation, that is, from evapotranspiration.[2]

The rate of evapotranspiration is influenced by several important factors, including

- solar radiation – the largest energy source available to change liquid water into water vapour
- air temperature – evaporation is greater in hotter environments

The water table

The water table is the upper level of an underground area of soil and rock that is completely saturated with water, that is, all the openings within and between the rocks are filled with water (Fig. 3.2). It therefore separates a groundwater area from the area of soils and rock above it that might contain water but not be saturated. The water table is affected by climatic variation and by the amount of water vegetation draws from the soil, and it therefore fluctuates with the seasons and from year to year. It is also affected by substantial withdrawal of water from wells, or by artificial recharging of them.

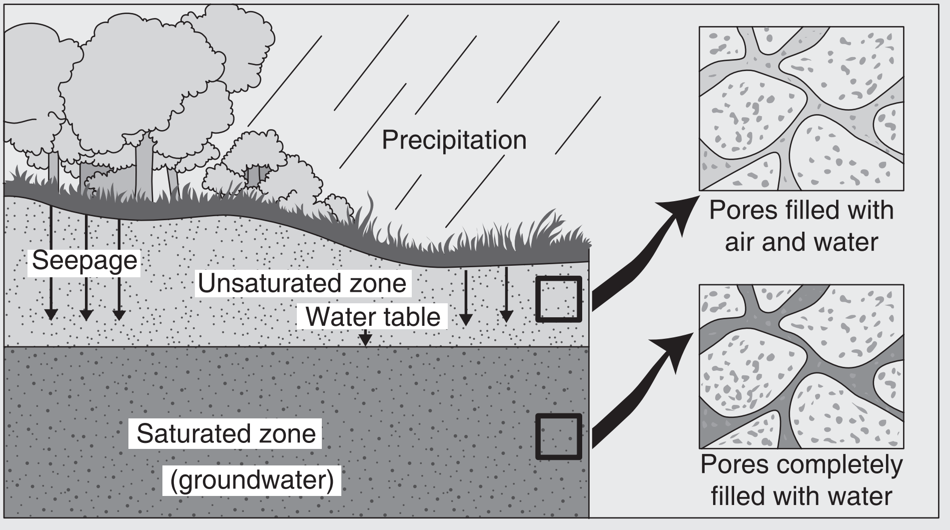

Fig. 3.2. The water table. Used with permission. James Garry, NYS Department of Environmental Conservation.

- air movement – a breeze will increase the rate of evaporation
- humidity – the dryer the air, the greater the evaporation
- the surface area exposed to the air – the greater the surface area, the greater the rate of evaporation.[4]

These factors explain why in hot, dry climates large areas of water, wet soil, and vegetation are subject to substantial water losses, and why water conservation measures in arid regions are especially important. Areas of Central Australia that are very dry have high rates of evaporation – averaging up to 500 mm and more per month from an open pan in summer. Daily rates of evaporation in these areas can approach 50 mm; that is, the depth of water in an open pan would reduce by nearly 50 mm in a 24-hour period.[5]

Covered storage cisterns, wells and aqueducts in Roman times reduced losses due to evaporation (as well as reducing contamination of the water supply). Protecting water from evaporative losses was crucial in the case of the enormous storage cisterns used in the Roman cities of Dougga and Carthage (Chapter 2). Water flowing underground in *qanats* through several kilometres of hot desert was also protected from the risk of evaporation.

Plate 5.2. The Darling River 'running a banker' near Menindee in December 2010 after a wet year.

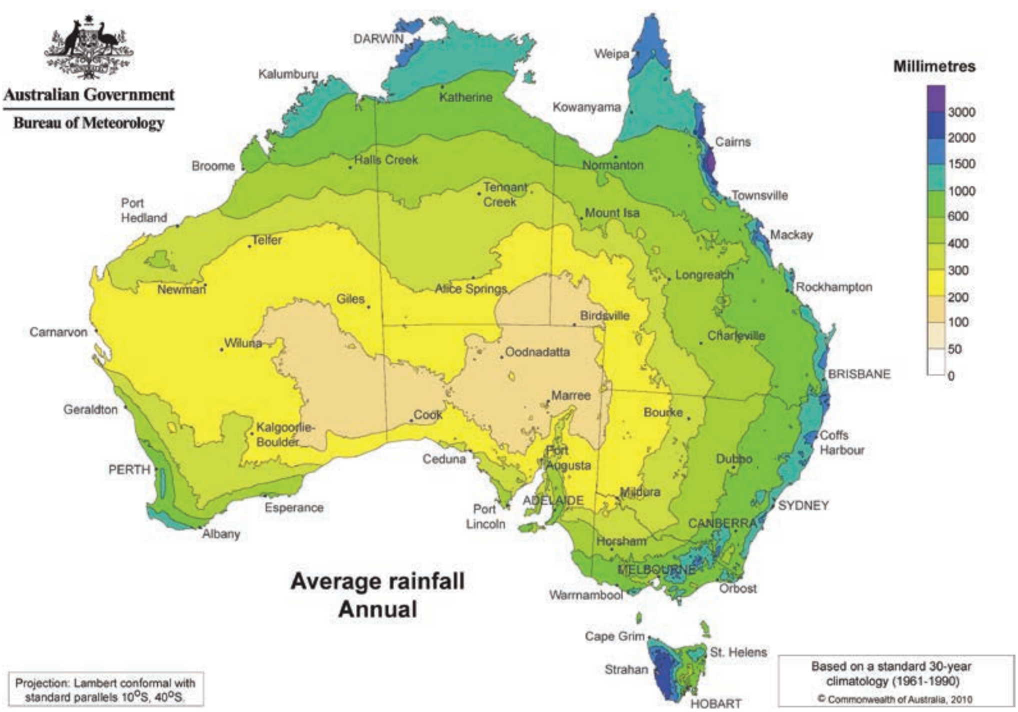

Plate 5.3. Australia's average annual rainfall distribution 1961-1990. Bureau of Meteorology (CC BY 3.0 AU).

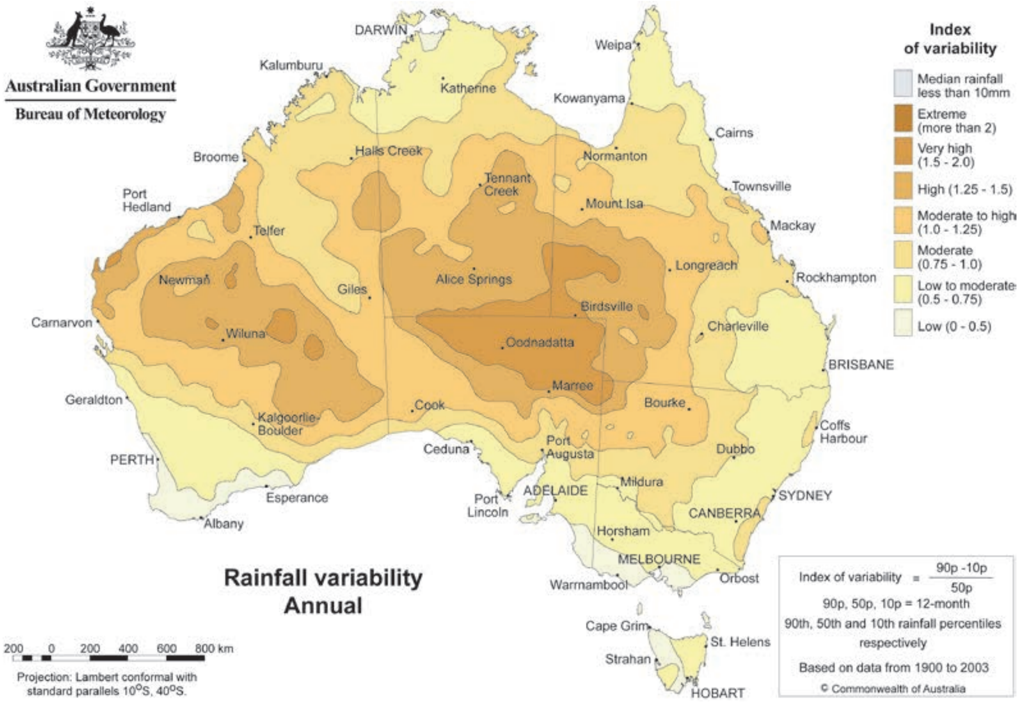

Plate 5.4. Map showing how rainfall varies from year to year (based on data from 1900-2003). Low variability means rainfall is more consistent from year to year. The darker the shading, the more extreme the variability. Bureau of Meteorology (CC BY 3.0 AU).

Plate 6.1. A section of the Brewarrina Aboriginal fish traps (August 2011). Courtesy Bradley Moggridge, ref. Maclean K, Bark RH, Moggridge B, Jackson S, Pollino C (2012) *Ngemba Water Values and Interests: Ngemba Old Mission Billabong and Brewarrina Aboriginal Fish Traps* (*Baiame's Nguunhu*). CSIRO, Australia.

13

The Murray–Darling Basin

The rivers of the Murray–Darling Basin have supported Aboriginal communities for more than 50 000 years, and probably a great deal longer than that.[1] Archaeological evidence points to the length of continuing occupation, and direct evidence from the accounts of the early European explorers shows that Aboriginal people were widespread and numerous. They lived not only along the larger rivers – the Darling, the Murray and the Murrumbidgee – where especially large populations were observed, but also in the vicinity of other rivers of the Basin, such as the Namoi, Gwydir, Barwon and Bogan, as we saw in Chapter 6. Furthermore, reports of the early European explorers receiving help from the local people in relation to sources of water and navigation were commonplace.

The Aboriginal communities lived in accord with an environment that sustained their cultural, social, economic and spiritual life. Ceremonies preserved their traditions from one generation to the next. The rivers and their surroundings were their spiritual and economic lifeblood.[2] They used the natural resources of the rivers and the animals and plants in the vicinity for water, food, shelter, tools, weapons and cultural objects. These included fish, crustaceans, water rats, turtles, kangaroos, possums, birds and their eggs, reeds, trees, grasses and their seeds, and fruits. Wetlands were a particularly bounteous resource. Weirs, dams and traps were used but these had a low impact on the streams; the rivers still flowed free and clear. Mitchell reported in 1835 that 'the waters of the Darling were fresh and sweet', echoing the observations of other European explorers.[3] It was also evident that the people were able to find abundant, nutritious food; many early European explorers reported that the men they encountered looked strong and healthy. The communities' use of firestick farming over many generations (Chapter 6) changed the mix of vegetation in some areas, but these changes were far less dramatic than the changes to be wrought later by the European arrivals after 1788.

Today, more than two centuries later, these same rivers and their environs are still a major source of food and water, but for very different and greatly expanded sets of communities – mostly those of European and other non-Indigenous origins. Now, the primary uses of the rivers are those of irrigating land to grow food (fruits, grapes, vegetables, dairy products, cereals, nuts, rice, meat cattle) and other consumables such as cotton, and supplying water for towns in the regions. But in the process of making the change from the past, the rivers have been extensively modified. Instead of running free, fluctuating with the seasons and experiencing floods and droughts, they are regulated and controlled by diversions, dams, pumps, weirs, locks and gates so that their water can be made available year-round to produce food for growing populations. The communities within the Basin are no longer self-sufficient but are part of a network of communities across Australia and overseas among which food and other goods are traded.

Fig. 13.1. The Murray–Darling Basin showing main rivers. The waters of the northern catchments run to the Darling River and the waters of the southern catchments run to the Murray River. Source: Murray–Darling Basin Authority, CC BY 4.0.

14

Saving the Murray–Darling Basin?

For more than a century, the demands on the water in the Basin have been continually increasing with more extensive irrigation, the granting of more water entitlements and the escalating needs of a growing population. As a result, the Basin water has been over-allocated. That is, greater water entitlements have been approved for the various uses – irrigation, town and community supplies, and industry – than are able to be sustained in the long-term by the resources available. This situation was brought to the forefront of public attention during the Millennium drought, referred to in the previous chapter, when farmers and their communities suffered hardship and uncertainty over their future, streams and wetlands and lakes dried, and the Murray stopped flowing into the sea. It was a critical situation that led the Australian (Coalition) Government in 2007, at last, to take radical new action. A $10 billion water management plan was proposed which included funding for the Basin states to modernise their irrigation infrastructure, to boost water efficiency on farms, and to address over-allocation in the Basin including buying back water entitlements. Significantly, the plan also involved the Australian Government taking more control of the management of the ailing river system in place of the existing consensus-based joint management by the four Basin states (New South Wales, Victoria, South Australia and Queensland) and the Australian Capital Territory. The proposal had the in-principle support of both major political parties.[1]

The Murray–Darling Basin Authority

The *Water Act 2007* of the Australian Government established the Murray–Darling Basin Authority (MDBA) as an independent expertise-based statutory agency that replaced the former Murray–Darling Basin Commission. The MDBA is responsible for planning the Basin's water resources in the interests of the Basin as a whole, and also has operational, monitoring, research and communication roles. It works in collaboration with the 'Basin states and the Australian Government, with river dependent industries and communities', and engages in partnerships, including with the research community and with Aboriginal organisations. Its primary roles include:

- preparing, implementing and reviewing an integrated plan [the Basin Plan] for the sustainable use of the Basin's water resources
- operating the River Murray system and efficiently delivering water to users on behalf of partner governments
- measuring, monitoring and recording the quality and quantity of the Basin's water resources

- supporting, encouraging and conducting research and investigations about the Basin's water resources and dependent ecosystems
- advising the Australian Government Minister for Water Resources on the accreditation of state water resource plans
- providing water rights information to facilitate water trading across the Basin
- engaging and educating the Australian community about the Basin's water resources.[1]

Responsibilities cover both surface water and groundwater, and the role of determining the sustainable amount of water that can be taken from the system.

These arrangements were preceded by almost a century of different forms of collaborative management between the Basin states and attempts to restore the health of the rivers. The signing of the River Murray Waters Agreement in 1914 (Chapter 11) was followed in 1917 by establishment of the River Murray Commission to administer the agreement. The agreement was amended significantly in 1982 to expand its scope to include water quality issues and environmental and recreational matters, following alarming findings from investigations into salinity levels in the river in the late 1960s. The agreement underwent further change in 1987 and was renamed the Murray–Darling Basin Agreement, as a result of increased understanding of environmental problems in the Murray–Darling system and further negotiations between the relevant ministers of the four governments (Australia, New South Wales, Victoria, South Australia).

In 1992 a completely new Murray–Darling Basin Agreement replaced the 1987 agreement and the Murray–Darling Basin Commission was formed to implement it. Its role was to advise on all aspects of water, land and environmental issues throughout the whole Basin, as well as to manage the allocation and delivery of water to the three Murray River states.

The health of the Murray continued to decline. The mouth had closed in 1981, and algal blooms appeared on most rivers across the Basin in 1992 and more recent years – and an audit of the Murray River waters in 1995 showed that continued increase in the use of water from the river would exacerbate problems such as salinity and water quality, and worsen the inconstancy of water supply. As a result, in a significant step in 1996 the Murray–Darling Ministerial Council (the relevant ministers from the four governments) imposed a Cap on the amount of surface water that could be diverted from the rivers of the Basin. The Cap varied in volume from year to year depending on climatic conditions. The application of the Cap stopped the growth in water use but was not successful in making sure that the overall level of use was sustainable in the long-term. Queensland and the Australian Capital Territory joined the agreement in 1996 and 1998 respectively.[2]

In 2002 the Living Murray program was introduced to 'create a healthy working river – one that assures us of continued prosperity, clean water and a flourishing environment'.[3] A key issue to be addressed by this program was how much water should be returned to the environment. The Ministerial Council decided on 500 GL 'as a first step'. However, despite this there were many gaps left, including the thousands of wetlands that rely on environmental water being available.

In a major step in 2004, the state and Australian governments agreed on a National Water Initiative setting out a broad suite of water reforms. Topics covered included planning for environmental flows, water pricing and trading, dealing with over-allocated or stressed water systems, managing urban and rural demands, and standards for water accounting. It also included reforms designed to return a sustainable balance to the Basin. The National Water Initiative has remained as Australia's enduring national blueprint for water reform.[4]

Looked at in retrospect, the many measures taken – or not taken – in recent decades were inadequate patch-ups applied too late to an ailing system, despite some steps being in the direction needed. They represent a failure of governments to address the fundamental issues properly and to ensure necessary Basin-wide action was taken. The *Water Act 2007* was the eighth major attempt since the late 1980s to substantially reduce the volume of water extracted from the Murray–Darling Basin for irrigation and to provide more for the environment.[5] It represented a last minute opportunity to redress these inadequacies and restore the Basin to a sustainable and healthy working state, especially in relation to the health of the natural environment and the quality of water for users.

The new 2007 proposal for managing the Murray–Darling Basin was not received well by everyone. Some, including a few senior members of the government, denied that over-extraction was a problem and argued that the source of the water crisis was drought rather than over-allocation.[6] In addition, not all of the states were immediately willing to cede their powers to the Australian Government. Disagreement and conflict over the use of water from rivers in the Basin has always existed – between the states; between upstream and downstream users; between different views on what rights property owners have to water that flows through their property; and between views as to whether water should be set aside for environmental watering.[7] It was therefore not surprising that such conflict would continue after the passing of the *Water Act 2007*, despite the dire condition of the Basin's rivers (Fig. 14.1).

In the meantime, the first comprehensive audit of the health of the Basin's rivers, the Sustainable Rivers Audit, was released in June 2008. This was prepared for the Murray–

Fig. 14.1. Dry bed of Stephens Creek east of Broken Hill, NSW in June 2010.