DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Rivers: Sharing our water

Teacher resource

environment.nsw.gov.au

Cover photo: Kayaking on the Macquarie Marshes (John Spencer/DPIE)

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About this resource

Egret chicks in the Macquarie Marshes. John Spencer/DPIE.

Rivers: Sharing our water is an education resource for secondary schools. It includes two separate workbooks, a teacher resource and a student workbook. This teacher resource is designed to support teachers when teaching students content relevant to years 7, 8, 9 and 10 geography and years 7, 8 and 9 science consistent with the Australian curriculum/NSW Science and Geography syllabus.

The workbooks would ideally accompany teachers and students throughout years 7 to 10, as the content progresses through different levels of learning. The content provides a balance between meeting curriculum requirements and exploring skills students can use in real-world examples of water management in the Murray–Darling Basin.

Theory- or classroom-based learning, hands-on activities, demonstrations, and field studies are used to connect students with the complexities of managing water for the environment.

Students are encouraged to inquire, investigate and complete a range of tasks, including gathering data and using appropriate methods to present and communicate what they have found. By engaging in these tasks we hope to inspire future water managers.

Introduction

Healthy rivers carry water to homes, farms, schools and businesses. Along the way, they nourish entire ecosystems and provide important habitat for a vast range of native fish, birds and plants.

Majestic river red gum on the banks of the Murray River. John Spencer/DPIE.

Our river systems have changed

Growing demand for river water has changed the patterns of flows and reduced the amount of water flowing through rivers and out into floodplain habitats.

Rivers, creeks and wetlands are the lifeblood of New South Wales (NSW). They make towns more liveable. They provide a place to relax, unwind and reconnect with nature. Healthy rivers are an essential part of our spiritual, cultural and physical wellbeing.

The rivers of the Murray–Darling Basin form a huge interconnected system. Events in one part of the Murray–Darling Basin can have a flow-on effect for other parts of the river network. For example, native fish that breed in one river may travel hundreds or even thousands of kilometres in their lifetime, making use of the river network to feed, breed and play their role in these important ecosystems.

The benefits of a robust and productive river system extend well beyond the riverbank. Some of these benefits are easy to see, others are less so, but all are critically important to the future of our river communities – plant, animal and human.

Over the past 230 years, many creeks and wetlands in NSW have had their natural flow cycles disrupted as a result of dams and weirs. While these structures have provided a more reliable water source for people, they have disrupted the natural flow cycle needed to maintain healthy rivers and wetlands.

History

Aboriginal people were the first river managers. They worked with nature to provide for their families and look after the health of rivers and wetlands

Rivers are used for transport and communication, food, medicine, building materials and culture. They connect individuals, families and groups. Aboriginal connection to rivers is alive today and is as important as it was before European settlement.

European settlement brought with it increasing demand for land, water and wealth. Early explorers pushed inland in search of rivers to help build a 'new nation'.

Rich floodplain soils, abundant native fish, timber and water drew settlers from around the globe to make use of the natural resources.

Settlers soon realised that the rivers of the Murray–Darling Basin ran dry from time-to-time. It was part of the natural wet–dry cycle but caused tremendous hardship for early settlers faced with stock and crop losses.

Traditional gunyah at Narran Lakes. Kelly Coleman/PeeKdesigns.

Yanco circa 1912. Murrumbidgee Irrigation.

Lachlan River regulator. DPIE.

The era of harnessing water

Major droughts in the 1800s prompted an era of 'harnessing water' in NSW, which set the scene for construction of large-scale dams, locks, weirs and irrigation systems. These structures 'regulated' the water in the rivers and provided more certainty around water supplies for human use.

There are now numerous man-made dams on major rivers and lakes in NSW. These include:

- Blowering Dam
- Burrendong Dam
- Burrinjuck Dam
- Carcoar Dam
- Chaffey Dam
- Copeton Dam
- Hume Dam
- Keepit Dam
- Lake Mulwala
- Lake Victoria
- Menindee Lakes
- Oberon Dam
- Pindari Dam
- Split Rock Dam
- Talbingo Dam
- Windamere Dam
- Wyangala Dam.

Dams change rivers and floodplains

When the dams were first built there was little understanding of the impact these structures would have on native plants, animals and ecosystems.

Pattern of water flow has changed

River regulation has changed the frequency, timing and duration of water flows. For example, large rainfall events are now 'captured' by dams, often in winter, and the flow is delivered later in the year to meet consumptive (agricultural, industry and community) needs.

Floods that once lasted months and allowed waterbirds to breed and plants to grow and set seed have been reduced, sometimes to weeks.

Floodplain connectivity has reduced

Dams and weirs hold back water that would usually spread out across the floodplains. This floodwater plays a critical role in ecosystems. It releases carbon and other nutrients from leaf-litter on the floodplain floor and helps kick-start the wetland food web. Less water over floodplains means less food in the rivers. This has an impact on native fish, frog and bird populations.

Water that once connected rivers and wetlands is no longer available, which means the movement of nutrients, fish and other animals is interrupted.

Stands of river red gum, black box and other river-dependent plants no longer receive water as often, or for as long as they need, leading to decline and in many cases death.

Fish and other wildlife that have adapted to the natural patterns of river highs and lows have also been affected. For example, the usual cues for some species of native fish to breed and move throughout the river system occur far less frequently.

The Macquarie Marshes are important wetlands for migratory birds.
John Spencer/DPIE.

Wavy marshwort, *Nymphoides crenata*. John Spencer/DPIE.

Other changes to rivers and floodplains

Snags that provided essential habitat for fish and other aquatic creatures were removed from rivers to allow paddle steamers to traverse the system. Snags slow the flows in rivers, particularly near riverbanks, and provide important habitat for fish and other animals that live in water. As well as loss of habitat for fish, the removal of snags caused riverbanks to erode and 'slump'.

Cold water is a problem for native fish immediately downstream of dams. When water is released from a dam, the water typically comes from the bottom of the dam. This water is much colder than the temperature of the water that flows in the river. This 'cold water pollution' prevents native fish from breeding, can affect food supplies for fish and limit their growth.

Regulation of the rivers has reduced flows that once carried nutrients to fertilise the floodplain soils. These flows no longer reach floodplains and soil vitality has declined. Some farming operations that relied on regular floods across the floodplain have now become unviable.

The very qualities that drew early settlers to the inland were altered so dramatically they no longer performed the functions necessary to maintain a healthy river system.

A regulated system

Australia's climate is driven by droughts and flooding rains. It's a climatic pattern that in some years is wet or very wet with widespread flooding, often followed by long periods of low rainfall or drought. Native plants and animals have adapted to survive and thrive within the wet–dry cycle of Australian rivers.

However, rapid change has occurred since European settlement and the cycles that occurred naturally are now carefully managed as part of a regulated system to ensure a healthy future for the river and all the communities that rely on it.

Finding a balance between the needs of the river system, its plants and animals, and the communities that rely on them is a complex task.

Managing and sharing water

The first steps toward managing rivers as a shared resource began around the time of Federation as river communities competed for shares of this valuable resource.

In 1914, Victoria, NSW and South Australia became signatories to the River Murray Waters Agreement. This was followed in 1917 by the establishment of the River Murray Commission to ensure water was shared equitably. A significant period of river development followed. This has put pressure on river ecosystems.

Emu footprint in dry river bed.
John Spencer/DPIE.

In 1995, a 'cap' on water diversions was introduced to limit the amount of water that could be taken from the river system. However, many of our rivers were already under stress.

The Millennium Drought

Local communities were noticing a decline in the health of their rivers and wetlands. When the Millennium Drought set in (1996–2010), the poor health of rivers and wetlands became even more evident. Whole river systems were at risk of collapsing.

Community-driven initiatives to provide water for wetland and river health gained momentum and the concept of 'water for the environment' was born.

Water for the environment

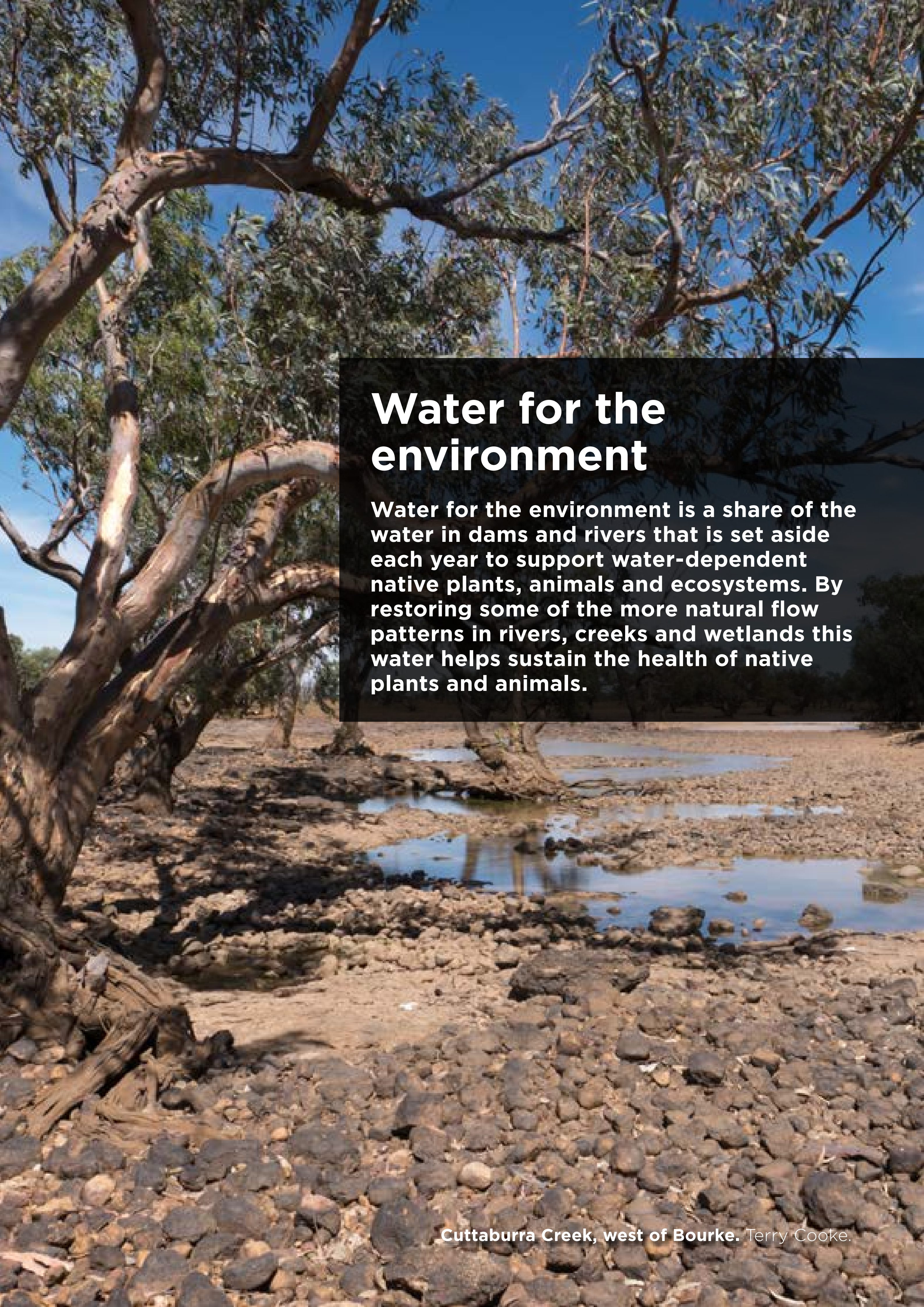
As the drought continued, state governments were called on to sign up for the National Water Initiative. This was followed by various strategies that culminated in the Murray–Darling Basin Plan (the Basin Plan), which became law in 2012.

The Basin Plan sought to recover water through improved water delivery infrastructure and the purchase of water licences. This water would then be used to support native fish, waterbirds, plants and the river system itself.

Implementation of the Basin Plan is now underway with the development of water resource plans, water sharing plans and long-term water plans to guide the use of all water for the benefit of rivers and the communities that rely on them.

Water for the environment is being used to reinstate some of the natural cues and conditions that have been removed by river regulation and provide native plants and animals with healthier places to live.

Today, communities across NSW along with government agencies and industry groups are working together to find the balance that will achieve social, cultural, economic and environmental outcomes.



Water for the environment

Water for the environment is a share of the water in dams and rivers that is set aside each year to support water-dependent native plants, animals and ecosystems. By restoring some of the more natural flow patterns in rivers, creeks and wetlands this water helps sustain the health of native plants and animals.

Cuttaburra Creek, west of Bourke. Terry Cooke.

Water availability

The volume of water in the Murray–Darling Basin available for the environment varies from year to year in response to rainfall, catchment conditions and allocations. Water for farms, towns and rivers is stored in dams and then released by river operators, who are guided by rules on running the river. The water may be directed to its destination through regulators and channels, depending on its location and available infrastructure.

Benefits of water for the environment

Water for the environment supports the health of rivers which, in turn, support plants, animals and ecosystems, including humans. Recreational fishing, tourism, agriculture, industry and public health all benefit from robust and productive river systems.

As water moves onto the floodplain, it releases carbon that energises the food web. This connection between floodplains and the river channel is vital for maintaining food supplies for native fish and other wetland-dependent animals.

Rivers deposit sediment on the floodplain, which nourishes soils and provides grazing habitat for native animals and livestock. River pulses trigger fish breeding and movement. Juvenile fish find safe havens in floodplain wetlands where they can feed and grow before returning to the river to continue their life cycle.

Wetlands are the kidneys of our rivers. Aquatic plants help to filter water as it moves through the system, slowing flows

Fish jumping at Bokhara River Weir, Goodooga. Terry Cooke.

A waterbird nest in the fork of a tree in the Macquarie Marshes. John Spencer/DPIE.

and performing an important nutrient-cycling function. These plants flower and set seed during watering events, providing food and shelter for a range of insects, frogs, reptiles, birds and mammals.

Wetlands are also a magnet for migratory waterbirds, some of which travel thousands of kilometres to feed and/or breed during times of inundation. Waterbirds flock to healthy wetlands. This makes rivers and wetlands a focal point for birdwatchers. Woodland birds also respond to a healthy wetland environment. They feed, breed and move into the surrounding landscape helping to pollinate plants and control pest insects.

Water for the environment is vital to help maintain a healthy, productive and resilient river system for the benefit of plants, animals and people.

Managing the water

Over the past 230 years, many rivers, creeks and wetlands have had their natural flow cycles disrupted by dams and weirs. Rivers that once ran low during the summer months now carry high volumes of water for use by farms and towns. Winter and spring flows are captured in dams with rivers downstream running low.

This has affected our rivers and floodplains in a number of ways. For example:

- reduction of habitat due to changes in area, frequency and duration of flooding on floodplains and terminal wetlands
- increased flows cause more permanent flooding of some wetlands
- riverbanks degrade through altered flow patterns
- temperature changes in the water of rivers
- loss or disruption of ecological functions, such as loss of plants and snags that create habitat for aquatic creatures.

River regulation

River regulation is the management of rivers using dams, weirs, pipes, regulators and channels to control the flow of water. River regulation brings more reliability to water supplies for human use, but interrupts the natural flow characteristics of rivers that native fish and other aquatic plants and animals need to breed, feed and grow.

Water for the environment is delivered via the same system of dams, weirs and channels used by other water customers. WaterNSW controls our dams and weirs. When a site is identified as needing water a water manager places an order with WaterNSW. The water is released at an agreed time. Sometimes this process is automated. In other cases, when a regulator is located closer to the target site, a water or land manager may need to physically open the regulator to allow water to enter the creek or wetland. In regions where wetlands are located near irrigation systems that carry water to farms, water managers pay a fee to use these same channels to deliver water to those wetlands.

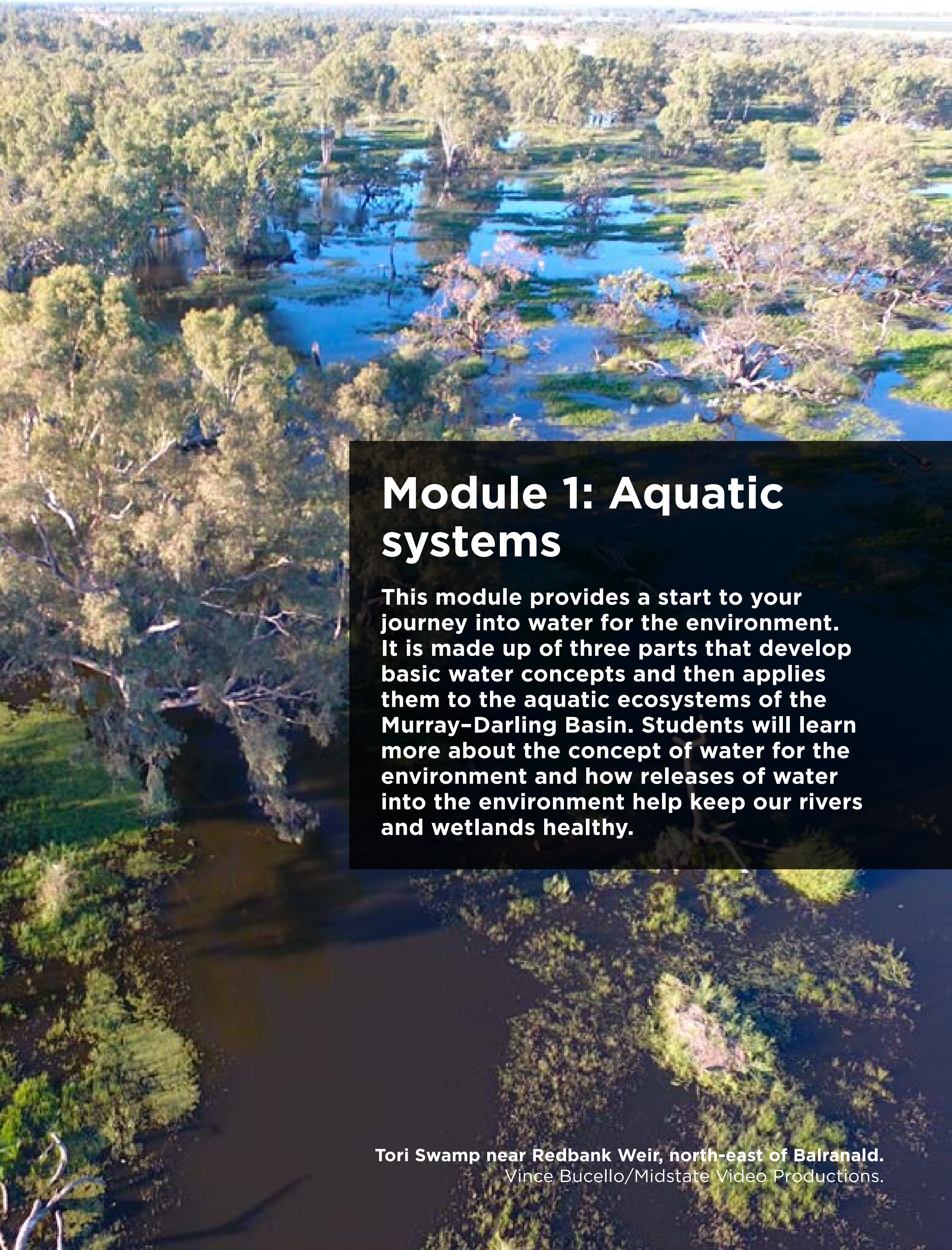
Policies that guide water management

A range of policies and plans are in place to guide the management of water in the Murray–Darling Basin.

The **Murray–Darling Basin Plan** (the Basin Plan) was enacted under the Australian Government's *Water Act 2007* to manage the water resources of the Murray–Darling Basin more sustainably to ensure long-term social, economic and environmental viability. The Basin Plan seeks to strike a balance between human and environmental needs, and identifies sustainable water diversion limits for catchments within the Basin. These diversion limits replace the previous Murray–Darling Cap on extraction.

Water resource plans (WRPs) give effect to the Basin Plan and determine sustainable diversion limits for particular areas. Each WRP outlines the system of infrastructure, entitlements, flow rules and management framework, consistent with the Basin Plan. Water resource plans are prepared by state authorities and accredited by the Australian Government under the Basin Plan.

Water sharing plans are a component of WRPs and were established under the *NSW Water Management Act 2000*. Each water sharing plan sets out specific rules for sharing and trading water between the various water users and the environment in a specified water management area.



Module 1: Aquatic systems

This module provides a start to your journey into water for the environment. It is made up of three parts that develop basic water concepts and then applies them to the aquatic ecosystems of the Murray–Darling Basin. Students will learn more about the concept of water for the environment and how releases of water into the environment help keep our rivers and wetlands healthy.

Tori Swamp near Redbank Weir, north-east of Balranald.
Vince Bucello/Midstate Video Productions.

Overview of materials

These teaching materials include content provided for students in Rivers: Sharing our water Student workbook and additional background content, questions and resources to help teachers deliver the student activities for Module 1.

They include:

- Australian curriculum outcomes and cross-curriculum priorities addressed by this module, listed in Tables 1 and 2.
- Fact sheets and related 'teacher notes' for teachers to use to introduce each part of this module and guide students through fact sheet content. This includes text-based descriptions for facilitating student activities, conducting demonstrations and field studies. 'Resources' boxes highlight what resources teachers will need to take students through each task.
- Student activity questions and answers to use to review the first two parts of this module:
- Part A: Water and the Murray–Darling Basin Student Activity 1.A How well do you know the Murray–Darling Basin – questions and answers
- Part B: Aquatic ecosystems Student Activity 1.B Murray–Darling aquatic ecosystems – questions and answers
- Part C: Murray–Darling Basin waterway field study and associated field study risk-management plan. Student Activity 1.C – No answers provided because questions are site-specific.

Dicks Dam on the Warego River west of Bourke. Terry Cooke.

Australian curriculum outcomes

Table 1 Australian curriculum links for Module 1: Aquatic ecosystems

Subject	Year	Curriculum link
Geography	7	**ACHGK037**: Classification of environmental resources and the forms that water takes as a resource **ACHGK038**: The way that flows of water connects places as it moves through the environment and the way this affects places **ACHGK040**: The nature of water scarcity and ways of overcoming it, including studies drawn from Australia and West Asia and/or North Africa examining why water is a difficult resource to manage and sustain (for example, because of its shared and competing uses and variability of supply over time and space) investigating whether the use of water in their place is sustainable investigating land-use management practices that have adversely affected water supply **ACHGK041**: Economic, cultural, spiritual and aesthetic value of water for people, including Aboriginal and Torres Strait Islander Peoples and peoples of the Asia region exploring the multi-layered meanings (material, cultural and spiritual wellbeing) associated with rivers, waterways, waterholes, seas, lakes, soaks and springs for Aboriginal and Torres Strait Islander Peoples
	9	**ACHGK060**: Distribution and characteristics of biomes as regions with distinctive climates, soils, vegetation and productivity identifying and describing the major aquatic and terrestrial biomes of Australia and the world, and their spatial distribution examining the influence of climate on biomass production (as measured by net primary productivity) in different biomes **ACHGK061**: Human alteration of biomes to produce food, industrial materials and fibres, and the use of systems thinking to analyse the environmental effects of these alterations identifying the biomes in Australia and overseas that produce some of the foods and plant material people consume identifying the differences between natural and agricultural ecosystems in flows of nutrients and water, and in biodiversity
	10	**ACHGK070:** Human-induced environmental changes that challenge sustainability discussing the concept of sustainability in relation to environmental functions identifying human-induced environmental changes (for example, water and atmospheric pollution; loss of biodiversity; degradation of land, inland and coastal aquatic environments) and discussing the challenges they pose for sustainability evaluating the concept of ecosystem services and the importance of these services for sustainability of biodiversity **ACHGK074**: The application of geographical concepts and methods to the management of the environmental change being investigated **ACHGK075**: The application of environmental economic and social criteria in evaluating management responses to the change

Subject	Year	Curriculum link
Science	7	**ACSSU112**: Interactions between organisms, including the effects of human activities can be represented by food chains and food webs investigating the effect of human activity on local habitats, such as deforestation, agriculture or the introduction of new species **ACSSU116**: Some of Earth's resources are renewable, including water that cycles through the environment, but others are non-renewable considering what is meant by the term 'renewable' in relation to the Earth's resources investigating factors that influence the water cycle in nature exploring how human management of water impacts on the water cycle **ACSHE223**: Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE223 **ACSHE120**: Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations considering issues relating to the use and management of water within a community considering how human activity in the community can have positive and negative effects on the sustainability of ecosystems
	9	**ACSSU176**: Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems

Cross-curriculum priorities

Table 2 Cross-curriculum priorities addressed by Module 1: Aquatic ecosystems

Sustainability	
Organising ideas	
Systems	
01.1	The biosphere is a dynamic system providing conditions that sustain life on Earth.
01.2	All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.
01.3	Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.
Futures	
01.6	The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future.
01.7	Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments
01.9	Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

Part A: Water and the Murray–Darling Basin

Resources

Module 1 Part A: Water and the Murray–Darling Basin fact sheets 1.1–1.4

Student activity 1.A worksheet

Murray–Darling Basin map, printed at A3 size

Watch this video

Drainage basins and river systems

This section starts the conversation about water. It includes a brief introduction to the Murray–Darling Basin as well as a series of fact sheets for teachers to use to:

- revise student knowledge about basic water concepts
- identify that our freshwater resources are precious
- familiarise students with the Murray–Darling Basin as Australia's largest river catchment.

Students will be required to answer a series of questions and mapping exercises relating to the information provided.

Open fact sheets 1.1 to 1.4, located in the Module 1 Student materials section for Part A: Water and the Murray–Darling Basin, on your interactive white board or projector equipment.

Provide students with a printed copy of the Student activity 1.A worksheet so they can answer the questions as relevant topics are discussed (see Rivers: Sharing our water Student workbook for worksheet with questions only). Students will also need an A3 copy, preferably colour, of the Murray–Darling Basin map for mapping activities. Highlight to students they need to keep this map for future activities. You can also give students a digital version of the map to keep on their laptops/ipads, etc.

Notes for each fact sheet are provided as prompts for teachers to use with students.

Kia Lake at Gayini (Nimmie-Caira) east of Balranald. Vince Bucello/Midstate Video Productions

Fact sheet 1.1

> Water is a unique substance on Earth. It occurs naturally in three different states of matter:
>
> - **Liquid** – rain, rivers, oceans, etc.
> - **Solid** – ice and snow
> - **Gas** – steam/water vapour

The basics of water

Water on Earth is perhaps our most precious resource. It is the main reason that life has been so successful evolving and colonising nearly every part of the planet. From the highest mountains, to the deserts and even to the deepest trenches of the ocean, the availability of water has meant life has found a way to flourish and survive.

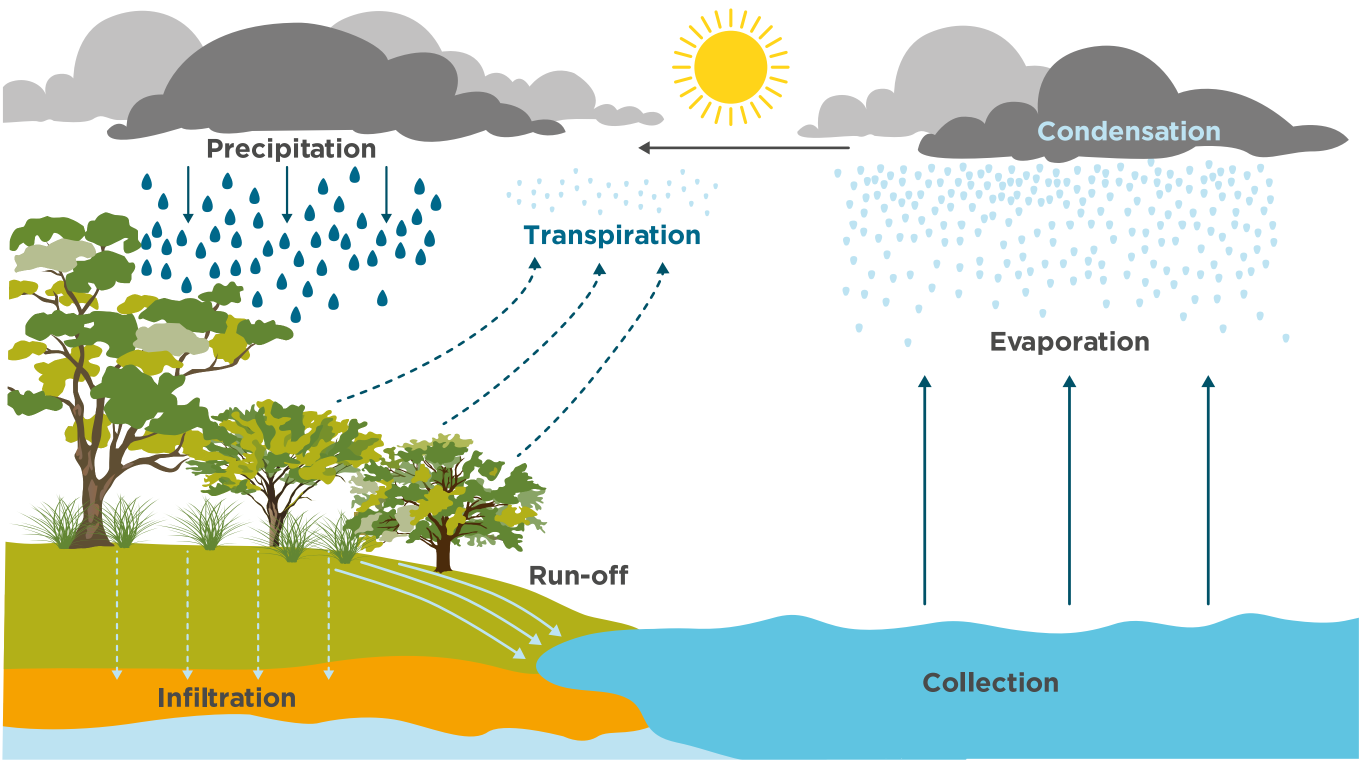
Water is not an unlimited resource. Scientists consider that the Earth is a 'closed system'. This means that the resources of our planet are the only resources we have, as very little material enters or exits the system. This closed system is why water is such a valuable resource – it is the only water we have!

The water cycle

The journey that water takes as it changes in state, moving through our environment is called the water cycle (or hydrological cycle). It travels through this cycle continuously and, with help from the sun's energy, is responsible for creating climatic conditions suitable for life on our planet. Water is naturally recycled through this cycle, which makes it a renewable resource.

The main problems with water as a renewable resource occur when humans change the natural environment by:

- altering rivers for our own use
- polluting rivers with chemicals, rubbish, waste or extra sediment from urban or agricultural practices
- changing natural landscapes
- altering natural weather patterns through accelerated climate change.



The water or hydrological cycle.

Teacher notes for Fact sheet 1.1

Go through the content of this fact sheet on your interactive white board. Highlight the following main points:

- water is a precious resource
- all life on Earth needs water in some form to survive
- the water on Earth is the only water we have – Earth is a closed system
- water can be found occurring naturally in three states of matter – liquid, solid and gas
- water is a renewable resource that moves through the environment in the water cycle
- human-induced changes to the natural environment are the main cause of disruption to the water cycle

Students should answer questions 1–5 on the Student activity 1.A worksheet.

Fact sheet 1.2

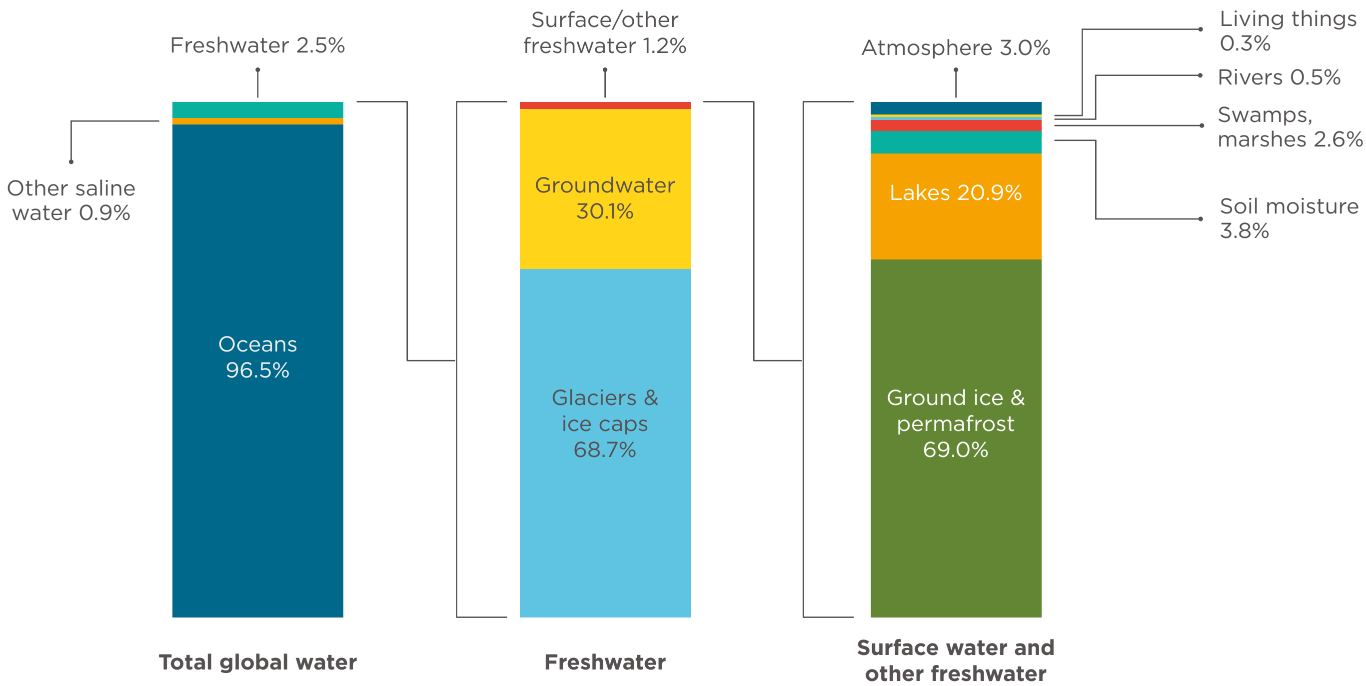
Even though about 71% of the Earth's surface is covered in water, the total volume of water when compared to the volume of the planet is actually quite small.

Where is the Earth's water?

Water exists in many places and forms. It is found in:

- oceans
- rivers
- lakes
- wetlands
- dams
- ice caps
- glaciers
- aquifers in the ground
- soil – as moisture and groundwater
- the air – as a gas (water vapour)
- ground ice/permafrost
- all living things – plants and animals use water to run almost all of their vital systems.

In 1993, Igor Shiklomanov created a visual image to represent how water on, in and around our planet is distributed. This is an effective way of displaying where our water is located, and how precious and rare our freshwater resources are.



Shiklomanov's breakdown of where water on Earth can be found or accessed.

Total global water

The total global water column in Shiklomanov's diagram shows that almost all water on our planet is saline – saltwater in our oceans (96.5%) or other saline water (0.9%), and only a small 2.5% is freshwater.

Freshwater

The freshwater column in Shiklomanov's diagram represents a further breakdown of the freshwater resources on Earth. Most of our freshwater is contained in glaciers and ice caps (68.7%) and groundwater (30.1%) with only 1.2% of freshwater being surface/other freshwater.

Surface water and other freshwater

This column in Shiklomanov's diagram shows a further breakdown of our surface/other freshwater resources. Most of these resources are locked away in ground ice and permafrost (69%), with much smaller amounts available in our lakes (20.9%), wetlands (2.6%) and rivers (0.49%).

View the United States Geological Survey Where is Earth's Water? webpage for an estimation of the volume of global water and where it is distributed, such as fresh liquid water, freshwater in rivers and lakes, compared to total volume of water on Earth (see table at bottom of webpage).

Teacher notes for Fact sheet 1.2

Go through the content of this fact sheet on your interactive whiteboard or projector equipment. Highlight the fact that water exists in many places and forms – oceans, rivers, lakes, wetlands, dams, ice caps, glaciers, aquifers, the soil, the air, ground ice and in all living things.

Focus on Shiklomanov's diagram and discuss what each column means. Moving from left to right, each column is a percentage of the previous column, so the amounts of water in the column on the right-hand side, 'Surface water and other freshwater', are very small.

Students should answer questions 6–8 on the Student activity 1.A worksheet and complete the tables provided as part of these questions. Students will need a calculator for this task.

Fact sheet 1.3

Where the water flows

It's all downhill!

The most basic thing to recognise when studying water is that it is controlled by gravity. It will always try and flow towards the lowest point. If the water meets an obstacle, it will divert and be guided by the natural (or human-made) depressions in the landscape, but it will still move towards the lowest point.

Watch this video

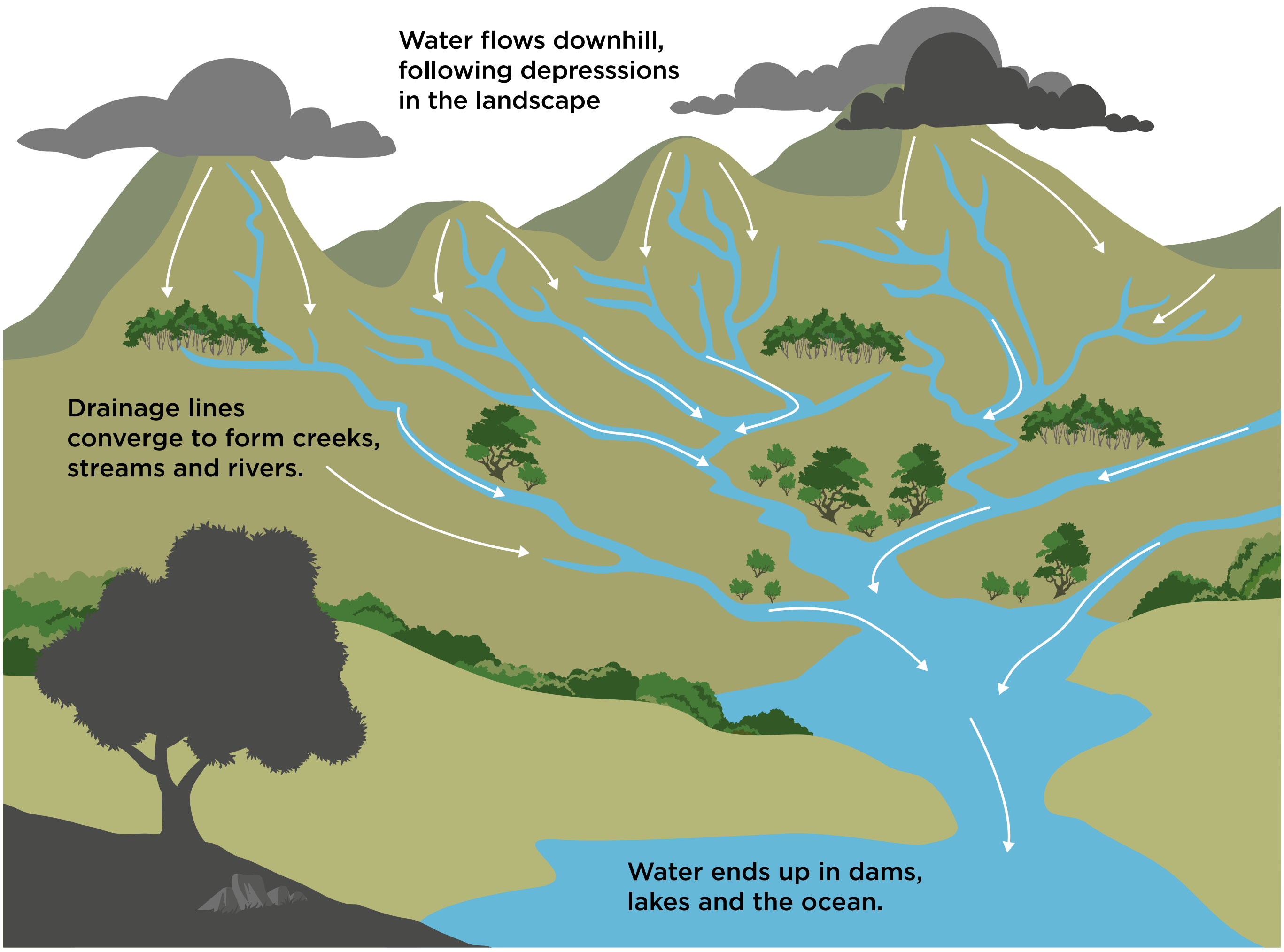
[Drainage basins and river systems]

What is a catchment?

A catchment, also known as a drainage basin, describes any surface where water falls, is collected and drains to a common end point. A catchment can be small like the roof of a house, or it can be a huge river catchment like the Murray–Darling Basin.

A river catchment is the entire geographical area where all of the precipitation (rain, snow and ice) falls and the run-off flows downhill across the land into an interconnected system of creeks, rivers, lakes and wetlands.

Geographical features like mountain ridges, hills or areas of higher ground separate different river catchments because they control where the water flows. These boundaries between catchments are known as 'drainage divides'.



A river catchment landscape.

Teacher notes for Fact sheet 1.3

Resources

Bucket of water (or hose)

A place to refill bucket

Large rocks or suitable obstacles to divert water

Rake, pitchfork, shovel or stick.

Gravity makes water flow towards the lowest point. This is a basic but extremely important concept when studying catchments like the Murray–Darling Basin. To emphasise this, discuss this section outside with your students where you can demonstrate the relevant information. This could easily be adapted from a teacher-led demonstration into a student-run experiment.

Start by reviewing students' knowledge by asking what they think has an effect on the flow of water. See whether they can identify gravity (force), slope and obstacles as things that can divert water.

Ask students to think about their answers as they observe you pour a slow and steady stream of water from the bucket onto your selected sloped site.

Then ask students these questions:

- **Why did the water flow in the way that it did?** The answer is that water flows downhill.
- **What was the force that acted on the water?** The answer is gravity.

Then place (or make) some obstacles on your slope, repeat the demonstration and ask students this question:

- **What did the water do when it reached the obstacles?** The answer is that the obstacles diverted the water – water follows the path of least resistance.

Combine students' acquired knowledge by telling them the most important thing to remember is: 'Water follows the downhill path (slope) of least resistance (around obstacles) to reach the lowest point (gravity pulling down)'.

Use your rake or stick to scratch some marks into the soil. Start the marks from different points near the top of your slope and bring them together towards the bottom. Pour just enough water down your slope to demonstrate that a catchment describes any surface where water falls and is collected. Reiterate that 'Water follows the downhill path (slope) of least resistance (around obstacles) to reach the lowest point (gravity pulling down)'. Liken this last experiment to rainwater draining across the land and gathering in creeks and rivers that flow towards a common point.

- Discuss what a catchment is with your students. Use the last demonstration to reaffirm that 'A catchment describes any surface where water falls, is collected and drains to an end common point.'
- Ask for a volunteer to describe what a river catchment/ drainage basin is. Use the school roof to demonstrate what a catchment is and liken it to a river catchment/ drainage basin. That is, water runs down the roof (surface runoff), into the gutters and drainpipes (creeks

and rivers), and then collects in the tanks (lakes, dams, oceans, estuaries, etc.). This could be easily demonstrated with a hose to get students thinking about where the water is going.

- Discuss boundaries between catchments (drainage divides). Have students suggest what the drainage divides are on the roof catchment system.
- Return to the classroom, discuss Fact sheet 1.3: Where water flows, and watch the Drainage basins and river systems video on your whiteboard/projector equipment to reinforce learning from the demonstration.

Students should answer questions 9–11 on the Student activity 1.A worksheet.

Fact sheet 1.4

The 23 major rivers and more than 30,000 wetlands of the Murray–Darling Basin support a vast array of plants and animals in ecosystems that depend on a regular or intermittent supply of water.

Getting to know the Murray–Darling Basin

The Murray–Darling Basin is Australia's largest river catchment. It covers an enormous area of around 1,059,000 square kilometres, which makes it the 20th largest river catchment in the world. It is an interconnected system of hundreds of streams, creeks, rivers, lakes, dams and wetlands that come together to form an integral part of the eastern Australian landscape.

Catchments

The Murray–Darling Basin is made up of more than 20 river catchments that mostly flow into the major rivers. Some catchments end in wetlands or marshes and only flow into the main system in extremely wet years.

Three rivers in the Murray–Darling Basin are considered Australia's longest:

- the Darling–Barwon River system at 2740 kilometres
- the Murray River at 2530 kilometres – Australia's longest standalone river
- the Murrumbidgee River at 1690 kilometres.

Catchments of the Murray–Darling Basin. Source: Land use of Australia 2010-11, Australian Government Department of Agriculture and Water Resources.

The Murray–Darling Basin is often spoken about in terms of two halves:

1. the northern Murray–Darling Basin catchment, which contains all of the rivers that drain into the Darling River
2. the southern Murray–Darling Basin catchment, which contains all of the rivers that drain into the Murray River.

Storing water in western NSW.
Terry Cooke.

Diverse ecosystems

The waters of the Murray–Darling Basin are essential for healthy river and wetland environments that support life throughout the region. The Basin has a diverse range of climates and conditions that range from subtropical rainforests in the north and alpine meadows and snowfields in the south, to fertile plains of the central basin and semi-arid desert in the west. These landscapes combine to make thousands of different types of ecosystems. Like the rivers themselves, these ecosystems are interconnected communities with complex and finely balanced functions that depend on one another. Changes to these ecosystems and/or the physical conditions that support them can have adverse effects on the natural environment of the whole Basin.

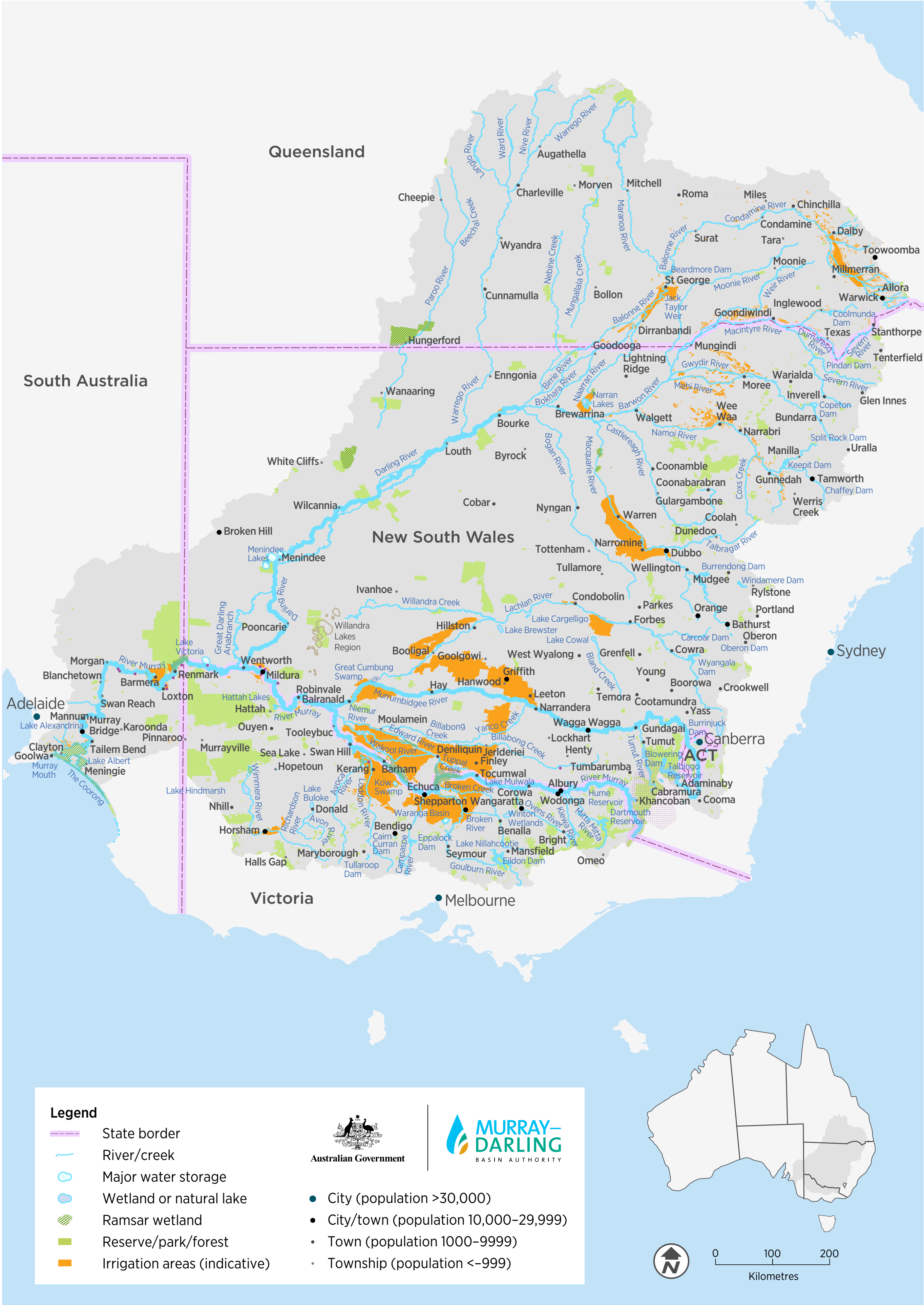
Murray–Darling Basin population

> *'The Murray–Darling Basin has supported and been home to Australia's First Nations People for tens of thousands of years and they are recognised as the traditional custodians of the land. The region's land, rivers, mountains and plains are steeped in Aboriginal history, culture and spirituality – having many important cultural locations which continue to support and sustain communities'*
> (Coleman et al 2018).

Over 2 million people live within the Murray–Darling Basin, and almost 4 million people rely on its catchments for water – this includes communities and industries.

The combination of a suitable climate and fertile land for producing food and fibre resources make the waters of the Murray–Darling Basin one of Australia's most important natural resources. These ideal growing conditions for crops, pastures and livestock have led to more than 40% of all farms in Australia being located within its boundaries.

To try and ensure water supply meets the demands of the Murray–Darling Basin population, water regulation or the control of water resources is necessary. This has led to the development of many major water storages or dams. Most of these dams are located in the upper catchments along the western fall of the Great Dividing Range.



Murray–Darling Basin map. Source: Murray-Darling Basin Authority.

Resources

Murray–Darling Basin map, printed at A3 size

Catchments of the Murray–Darling Basin map, printed at A3 size.

Teacher notes for Fact sheet 1.4

This fact sheet provides a brief introduction to Australia's largest river catchment, the Murray–Darling Basin.

First, provide students with an A3 printed colour copy of the Murray–Darling Basin map. Tell them to take care of their map and keep it safe because they will need it for other activities in this resource.

Go through the content of this fact sheet on your whiteboard with students. You will need access to the Catchments of the Murray–Darling Basin map to discuss the information.

Highlight the following main points:

- The Murray–Darling Basin is Australia's largest river catchment, it is immense in size (20th largest in the world).
- The Murray–Darling Basin is an interconnected system of hundreds of rivers, creeks, lakes and wetlands.
- The Murray–Darling Basin contains more than 20 major river catchments. Use the Catchments of the Murray–Darling Basin map to show students major river catchments. Identify the catchment your school is in if you live in the Murray–Darling Basin.
- Identify (or ask students to identify) Australia's three longest rivers on the Murray–Darling Basin map. Trace the path of these rivers. Also focus on where the Darling River flows into the Murray River and trace backwards to show the divide between northern and southern halves of the Murray–Darling Basin.
- Focus on the importance of the Murray–Darling Basin to Australia's agriculture. Discuss reasons why the Murray–Darling Basin has 40% of Australian farms; i.e., huge areas, suitable climate, soil resources and access to water make ideal growing conditions.
- Identify, or ask students to identify, some of the major water storages on the Murray–Daring Basin Map. For example: Beardmore and Coolmunda dams in Queensland; Burrendong, Burrinjuck, Copeton, Keepit, Hume (one-third in NSW) and Wyangala dams in NSW; and Dartmouth, Eppalock and Hume (two-thirds in Victoria) dams, Lake Eildon and Waranga Basin in Victoria. Discuss with students why they think these water storage reservoirs are mostly in the upper eastern sections of catchments along the Great Dividing Range.
- Emphasise that whilst water storage is good for regulating water for human use, it does not necessarily create a good environment to maintain healthy rivers and wetlands.

Students should answer questions 12–29 on the Student activity 1.A worksheet.

Student activity 1A How well do you know the Murray–Darling Basin? Questions and answers

The basics of water

Question 1
What sort of system do scientists consider the Earth to be? What does this mean?

A 'closed system'. This means that the resources of our planet are the only ones we have as very little material enters or exits the system.

Question 2
What are the three states of matter that water occurs in?

Liquid (water – rain, rivers, oceans etc.), solid (ice and snow) and gas (steam/water vapour).

Question 3
What are the stages of the hydrological cycle? Draw your own representation of how water moves from the Earth to the atmosphere and back again.

Condensation, precipitation, run-off, infiltration, transpiration, collection and evaporation.

Question 4
Is water considered a renewable resource?

Yes.

Question 5
Who is responsible for altering the natural water cycle? How?

Humans – we divert, alter and pollute rivers, change the natural landscapes surrounding rivers and have caused climate change.

Question 6
Use the values from the diagram of Shiklomanov's breakdown of water on Earth in Fact sheet 1.2 to calculate the percentage that surface/other freshwater makes up of total global water resources.

Take the percentage of freshwater from the 'Total global water' column in the diagram and write it in space A in the table. Take the percentage of surface/other freshwater from the 'Freshwater' column in the diagram and put it in space B in the table. Convert A into a decimal and put this value in space C (A/100). Convert B into a decimal and put this in space D (B/ 100). Multiply C and D and write it in space E. Convert E back into a percentage and put in space F (multiply E by 100).

Surface/other freshwater makes up 0.03% (F) of total global water resources.

	Amount of freshwater in total global water	Amount of surface/ other freshwater in total freshwater	Amount of surface/other freshwater in total global water
Percentage	**A** 2.5%	**B** 1.2%	**F** 0.03%
Decimal	**C** 0.0025	**D** 0.012	**E** 0.0003

Question 7
Using values from the diagram of Shiklomanov's breakdown of water analysis on Fact Sheet 1.2, calculate the percentage that rivers, lakes and wetlands/swamps make up of total global water resources.

Carry your values F and E over from question 6. Take the total percentage contained in rivers, lakes and wetlands/swamps from the 'Surface water and other freshwater' column in the diagram and write it in space G (percent rivers + percent lakes + percent wetlands/swamps). Convert G into a decimal and put this value in space H (G/100). Multiply E and H and put in space I. Convert I back into a percentage and put in space J (multiply I by 100).

Rivers, lakes and wetlands/swamps make up 0.0072 % (J) of the total global water resources.

	Amount of surface/other freshwater in total global water	Surface/other freshwater (rivers, lakes and wetlands/swamps)	Amount of surface/other freshwater in total global water
Percentage	**F** 0.03%	**G** 23.99%	**J** 0.0072% (rounded up)
Decimal	**E** 0.0003	**H** 0.2399	**I** 0.00007197

Question 8
What does your answer for Question 7 tells us about the percentage that rivers, lakes and wetlands/swamps make up of the total global water resources?

Rivers, lakes and wetlands/swamps make up a tiny percentage (0.00072%) of the world's total global water resources. This means that water is scarce and a very precious commodity.

Question 9
Complete the following sentence: The force of gravity causes water to always try and flow downhill towards the lowest point.

Question 10
Describe what a river catchment/drainage basin is.

A river catchment is the entire geographical area where all of the precipitation (rain, snow and ice) falls and the run-off flows downhill across the land into an interconnected system of creeks, rivers, lakes and wetlands.

Question 11
What sort of geographical features usually make up drainage divides?

Geographical features like mountain ridges, hills or areas of higher ground separate different river catchments as they control where the water flows. These boundaries between catchments are known as 'drainage divides'.

The Murray–Darling Basin

You will need your Murray–Darling Basin map for some of these questions.

Question 12
The Murray–Darling Basin is Australia's largest what?

River catchment.

Question 13
Does the Murray–Darling Basin drain to the northeast or southwest?

The Murray–Darling Basin drains towards the southwest.

Question 14
Does the Murray–Darling Basin reach the sea? Where?

Yes. At the Coorong estuary in South Australia.

Question 15
How many states/territories have land within the Murray–Darling Basin? Name them.

Five – Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia.

Question 16
Does the Murray River drain into the Darling River or does the Darling River drain into the Murray River?

The Darling River drains into the Murray River.

Question 17
Use the size of the Murray–Darling Basin to work out the percentage it makes up of Australia's total land area (7,692,000 square kilometres).

Hint (land area of Murray–Darling Basin/land area of Australia) x 100 = percentage land area of Australia Murray–Darling Basin takes up.

13.76%

Question 18
Use the Catchments of the Murray–Darling Basin map to identify the major river catchment that you live in. Mark this major river catchment on your map. If you live outside the Murray–Darling Basin choose an area you have visited.

Students will have location-specific answers on map.

Question 19
On the Murray–Darling Basin map, highlight the entire journey your local creek/ river takes until it meets the Murray or Darling River. Which one river does it meet? Continue to highlight the journey along the Murray and Darling rivers until they reach the sea.

Students will have location-specific answers on map. Either Murray or Darling rivers depending on local creek.

Question 20
The Barwon–Darling system is the longest Australian river, followed by the Murray River and then the Murrumbidgee River.

Question 21
Draw a line on your map to show the northern (Darling River catchment to Menindee Lakes) and southern (Murray) halves of the Murray–Darling Basin.

Students will have a divide line on their map.

Question 22
Does the Murray–Darling Basin have a range of diverse environments or is it considered to be all very similar? What sort of environments does it have?

A range of diverse environments from subtropical rainforest in the north, alpine meadows and snowfields in the south, fertile plains of the central basin, to semi-arid desert in the west.

Question 23
Are the communities of ecosystems within the Murray–Darling Basin interconnected? What does this mean if something is altered or changed?

Yes, they are interconnected. If changes occur it can have adverse effects on the whole Basin.

Question 24
What is the geographical feature to the east of the Murray–Darling Basin where most of its rivers start?

The Great Dividing Range.

Question 25
Why is the Murray–Darling Basin such a good spot for agriculture?

Good climate and soil resources.

Question 26
Find the major irrigation areas on your map (use the legend for help). Would you define the major irrigation areas as being up in the steeper hills and mountains or on the flatter plains? Why?

Flatter plains – water slows down on the flatter plains and drops more sediment so you get richer, more fertile soils. The temperature is also a lot colder in the higher mountain areas, which limits growing conditions. Flatter plains are also easier to cultivate for intensive agricultural practices.

Question 27
Identify where the following major water storages are on your map: Burrendong, Burrinjuck, Copeton, Hume, Keepit and Wyangala dams. Are any of these upstream or downstream on your local river/creek. Do you think these storages change the flows your local river or creek would normally receive?

Students will have location-specific answers on map. Listed water storages are all in NSW. Yes, they definitely change natural flows that creeks, rivers and wetlands receive.

Question 28
Identify the following significant wetlands by carefully circling them on your map: Currawinya Lakes, Fivebough/Tuckerbil swamps, Macquarie Marshes, Millewa forest (NSW Central Murray Forest) and Narran Lake Nature Reserve.

Students will have location-specific answers on map.

Question 29
Using your map, the internet and your local knowledge, identify wetlands you know of in your local region. Have you visited any of them? How would you describe them?

Student and locality-specific answer.

Part B: Aquatic ecosystems

Resources

Module 1 Part B: Aquatic ecosystems fact sheets 1.5–1.13

Student Activity 1.B worksheet

Murray–Darling Basin map, printed at A3 size.

This section introduces students to aquatic ecosystems. A series of fact sheets cover general information about ecosystems. Information covered includes:

- the Earth's environmental spheres
- components of ecosystems
- biomes/ecoregions
- aquatic ecosystems
- freshwater ecosystems
- floods and flows
- wetlands
- the cultural importance of the Murray–Darling Basin.

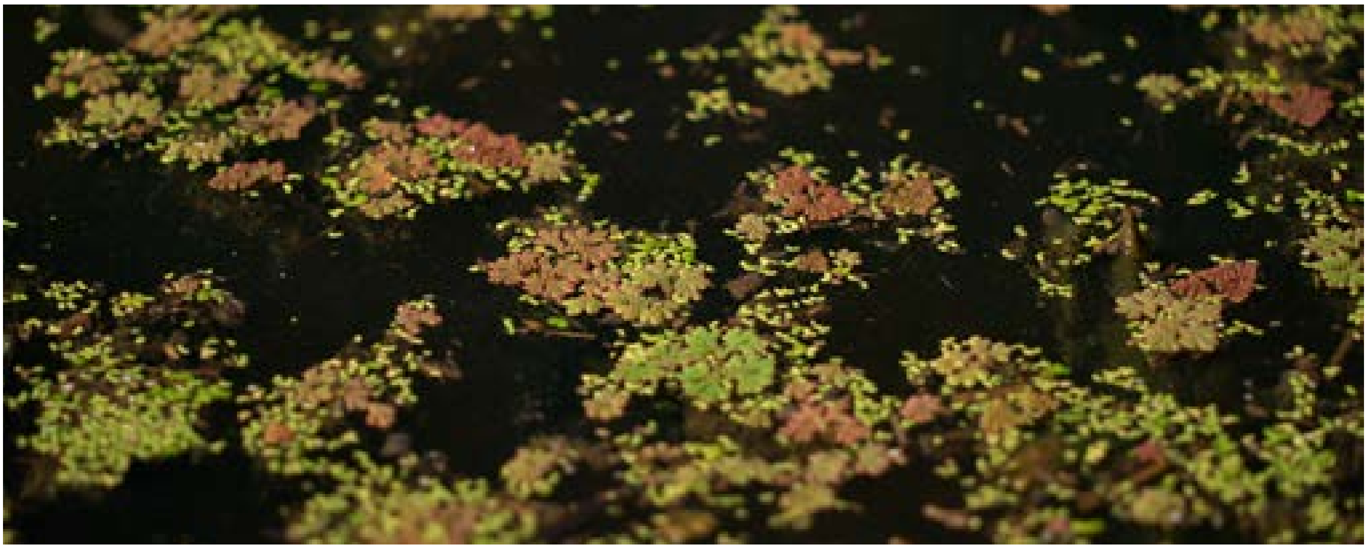
The aim is to start students thinking about water for the environment.

Students will then apply their acquired knowledge about aquatic ecosystems to the Murray–Darling Basin by completing the series of activities in the Student activity 1.B worksheet). Provide students with a printed copy of the Student activity 1.B worksheet so they can answer the questions as relevant topics are discussed and tell them to have their A3 copy of the Murray–Darling Basin map at hand.

Fact sheets 1.5 to 1.13 are designed to work through with your class on an interactive whiteboard or projector equipment. Computer access is required for students to research different components of the fact sheets and the Student Activity Part 1.B section.

Go through the content of each fact sheet on your interactive whiteboard/projector and highlight these main points from each fact sheet.

'Extension' represents extra activities you can do with students to support their learning.



Azola floating at Tori Swamp near Redbank Weir, Balranald. Vince Bucello/Midstate Video Productions.

Fact sheet 1.5

The natural environment

The Earth's natural environment is a complex and amazing place. To study how it all works we can break it down into four spheres that interact to make up the natural environment of our planet:

Atmosphere – layers of gas that surround the Earth.

Hydrosphere – all of the Earth's water bodies including oceans, lakes, streams, rivers, groundwater, ice caps and ground ice/permafrost.

Biosphere – all the living things on our planet, including plants, animals, fungi and microbes.

Lithosphere (Geosphere) – consists of rocks and soil that make up the solid part of the Earth's crust.

The atmosphere, lithosphere and hydrosphere interact as materials move between them. This interaction and transfer of matter and energy make the perfect mix of conditions for the fourth sphere to develop: LIFE!

The four spheres that make up planet Earth's natural environment. Yarradda Lagoon, mid-Murrumbidgee River.
Vince Bucello/Midstate Video Productions

Watch these videos

Four Spheres Part 1 (Geo and Bio): Crash Course Kids, episode 6.1

Four Spheres Part 2 (Hydro and Atmo): Crash Course Kids, episode 6.2

Teacher notes for Fact sheet 1.5

- The Earth's four environmental spheres:
- atmosphere
- hydrosphere
- biosphere
- lithosphere.

Students should answer question 1 on the Student activity 1.B worksheet and apply each sphere to a real-life setting. Students should also acknowledge that the four spheres interact to make up the natural environment.

Fact sheet 1.6

Dragonfly emerging, Macquarie Marshes. Dr Joanne Ocock/DPIE.

Ibis at Tori Swamp near Redbank Weir. Vince Bucello/Midstate Video Productions.

Watch this video

Understanding Ecosystems for Kids: Producers, Consumers, Decomposers

What is an ecosystem?

An ecosystem is a unique community of interacting living organisms (biosphere) that has developed due to conditions created by the surrounding non-living environment (lithosphere, hydrosphere and atmosphere).

The living components (biosphere) of an ecosystem closely depend on one another as they create and provide energy for one another (feed each other), shelter each other (provide habitat) and recycle nutrients (decompose waste).

The non-living components of an ecosystem that determine the ability of life to survive include:

Climate is probably the most important influencing non-living element of an ecosystem as it includes temperature, water availability (precipitation), light availability, humidity and wind. Climate controls what type of soil forms, how much water there is and what type of plants, animals and other organisms can develop in an ecosystem.

Landforms control exposure or how sheltered an ecosystem is from the elements, light (for example, different plants need different amounts of light for photosynthesis), altitude (temperature changes drastically depending on altitude) and most importantly drainage (the availability of water to support an ecosystem).

Soil provides an essential medium for plants and other organisms to live in. It contains minerals and nutrients that help plants grow and produce energy for all other species. Soil absorbs and stores water for ecosystems and contains decomposers, such as bacteria, fungi and earthworms, that recycle waste to create more minerals and nutrients.

Water availability has an incredibly important influence on what can survive in a region. It is closely linked to climate (precipitation and evaporation), landforms (drainage) and soils (absorption).

Chemistry or the chemical make-up of air, water and soil resources, determines whether conditions are suitable for species to live in an area. Chemical factors include pH, phosphates, nitrates and salinity.

Teacher notes for Fact sheet 1.6

Ecosystems are made of unique communities of interacting living organisms that have developed due to conditions created by the surrounding non-living environment. Students should be able to identify non-living components that affect an ecosystem.

Fact sheet 1.7

The big and the small – biomes and puddles

Ecosystems can be described in a range of ways depending on the scale used.

The small

The word 'ecosystem' is usually used to describe small, specific areas. It distinguishes specific communities of species living under specific conditions. This could be as small as a puddle of water or a particular patch of ground, to a lake or woodland that varies slightly to the areas surrounding it.

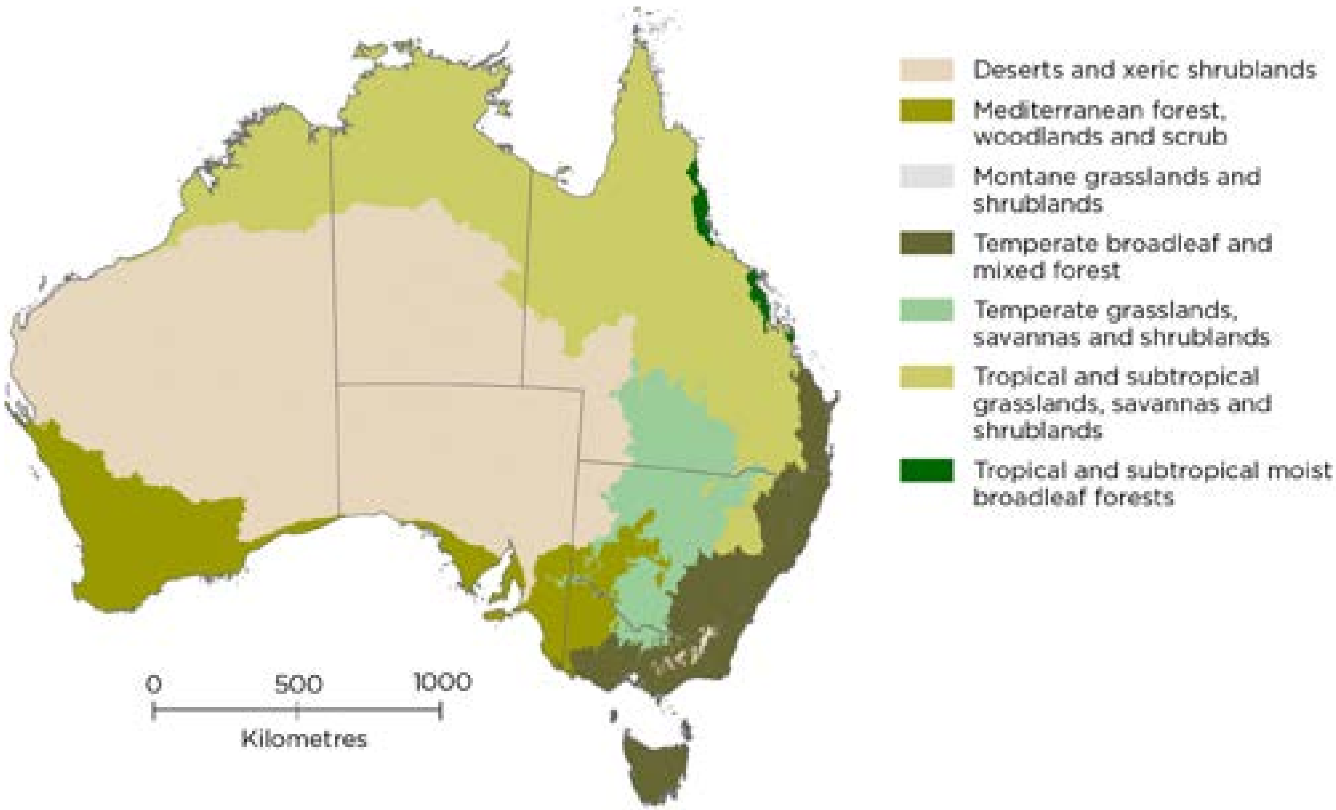
The big

The term 'ecosystem' can also be used to describe large regions of similar characteristics that have led to the development of communities of similar species. These large ecosystems are called 'biomes' or 'ecoregions'. They are a form of classifying whole regions according to climate, dominant vegetation and other characteristics.

Biomes are usually described as aquatic or water-based – marine or freshwater, and terrestrial or land-based. Freshwater biomes are closely linked to surrounding terrestrial biomes as they support life in the region and rely on water run-off from the surrounding land. The terms 'biomes' and 'ecoregions' are somewhat interchangeable because they both classify environments on a very large scale. However current best-practice is to use ecoregions because they take into consideration more determining characteristics.

Terrestrial ecoregions

The Australian Government recognises 14 terrestrial ecoregions across the globe, based on the World Wildlife Fund for Nature classification system. Eight of these are found in Australia – note the Australian tundra is located on subantarctic islands.



Terrestrial ecoregions in Australia. Source: Australian Government Department of Agriculture, Water and environment.

Teacher notes for Fact sheet 1.7

This fact sheet overviews terrestrial ecosystems in Australia.

Explain that an ecosystem is a combination of living and non-living parts that interact and function together as a system. These parts are linked through the flow of energy and/or nutrients. They can be very small like a puddle or medium-sized like a lake or forest.

Biomes and ecoregions are much larger areas, which means these are general terms and represent large-scale classification. For example, a terrestrial biome may encompass large numbers of living and nonliving components classified into large numbers of classes.

Extension

Go through the terrestrial biomes listed here to help students better understand the language we use to describe Australia's ecoregions. The Australia's ecoregions webpage on the Australian Government's website includes the map, which identifies terrestrial ecoregions, and a description for each ecoregion.

Rainforests – extremely dense ecosystems made up of many different types of plants, animals and microbes living in a very small area.

Tundra – the Australian tundra is located on subantarctic islands such as Macquarie Island, a bit like a frozen desert this ecoregion usually has relatively simple ecosystems because of the limited amount of life that can be supported in these harsh environments.

Deserts and xeric (moisture deficient) shrublands – quite the opposite of tundra in many ways, but still harsh. Extreme temperatures are characteristic of this type of ecoregion, but it supports a diversity of habitats although many of these are ephemeral. More animals live in the extreme heat than live in the extreme cold of Antarctica, for instance.

Temperate grasslands, savannas and shrublands – these differ from deserts because of the amount of rain that they get each year. Whereas deserts get only a tiny amount of precipitation every year, savannas tend to be a bit wetter which is better for supporting more life.

Forests – there are many different types of forests all over the world including deciduous forests, tropical rainforests and coniferous forests. These can support a lot of life and can have very complex ecosystems. Australian forests include subtropical forests, tropical rainforests, temperate forests, temperate rainforests and central highland forests.

Grasslands – support a wide variety of life and can have very complex and involved ecosystems.

Students should answer questions 2 and 3 on the Student activity 1.B worksheet.

Fact sheet 1.8

Permanently saturated aquatic ecosystems

Basic rule: Anywhere that relies on always being covered by water – lakes, rivers, dams, seas and oceans, etc.

Ecosystems dependent on flows, periodic or sustained inundation/ waterlogging

Basic rule: Anywhere that relies on water but is not covered all of the time – wetlands, rivers, other groundwater-dependent ecosystems, saltmarshes, estuaries, and tidal or shallow marine water.

Aquatic ecosystems can have both permanently saturated and flow-dependent components. For example, a river with a floodplain, or a wetland that has a permanent deep channel.

What is an aquatic ecosystem?

An aquatic ecosystem is a community of living things that rely on each other and on water for their survival. This includes environments that are permanently saturated or dependent on flows, periodic or sustained inundation or waterlogging for their ecological integrity (Aquatic Ecosystems Task Group 2012).

Aquatic ecosystem categories

Scientists usually divide aquatic ecosystems into three main types.

Marine – a saltwater ecosystem relating to the seas and oceans. Coral reefs are often considered to be a separate category, and other smaller categories, like terrestrial saline ecosystems also exist.

Estuarine – a semi-enclosed coastal ecosystem that has connection with the open sea, and within which sea water is measurably diluted with freshwater derived from land drainage (Pritchard 1967).

Freshwater – ecosystems that rely on freshwater for their survival.

Teacher notes for Fact sheet 1.8

Water is an important non-living component that aquatic ecosystems need for living components to survive.

Aquatic ecosystems can be permanently covered with water (permanently saturated), reliant on water some of the time (inundations), or a combination of both. Students should be able to identify three main types of aquatic ecosystem:

- marine
- estuarine
- freshwater.

Students should answer questions 4 and 5 on the Student activity 1.B worksheet.

A saltwater ecosystem: Nelson Beach, Mimosa Rocks National Park. John Yurasek.

A semi-enclosed coastal ecosystem: a coastal estuarine mangrove. John Turnbill.

A freshwater ecosystem: the Darling River. Terry Cooke.

Fact sheet 1.9

Even though wetlands, marshes and swamps are lentic, they are often classified as a separate type of freshwater ecosystem. Fluctuating water levels and frequency of inundations in wetlands create completely different environmental conditions to other lentic ecosystems such as lakes and ponds.

Turbidity refers to the suspended solid particles in a fluid. It is a measure of the amount of cloudiness. Faster-moving systems are usually more 'turbid' due to their high energy picking up sediment and other matter.

Freshwater ecosystems

The change in flow of freshwater ecosystems means they can be divided into two categories – still water or lentic and flowing water or lotic.

Lentic ecosystems

Lentic ecosystems, also known as lacustrine, are communities of organisms that live in standing or still water. Lentic ecosystems occur in ditches, seeps, ponds, pools, lakes, dams and wetlands. Varying depths in these systems influence the temperature and amount of available light, which causes different layers of ecosystems to develop. The period of inundation also plays a major role in the types of ecosystems that develop (Sciencing 2020).

Lotic ecosystems

Lotic ecosystems are communities of organisms that live in running or moving water. Lotic ecosystems occur in creeks, streams, rivers, springs and channels. These systems are high in energy and water currents, mainly caused by the slope of the land. The current mixes the water with the air giving it high oxygen content, and transports materials which increase turbidity.

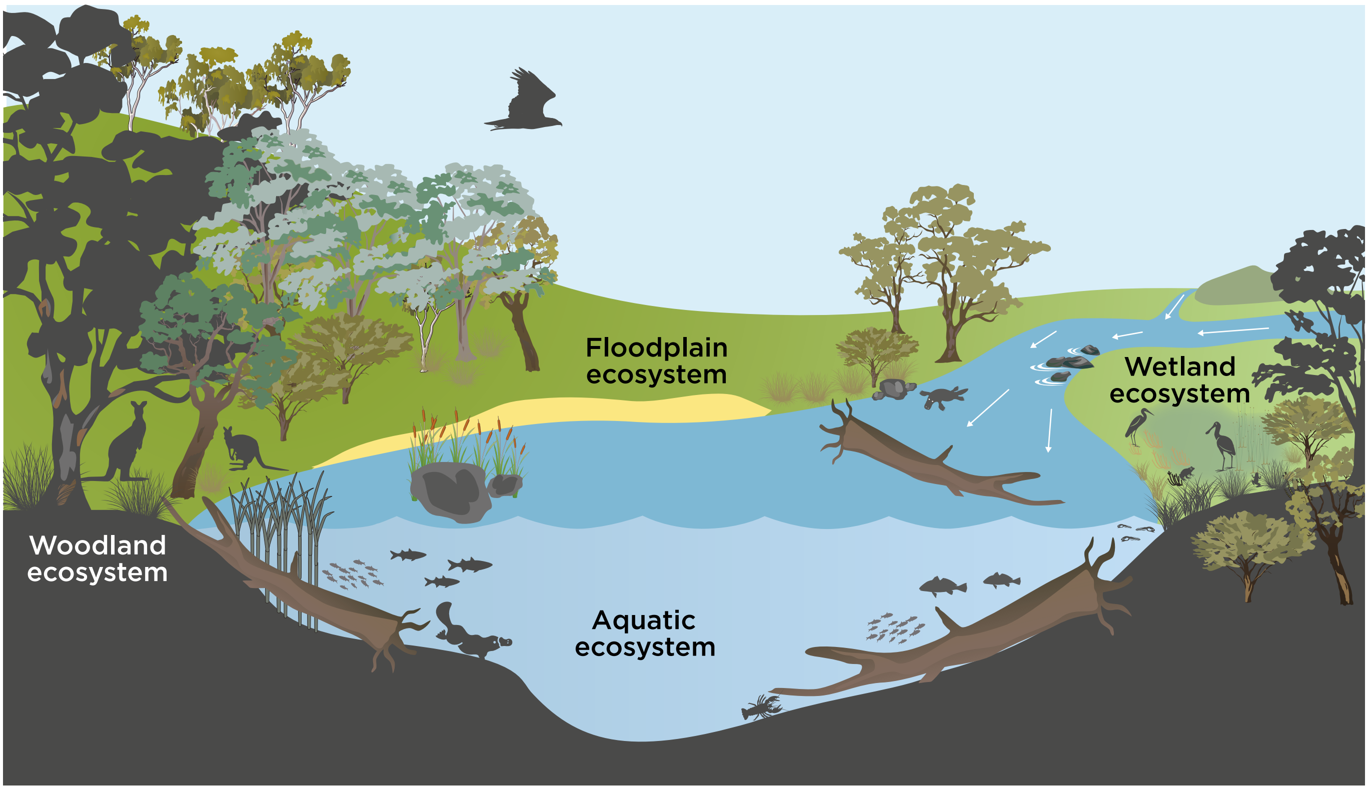
The two main zones in lotic ecosystems are rapids with their fast running water that keeps the bottom clear, and pools with slow moving water that is usually deeper and allows silt to build up (Sciencing 2020).

An interconnected system

A **river catchment/drainage basin** is an interconnected system of rivers that includes thousands or millions of freshwater aquatic ecosystems.

Most aquatic ecosystems interact and are linked with surrounding non-aquatic landforms and processes (Aquatic Ecosystems Task Group 2012). This is especially true for freshwater ecosystems because they are usually part of larger interconnected river systems that rely on surface run-off from their surrounding catchment/drainage basin.

The entire area of land that makes up a catchment influences the amount and frequency of water that flows into the creeks, rivers, lakes and wetlands. The surrounding landforms and processes also have a major influence on the types of substances that wash into freshwater ecosystems.



Interconnected ecosystems on the riverbank (riparian zone).

Resources

Module 1 Part B: Aquatic ecosystems fact sheets 1.5–1.13

Student Activity 1.B worksheet

Murray–Darling Basin map, printed at A3 size.

Teacher notes for Fact sheet 1.9

Lentic ecosystems have still water with very low energy where depth influences temperature and light availability, such as ditches, seeps, ponds, pools, lakes, dams and wetlands.

Lotic ecosystems have running/moving water with high energy, high oxygen and high turbidity, such as creeks, streams, rivers, springs and channels.

Extension: Guide students to design and create simple experiments to observe the characteristics of lentic and lotic systems.

Lentic – use some slightly cloudy (turbid) water and different sized containers to demonstrate how light availability changes with depth. Shine a torch through the different sized containers onto a white sheet of paper and observe how much light gets through.

Lotic – pour clear water down a slope that has loose soil. Observe colour changes as water picks up sediment and becomes more turbid. Collect the water and let it settle in a container. Observe what happens as the lotic system with moving water changes into a lentic system of still water where the sediment falls out because there is no energy to carry it.

Students should answer question 6 on the Student activity 1.B worksheet.

Fact sheet 1.10

Watch this video

Abiotic and biotic factors

Components of aquatic ecosystems

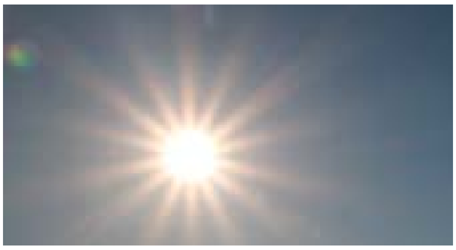
Freshwater ecosystems have a combination of abiotic and biotic components.

Abiotic

The non-living components of an ecosystem are the hydrosphere, atmosphere and lithosphere.

As part of the ecosystem, abiotic components affect the living things in it, but they are not living themselves (Biology Dictionary 2020).

Abiotic components include temperature, water, soil, elevation, sunlight, chemistry (air, soil and water) and climate., Chemical and physical factors such as oxygen levels and flow rate, for example, determine the conditions of an ecosystem and therefore control the types of biotic factors present. Time is a formative factor in many abiotic processes because they can occur very quickly and/or over a long period of time.



Sunlight. Kelly Coleman/ PeeKdesigns.

Soil. Terry Cooke.

Water. DPIE.

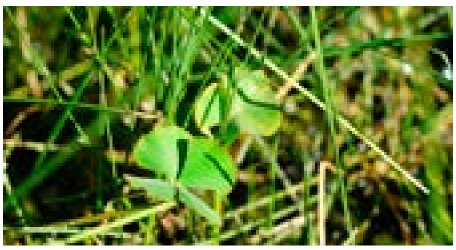
Biotic

The living component of an ecosystem is the biosphere.

Each living part of an ecosystem is classed as a biotic component. Examples include plants, animals, bacteria and fungi.

Biotic components make up every level of the food chain in an ecosystem:

- Producers – create their own energy, usually through photosynthesis, these include plants, algae and cyanobacteria.
- Primary consumers – are herbivores that eat the producers.
- Secondary and tertiary consumers – are carnivores that eat other consumers.
- Decomposers – are the living organisms that breakdown dead organic (living) material and waste, recycling the nutrients back into the soil.



Nardoo, producer. Vince Bucello/ Midstate Video Productions.

Spoonbills, secondary consumers. John Spencer/DPIE.

Yabbies, decomposers. Terry Cooke.

Teacher notes for Fact sheet 1.10

Dragon fly. John Spencer/DPIE.

A combination of abiotic and biotic components make up aquatic ecosystems.

Introduce students to the Biology Dictionary as a useful resource for learning biological terms.

Extension: Revise food chains/food webs with students – producers, primary consumers, secondary and tertiary consumers and decomposers. Brainstorm the types of species that are likely to live in freshwater ecosystems and have students divide the list into producers, primary consumers, secondary and tertiary consumers and decomposers. Create food chains to show the flow of energy.

Students should answer question 7 on the Student activity 1.B worksheet.

Fact sheet 1.11

Tori Swamp, near Redbank Weir at Balranald, after a flood.
Vince Bucello, Midstate Video Productions.

Floods and flows

Maintaining healthy rivers and wetlands is essential for the freshwater ecosystems they support.

Freshwater ecosystems contain a diversity of plant and animal species and rely on a range of different types of:

- water flows – water heights
- durations of inundation – how long they are covered
- timing of flows – time of year and frequency of inundation.

Water provides pathways for plants and animals to move around, and triggers suitable conditions for reproduction. The type and timing of flows combined with the duration of inundation is what we call the flow regime.

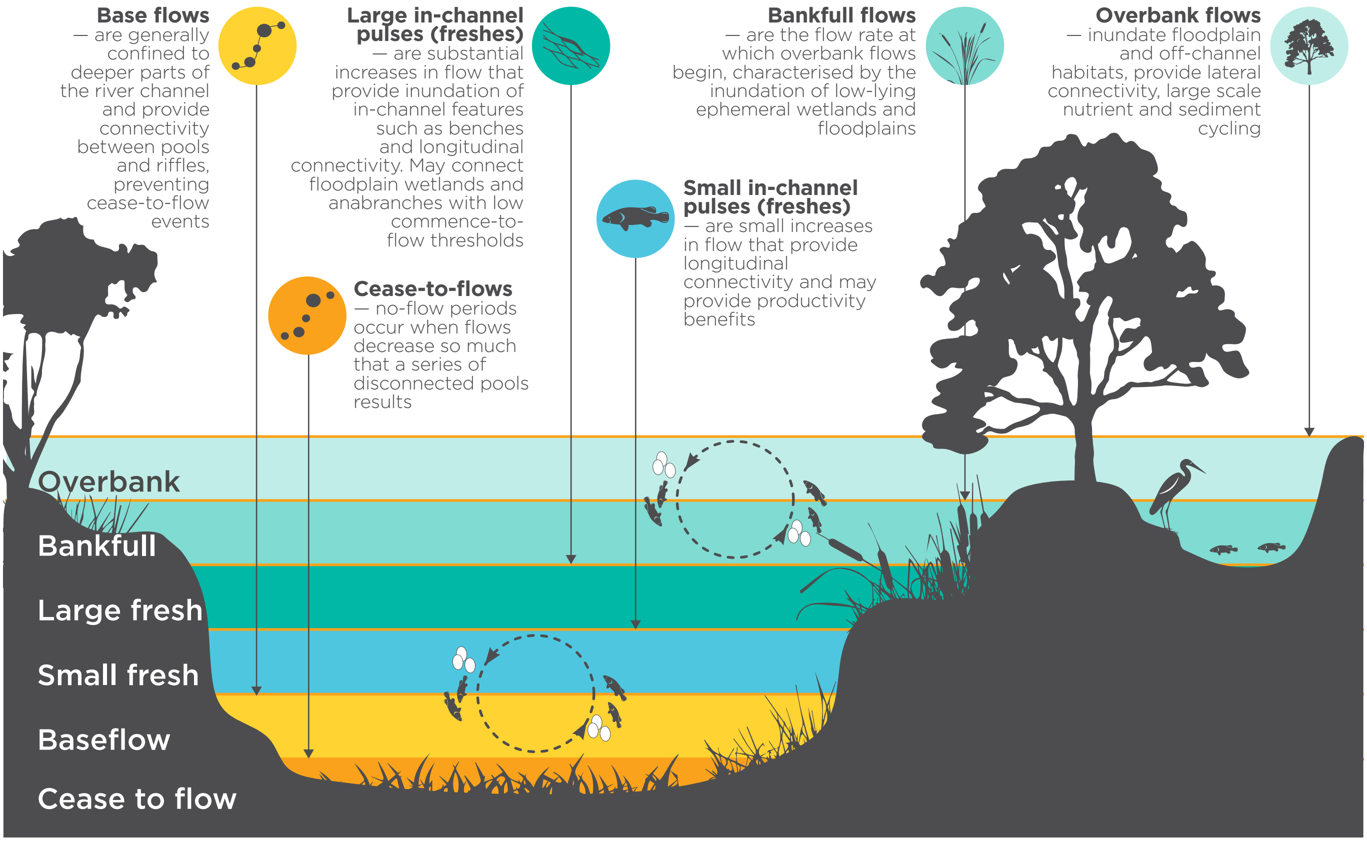
Teacher notes for Fact sheet 1.11

This fact sheet introduces students to the flow regime. Use the Murray–Darling Basin as an example to look at the flow regime and its components with students.

Different flows serve different purposes. Highlight that healthy rivers and wetlands need different:

- types (heights, such as base flows or bankfull flows) of flows
- durations of inundation (length of time a wetland is inundated with water)
- timing of flows (frequency and time of year).

Students should answer question 8 on the Student activity 1.B worksheet.



Components of the flow regime.

Fact sheet 1.12

Wetlands – what an asset!

Wetlands are areas of land covered or saturated with water_ that's usually still or slow moving. Wetlands can be covered with fresh, brackish or salt water. The water can also sit just below the ground surface.

What is a wetland?

An area doesn't need to be permanently wet to qualify as a wetland. Flooding or saturation of a wetland can happen cyclically at regular times or intermittently at more random times. The area needs to be wet long enough for its plants and animals to be adapted to, or even dependent on, wet conditions for at least part of their life cycle.

Many inland wetlands can be dry for 10 years or longer before being flooded after heavy rainfall, after which they may stay wet for several years. This allows wetland plants and animals to regenerate and reproduce (DPIE – EES 2018).

Ecosystem services

Ecosystem services are defined as the benefits people obtain from maintaining healthy ecosystems (Wilborn, 2013).

Tori Swamp. Vince Bucello, Midstate Video Productions.

Macquarie Marshes. John Spencer/DPIE.

Murray wetlands. Vince Vince Bucello, Midstate Video Productions.

Macquarie Marshes. John Spencer/ DPIE.

'Wetlands are vital for human survival. They are among the world's most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival.

Wetlands are indispensable for the countless benefits or 'ecosystem services' that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation.' (Ramsar Convention)

Teacher notes for Fact sheet 1.12

Review this fact sheet with students and use the Murray–Darling Basin to look at examples of wetlands, including Ramsar wetlands.

Wetlands do not need to be permanently saturated with water. They are very productive environments. Wetlands provide ecosystem services like fresh water (filter out pollutants), food, support lots of species (biodiversity), help control floods, recharge groundwater and help climate change by absorbing lots of carbon dioxide and producing lots of oxygen).

Students should answer question 9 on the Student activity 1.B worksheet.

Lower Murray wetland. John Spencer/DPIE.

Fact sheet 1.13

Importance of the Murray–Darling Basin to Australia's First People

The Murray–Darling Basin has been home to Australia's First People for tens of thousands of years and they are recognised as the traditional custodians of the land. The region's land, rivers, mountains and plains are steeped in Aboriginal history, culture and spirituality. It has many important cultural locations that continue to support and sustain local communities.

First Peoples of the Murray–Darling Basin have a strong relationship with their traditional lands or Country. They believe that they are part of their Country just as their Country is part of them. This spirituality is based around the Dreaming, which is the continuous or timeless relationship between the people, the ancestors, the spiritual beings and the plants, animals, water and landscapes that make up Country (Coleman et al 2018).

Scarred tree, Yorta Yorta Country. Kelly Coleman/PeeKdesigns.

Caring for the Basin

The waters of the Murray–Darling Basin and its ecosystems have provided resources for over 45 nations/language groups since they first inhabited the region. In turn, they have a responsibility to take care of the Basin to ensure its prosperity and protect traditional lands. Healthy rivers and wetlands play an integral part in Aboriginal culture for spiritual, economic and environmental purposes.

Nari Nari man Rene Woods describes the rivers, creeks and wetlands of the Basin as 'our lifeblood… it's just like our veins. When there's water, there's a whole lot of community spirit lifted, just seeing the country come back and seeing it as good as it can be… So, we can go and continue our cultural practices around those water ways, which is crucial to us moving forward and strengthening our connection with Country' (Timms and Vidot 2017).

Ancient hearth or ground ovens, Narran Lakes Nature Reserve. Michael Mullholland/NPWS.

Teacher notes for Fact sheet 1.13

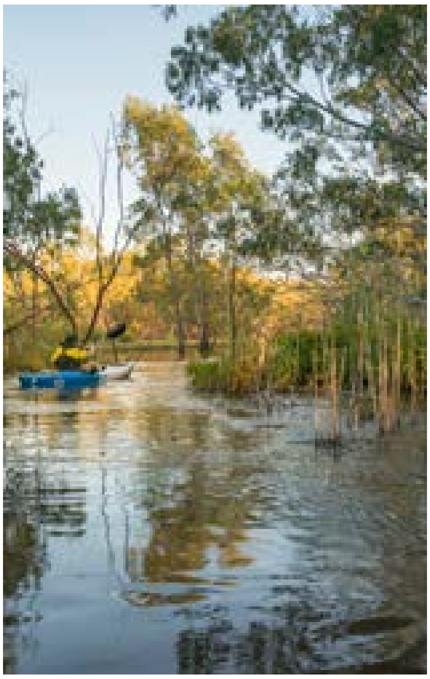
It is important that students understand Australia's First Nations People are not all the same, but rather a collection of different nations/language groups (there are over 45 nations in the Murray–Darling). The link to Country is not just where they come from but central to their entire being and way of life. Healthy rivers and wetlands are very important to the health of Aboriginal culture.

Extension: On your interactive whiteboard/projector (or individual computers) go to the Australian Institute of Aboriginal and Torres Strait Islander Studies map of Indigenous Australia.

Have students use their Murray–Darling Basin map to help them identify the language groups associated with the Murray–Darling Basin.

Reinforce concept that Aboriginal Australia is not made up of one Australian-wide group but is a collection of different nations/language groups. Note that due to the oral nature of Australian First Nations People's culture there are many variations of maps showing nations and language groups, etc. Use this as an opportunity for students to examine the importance of research, critical analysis and the use of references and citations.

Fact sheet 1.14



Macquarie Marshes wetlands – wetlands flourish with adequate flow regimes. John Spencer/DPIE.

Water for the environment

Freshwater aquatic ecosystems all have one thing in common – they rely on water for survival. This can be permanent saturation or different periods of inundation.

Healthy waterways

Rivers, creeks and wetlands play a vital role in sustaining healthy communities and economies. They provide connections across the landscape for people, plants and animals with benefits that extend well beyond the riverbank. Healthy rivers and wetlands support native wildlife alongside a range of industries, including irrigation, dryland agriculture, fishing, tourism, timber production and beekeeping (Office of Environment and Heritage, 2016).

Water storage disrupts natural flows

To try and ensure water supply meets the demands of the population, water regulation in the Murray–Darling Basin is necessary. Many large water storages or dams have been constructed to support the Basin's communities and industries.

Although these water storages are essential to supporting human endeavours, this regulation has changed the natural water flow patterns through the Basin's creeks, rivers and wetlands. This in turn has affected the ecosystems that rely on flowing water or periodic flooding.

Protecting and preserving natural flows

Water that is allocated and managed specifically to improve the health of rivers, wetlands and floodplains is known as **water for the environment**. It is the best tool we have to try and ensure a range of flows to protect and preserve our natural environment.

Water for the environment with certain types of flows, timing and duration (the flow regime) helps to:

- improve connectivity of rivers, creeks and wetlands
- maintain condition and diversity of lowland floodplain forests and woodlands
- increase water availability for plant species in wetlands and rivers
- maintain current species diversity and help breeding success of permanent and migratory waterbirds
- improve distribution and breeding success of native fish and other aquatic species
- provide pathways for species throughout the Murray–Darling Basin
- increase river and wetland health supporting cultural purposes.

Watch these videos

The video located on the What is water for the environment? webpage provides a great introduction to water for the environment.

Teacher notes for Fact sheet 1.14

Rivers and wetlands are important ecological assets. They are important for humans as well. Water storages and diversions are necessary to help support the population, but the key is finding a balance between human use and the environment. Water for the environment is a tool to help us maintain healthy rivers and wetlands.

Extension: River red gums are a species that line the rivers and wetlands throughout the Murray–Darling Basin. They rely on inundations every 2–4 years for their survival. Many forests are now dying because they do not get the frequency of flooding that they need.

Have students research the history of river red gums in the Murray–Darling Basin and develop a short report to outline what the problems are, why they are occurring and whether there is any way to help fix them. Do they think water releases for the environment are a positive step to help our river red gums?

Student activity 1B Murray–Darling aquatic systems

Students should apply their knowledge of aquatic ecosystems to the Murray–Darling Basin and complete this worksheet. Students will need computer access and a copy of the Murray–Darling Basin map (preferably A3).

Question 1
These three photos show different parts of the Murray–Darling Basin. Identify the different environmental spheres you can see in each photo.

1. Narran Lakes. Kelly Coleman/PeeKdesigns.

Answers have been added to photos in white text to indicate the different environmental spheres.

2. Narran River. Kelly Coleman/PeeKdesigns.

3. Cormorants, Macquarie Marshes. John Spencer/DPIE.

Question 2
In your own words, define the term 'ecosystem'. What are some of the non-living components that would affect the types of ecosystems that form in the Murray–Darling Basin?

An ecosystem is a unique community of interacting living organisms (biosphere) that has developed due to conditions created by the surrounding non-living environment (lithosphere, hydrosphere and atmosphere). Non-living components include climate, landforms, soils, water availability and chemistry.

Question 3
Visit the Australia's ecoregions webpage on the Australian Government's website and locate the map identifying terrestrial ecoregions in Australia.

Click on the map to make it larger and compare it to your Murray–Darling Basin map.

Identify the terrestrial ecoregions you think occur in the Murray–Darling Basin and write a couple of notes on each from the description provided on the webpage, including where in the Murray–Darling Basin you find them.

a. Temperate broadleaf and mixed forests – wide ranging temperature and precipitation, stretch from Queensland to South Australia (SA) on the eastern side of Murray–Darling Basin, *Eucalyptus* and *Acacia* species typify composition.

b. Mediterranean forests, woodlands and shrubs – southwest of Murray–Darling Basin, hot and dry summers, cool and moist winters, rare with uniquely adapted animal and plant species, plants have adapted and rely on fire.

c. Temperate grasslands, savannas and shrublands – cool and broad annual temperature range, generally devoid of trees except for forests along streams and rivers, positioned between temperate forests and arid interior in Murray–Darling Basin.

d. Montane grasslands and shrublands – high elevation above 1300 metres, grasslands and shrublands, only very small patches in southeast mountains of Murray–Darling Basin.

e. Tropical and subtropical grassland, savannas and shrublands – small patches in northeast of Murray–Darling Basin, not enough rainfall for extensive tree cover, mainly grasslands in Murray–Darling Basin region.

f. Deserts and xeric shrublands – location of this ecoregion on these maps is open to interpretation, there is possibly a small part on the edge of the Murray–Darling Basin in far western New South Wales (NSW) and in SA, characterised by evaporation exceeding rainfall, extreme temperatures of searing hot days and cold nights, seasonal water availability, prone to drought.

Question 4
Do you think the terrestrial and freshwater biomes are closely linked in the Murray–Darling Basin? Why or why not?

Yes. The Murray–Darling Basin involves an enormous network of interconnected rivers. Terrestrial and freshwater biomes are closely linked because rain falls all over the catchment and the runoff water drains across the land and into the rivers that make up the freshwater biome. The freshwater biome in turn supports life on the land throughout the catchment.

Question 5
Use your Murray–Darling Basin map to identify the types of aquatic ecosystems (marine, estuarine or freshwater) you think make up the rivers of the Murray–Darling Basin. Is the Basin predominantly one of these types of ecosystems?

Predominantly freshwater and estuarine at the end – in the lower lakes and Coorong.

Question 6

a. Define lentic and lotic freshwater ecosystems and list some of the characteristics that influence them. Provide examples of lentic and lotic ecosystems.

Lentic

Still water with very low energy where depth influences temperature and light availability. Ditches, seeps, ponds, pools, lakes, dams and wetlands.

Lotic

Running/moving water with high energy, oxygen and turbidity. Creeks, streams, rivers, springs and channels.

b. These photos show ecosystems in the Murray–Darling Basin. Indicate which would be considered lentic and which would be lotic.

1. Darling River, Terry Cooke. **2. Narran Lakes,** Kelly Coleman PeeKDesigns. **3. Tori Swamp,** Vince Bucello Midstate Video Productions. **4. Narran River,** Kelly Coleman PeeKDesigns. **5. Gwydir Wetlands,** Kelly Coleman PeeKDesigns. **6. Macintyre Falls,** Kelly Coleman PeeKDesigns.

Question 7
Read the wetland food web story.

See notes for Fact Sheet 1.10. Students will need a basic understanding of food chains, food webs and trophic levels before doing this activity.

A wetland food web

It is a lovely, sunny spring day and the plants and animals in the wetland are flourishing after some much-needed water was released from the dams upstream.

The spike-rush is growing along the water's edge and the algae in the water is starting to grow, thanks to the warm sunshine. Other water plants are also taking off, such as water ribbons.

Insects are buzzing around the plants and water surface, actively trying to feed, mate and lay eggs. It doesn't take long before they hatch and water boatman, dragonfly nymphs, mayfly nymphs and diving beetles start swimming in the shallow waters. Most of them are busy feeding on algae and various water plants, while the dragonfly nymphs are preying on other smaller invertebrates, such as water boatman and small tadpoles. Freshwater snails are busy munching on the water ribbons. The water is alive with insect activity.

Frogs are croaking loudly. They too are searching for a mate and laying eggs. As they feast on the flying and larval insects, they have to be careful... there are many larger animals that prey on them and their tadpoles too. A stalking egret makes all the frogs stay quiet, hoping to avoid being seen with their supreme camouflage. As one frog moves away from the overhead danger, it doesn't see a red-bellied black snake waiting in the rushes. One quick strike and the frog's gone.

Under the water's surface, fish are eating algae and macro-invertebrates at every opportunity. All macro-invertebrates, such as water boatman, diving beetles, mayfly and dragonfly nymphs, are not safe from the large number of hungry fish. This abundance of fish means that there will be plenty of water birds in the wetland.

It's not long before some black swans arrive, hoping to pick up some tasty freshwater snails and water ribbons, while a few pelicans fly in hoping to feed on the fish in the wetland. Herons are also making a tasty meal from the fish and frogs. Some swamp hens have taken up residency, feeding on water ribbons, diving beetles, freshwater snails and making nests in the rushes.

On the edge of the water a large goanna comes down to drink. He knows there are tasty frogs in the area and there will soon be easy to access swamp hen eggs that make a filling meal.

Watching all this from high up in the sky is a white-bellied sea eagle. Although far from the sea, these birds of prey are often found along inland rivers. The eagle has spotted all the activity in the wetland and is eyeing off his own prize – a lizard, snake, frog, fish or even a swamp hen.

The wetland supports many plants and animals. As each plant or animal dies, another organism benefits from the energy. Even in death, yabbies (which are also food for fish) and other detritivores feed on the decaying plant and animal matter, recycling nutrients in the food web.

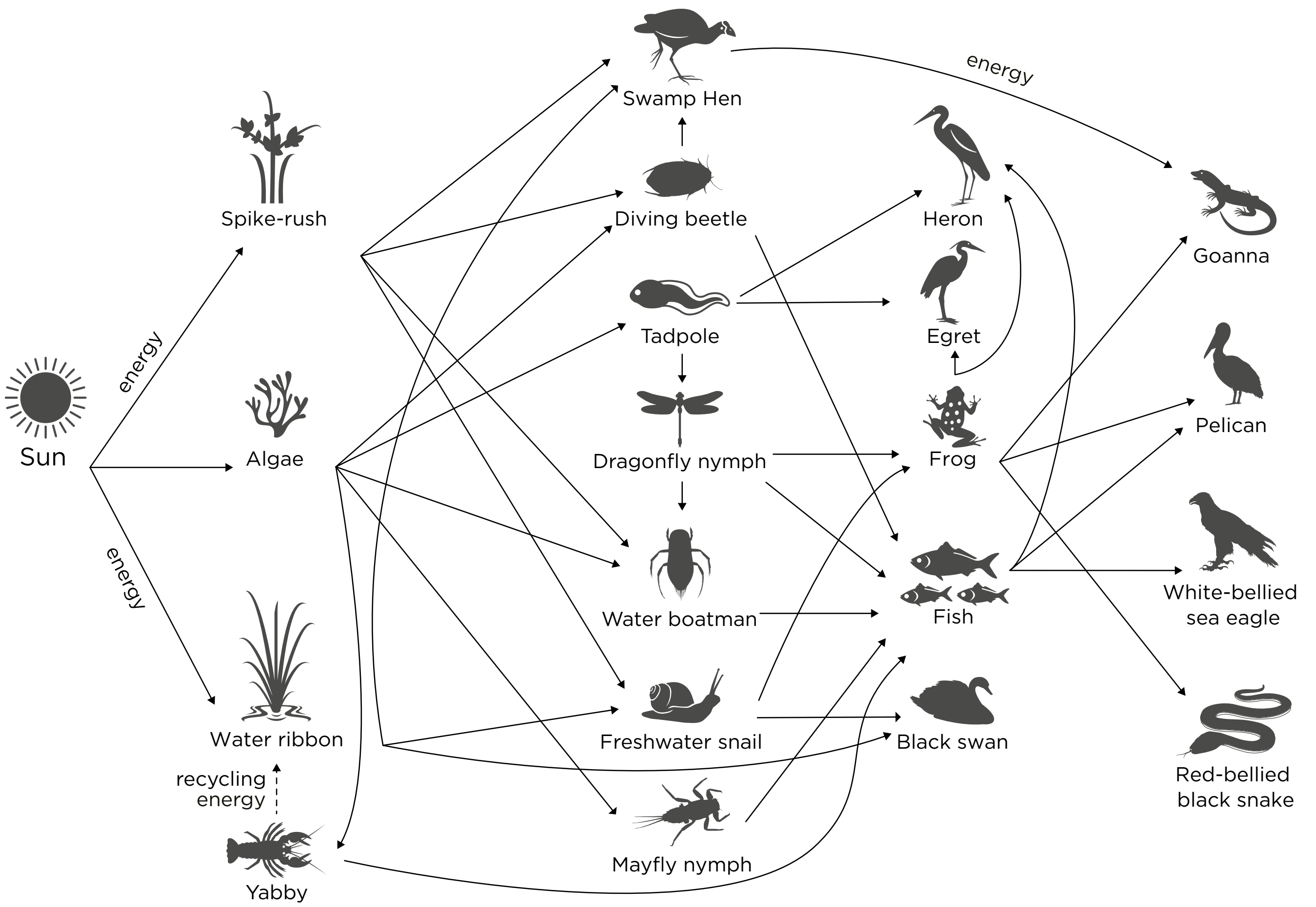
Complete these tasks:

a. Identify at least 3 food chains. Assign each element of the individual food chains to a level in the trophic pyramid (producer, primary consumer, secondary consumer, tertiary consumer, quaternary consumer or decomposer).

This is a list of food chains with each element of each food chain assigned to a level in the trophic pyramid (i.e. producer, primary consumer, secondary consumer, tertiary consumer, quaternary consumer or decomposer).

- algae (producer) > mayfly nymph (primary consumer) > fish (secondary consumer) > pelican (tertiary consumer)
- algae (producer) > tadpoles (primary consumer) > dragonfly nymph (secondary consumer) > frog (tertiary consumer) > goanna (quaternary consumer)
- algae (producer) > water boatman (primary consumer) > dragonfly nymph (secondary consumer) > frog (tertiary consumer) > egret (quaternary consumer)
- algae (producer) > yabby (primary consumer and decomposer) > fish (secondary consumer) > white-bellied sea eagle (tertiary consumer)
- water ribbons (producer) > water boatman (primary consumer) > frog (secondary consumer) > red-bellied black snake (tertiary consumer) > white-bellied sea eagle (quaternary consumer)
- water ribbons (producer) > freshwater snail (primary consumer) > black swan (tertiary consumer)
- spike-rush (producer) > swamp hen (primary consumer) > goanna (tertiary consumer).

b. Combine the 3 food chains to create a single food web diagram.



Example of how food chains can be combined to create a single food web diagram.

c. Identify human activities that would negatively impact this food web.

Human activities that would negatively impact this food web include:

- reduced frequency and duration of water
- opening the wetland up to stock grazing
- clearing vegetation
- turning wetland into pasture or other development
- introducing predators such as mosquito fish (gambusia), European carp, European fox, feral cats, feral goats and feral pigs.

d. Define the outcome/s water for the environment has on wetlands in the Murray–Darling Basin.

Water for the environment allows wetlands to receive water, which helps ephemeral wetlands and their dependent species/ecosystems to survive. Regular water allows habitat to grow and expand so that animal species can breed and feed, especially in times of drought. Some plant species require flood conditions to reproduce, water for the environment can simulate these conditions when there is enough water stored in dams.

Question 8
What are the four different factors that influence the flow regime of the Murray–Darling Basin? Explain what each means.

1. Type of flow – height at which the level of water flows and floods (cease-to-flow, base flows, small in-channel pulses/freshes, large in-channel pulses/freshes, bankfull flows and overbank flows).
2. Timing of flows – when flows occur naturally throughout the year
3. Timing of flows – how often flows occur or the frequency of inundation
4. Period of inundations – how long the rivers, wetlands and other waterways are flowing or covered with water.

Question 9
The Murray–Darling Basin contains over 30,000 wetlands. They all are important to the health of the Basin as a whole, but some are so significant they have become Ramsar sites. Research in your library or the internet (for example, the Australian Wetlands Database) and answer these questions:

a. What is a Ramsar site?

Ramsar sites are wetlands that are protected by the Ramsar Convention or the Ramsar Convention on Wetlands of International Importance. This is an international treaty for the conservation and sustainable use of wetlands. Its broad aims are to halt the worldwide loss of wetlands and to conserve, through wise use and management, those that remain. The Ramsar Convention encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity.

Countries that sign up to the convention can nominate sites to be listed as Wetlands of International Importance. These are referred to as Ramsar sites and must meet at least 1 of 9 internationally accepted criteria (Criteria for Identifying Wetlands of International Importance). In designating a wetland as a Ramsar site, countries agree to establish and oversee a management framework aimed at conserving the wetland and ensuring its wise use.

b. How many Ramsar sites are in the Murray–Darling Basin? See how many you can highlight/identify on your Murray–Darling Basin map.

There are 65 Ramsar sites across Australia, and 17 are located in the Murray–Darling Basin (the number in brackets after each site is the designated Australian Ramsar site number):

- Banrock Station Wetland Complex (63)
- Riverland (29)
- Barmah Forest (14)
- Currawinya Lakes – Currawinya National Park (43)
- Fivebough and Tuckerbil Swamps (62)
- Ginini Flats Wetland Complex (45)
- Gunbower Forest (15)
- Gwydir Wetlands: Gingham and Lower Gwydir (Big Leather) Watercourses (50)

- Hattah–Kulkyne Lakes (16)
- Kerang Wetlands (17)
- Lake Albacutya (22)
- Little Llangothlin Nature Reserve (47)
- NSW Central Murray Forests (64)
- Narran Lake Nature Reserve (53)
- Paroo River Wetlands (65)
- The Coorong, and Lakes Alexandrina and Albert Wetland (25)
- The Macquarie Marshes (28).

c. Pick one Ramsar site in the Murray–Darling Basin (preferably one that is closest to where you live). What are some of the justifications for why it was named as a Ramsar site?

Details about each site's Ramsar listing are available on the Australian Wetlands Database.

Question 10
What is the best tool that we currently have to try and ensure a range of flows to protect and preserve the natural environment of the Murray–Darling Basin? What natural regime does this try to replicate? List how this helps maintain healthy rivers and wetlands within the Basin.

Water for the environment is the best tool that we currently have to try and ensure a range of flows to protect and preserve the natural environment of the Murray–Darling Basin.

Water for the environment tries to replicate the natural flow regime.

Water for the environment aims to:

- improve connectivity of rivers, creeks and wetlands to maintain condition and diversity of lowland floodplain forests and woodlands
- increase water availability for plant species in wetlands and rivers
- maintain current species diversity
- help breeding success of permanent and migratory waterbirds
- improve distribution and breeding success of native fish and other aquatic species
- provide pathways for species to move throughout the Murray–Darling Basin
- increase river and wetland health supporting cultural purpose.

Part C: Murray–Darling Basin waterway field study

Resources

Student activity 1.C worksheet

Murray–Darling Basin map, printed at A3 size

Catchments of the Murray–Darling Basin map

Murray–Darling Basin Land Use map

NSW Waterwatch manuals

NSW Waterwatch kits – including waterbug equipment, pH and EC meters, dissolved oxygen kit, turbidity tubes, stopwatch and long-distance tape measure (or flow meter)

NSW Waterwatch water bug ID charts and posters

This section provides students with an opportunity to study a particular waterway within the Murray–Darling Basin. It uses knowledge students acquired from Module 1 Parts A and B and enables them to apply this knowledge in a practical setting. This activity is adaptable to a range of year levels, locations, available school resources and teacher preferences.

Teachers and students negotiate to determine:

- the study site
- whether activities are completed individually, in pairs, small groups or as a class (with students studying different aspects to contribute to a class report).

Expert knowledge

It is recommended you invite a water expert to join your class on the field study to provide insights and share knowledge about the chosen waterway and surrounding aquatic ecosystems.

Using existing resources

Student activity 1.C outlines suggested observations and experiments for students to conduct during their field study. 'Teacher notes' have been included for teachers to use to guide students through each task for this activity.

It is highly recommended that teachers use existing NSW Waterwatch resources for this field study section. These resources provide comprehensive details about studying water quality and waterway health.

Select relevant parts of these Waterwatch resources and provide to students to help them with the finer details of conducting their experiments and observations:

- Resources > Waterwatch manuals > High Schools Senior Waterwatch Teachers Guide.pdf >
- Resources > Waterwatch manuals > High Schools >Senior-Community Waterwatch Field Manual.pdf
- Resources > Water Bug ID Charts and Posters > Water Bug Detective Guide – Freshwater.

Student activity 1C Murray–Darling Basin waterway field study

Southern bell frog, *Litoria raniformis*. Carmen Amos/DPIE.

Introduction

It is now time to apply your acquired knowledge of aquatic ecosystems to a practical setting within the Murray–Darling Basin.

You will be required to prepare a report on a local Murray–Darling Basin waterway. The location of your site will be negotiated with your teacher. Your teacher will decide whether report preparation will be done as individuals, in groups or as a class. If the report is done as a class, people studying different aspects will contribute to different parts of the class report.

Your report should include:

1. Pre-field study background research – to show that you have an idea about things in the local environment that could influence your waterway.
2. Fieldwork (evidence):
    - site observations
    - biological components (biosphere)
    - physical measurements and water chemistry.
3. Discussion – this should include recommendations on whether the site is healthy, factors that could be influencing waterway health, whether you think your waterway would benefit from more frequent flows and inundations provided by water for the environment.

Reports can be presented in a number of ways. For example, as oral presentations, posters, experiment write-ups, PowerPoint presentations or other multimedia presentations. Negotiate this with your teacher.

Evidence to back up your findings must be provided and include things like photographs, video, maps, sketches, diagrams, etc.

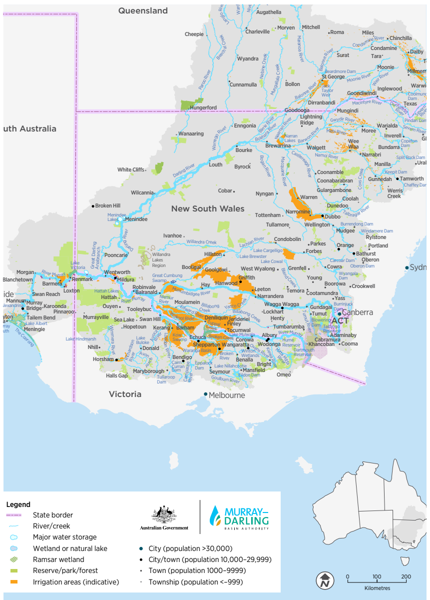
Teacher notes

Provide students with a copy of the Murray–Darling Waterway Field Study (see Rivers: Sharing our water Student workbook for copy of Student activity 1.C: Murray–Darling Basin waterway field study without teacher notes). Read through the information with your class and clarify the requirements of the field study with students.

This can be done individually, in groups or as a class with students studying different aspects to contribute to class report.

Negotiate or instruct your class on how you want them to present their report. You might leave it up to individuals/ groups to decide this.

> **Hint**
>
> The best sites for this report will have indicators of different flow levels and areas that rely on different periods of inundations.



[Murray–Darling Basin map.] Source: Murray-Darling Basin Authority.

[Catchments of the Murray–Darling Basin map.] Source Department of Agriculture and Water Resources.

Background research

When conducting a field study of a waterway it is important to carry out background research to gain a greater understanding of the designated area. Background research also helps to make some predictions (hypotheses) about what you might find at the site.

Start with an A3 copy of the Murray–Darling Basin map from your teacher – you can use the one you were given for previous activities.

Choose your field study location

As a class, discuss suitable Murray–Darling Basin waterway sites with your teacher and then negotiate the one your class will study. The site must have reasonable access so you can conduct field experiments. It can be a local wetland, river, creek or any other waterway. Choose a site that is as natural as possible, with as few human-made environments as possible.

Local area knowledge

Use your local knowledge combined with available maps and internet or library research on your waterway to see what information you can find that will help you gain a better understanding of your site.

Site details

Your research should include gathering details about your site, such as:

- name of the site
- grid coordinates (this can be worked out from a map or by using a GPS when on-site)
- altitude or height above sea level
- the type of aquatic ecosystem it is – freshwater, marine or estuarine
- the type of waterway it is – creek, river, lake, dam, wetland, etc.
- local river or creeks that feed the site
- the local major river catchment – use the Catchments Map
- is it in the northern (drains into Darling River) or southern (drains into Murray River) part of the Murray–Darling Basin?
- approximate size – if you cannot find this then estimate when you are on-site.

Expected species

It is important that you research plant and animal species found at the site, or in the surrounding area, because you may not see them on your field study. For example, aquatic species are likely to be submerged and terrestrial species may have moved on and not be present.

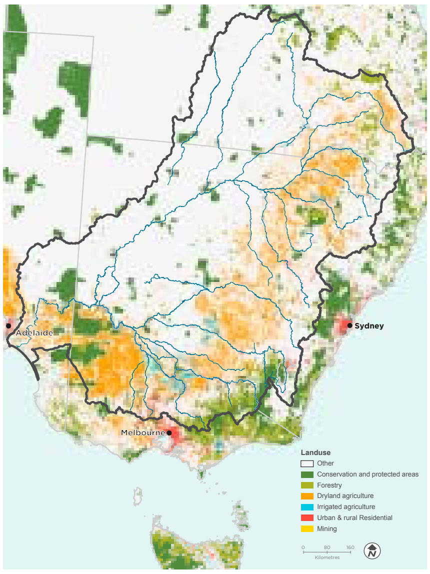
Hint

These websites may be helpful:

- Department of Planning, Industry and Environment – Environment, Energy and Science/Water for the environment
- Murray–Darling Basin Authority.

Hint

Look at the Basin Land Use Map.



Murray–Darling Basin Land Use map. Source: Land use of Australia 2010-11, Australian Government Department of Agriculture and Water Resources.

Hint

The Murray–Darling Basin Authority's Geographical profile maps for basin catchments may help you. Note that data provided is only for major systems.

Do some research on:

- aquatic plant species
- terrestrial plant species (especially those that rely on being close to the water)
- aquatic animals
- terrestrial animals
- threatened species or threatened/endangered ecological communities at your site
- the ecoregion specified by the national reserve system it falls into.

Land use and influences

Read these questions and add the answers and your ideas or predictions to your preliminary research.

Are there towns/cities close to your waterway site that could affect its overall health? Prediction: How do you think they could influence the site?

How is the site currently used? For example, is it used for recreation (fishing, bushwalking, boating, kayaking, etc.); does it supply water (urban, agriculture or other industries)? Prediction: Do you think any of these uses would have an effect on your aquatic ecosystem?

What land uses occur in the local area that could affect your waterway – both upstream and downstream? For example, agriculture (irrigation and dryland), conservation and protected areas, forestry, mining, tourism and other local industries. Prediction: Do you think any of these land uses would have an effect on your aquatic ecosystem?

Are there any water storage structures like dams, weirs, reservoirs or other water diversions upstream that could affect the waterflow of your site? Prediction: How would they affect the water flow through the site?

What has the weather been like in the area around the site? Is it a dry, average or wet year (check your local average rainfall)? Has the temperature been hot, cold or average (check your local average rainfall with the Bureau of Meteorology)?

From your research, can you identify any threats to the health of the site?

Find out the name of the Aboriginal people (nation/language or other group) whose traditional lands include your site.

Teacher notes for background research

Whilst students will need guidance on what is practical, it is important to involve them in choosing a site to study so they take greater ownership of the project.

As well as conducting research, encourage students to use their own local knowledge to choose a site; for example, get them to think of sites they currently use for fishing, swimming, camping, or kayaking. Use existing research and local knowledge to prepare their background material.

You could ask students to predict what they are likely to find at the site. Ask them questions such as:

- Have there been any water levels rises recently?
- Does the site have any known problems like pollution or erosion? Has the site been recently burnt?
- Do they know any species of plants and animals that they have seen there?

Just like they bring life to our plants and animals, rivers support the lives of our First Nations People. You could ask students whether they know any Aboriginal people who use the lands around their site, and why the waterway is important to them? Is there any evidence of historical uses remaining today? An extension of the background research may be to invite a local Aboriginal Elder or community member to speak with your students about the waterway and what it means to their people (and/or invite them on your field study). If an Elder joins you on your field study, ask them about uses of animals and plants in the area and to point out bush tucker.

Fieldwork: Site observations

Careful observation and documentation of your waterway will tell you a lot about your site. Use a combination of notes, drawings and photos/videos to document your site.

Mapping the site

The first thing to do is record the features of your site. This will help you remember things when you write up your report. This could be a quick bird's-eye sketch marking major features of the site, like this example sketch.

If you have a close-up aerial map of the site, you could make additions to the sketch to include your observations.

Example bird's-eye sketch of field site.

Moving or still water

Make some notes about the water at your site. Is the waterway a lentic or lotic freshwater ecosystem, or is it a combination of both? For example, a wetland can have a main channel with moving water flowing through it as well as areas where the water is very still.

Saturation

Determine whether your site is:

- a permanently saturated aquatic ecosystems (relies on always being covered by water)
- an aquatic ecosystem that is dependent on flows, periodic or sustained inundation or relies on water but is not covered all of the time
- a combination of both.

Use different shades or symbols to highlight different areas of saturation on your map.

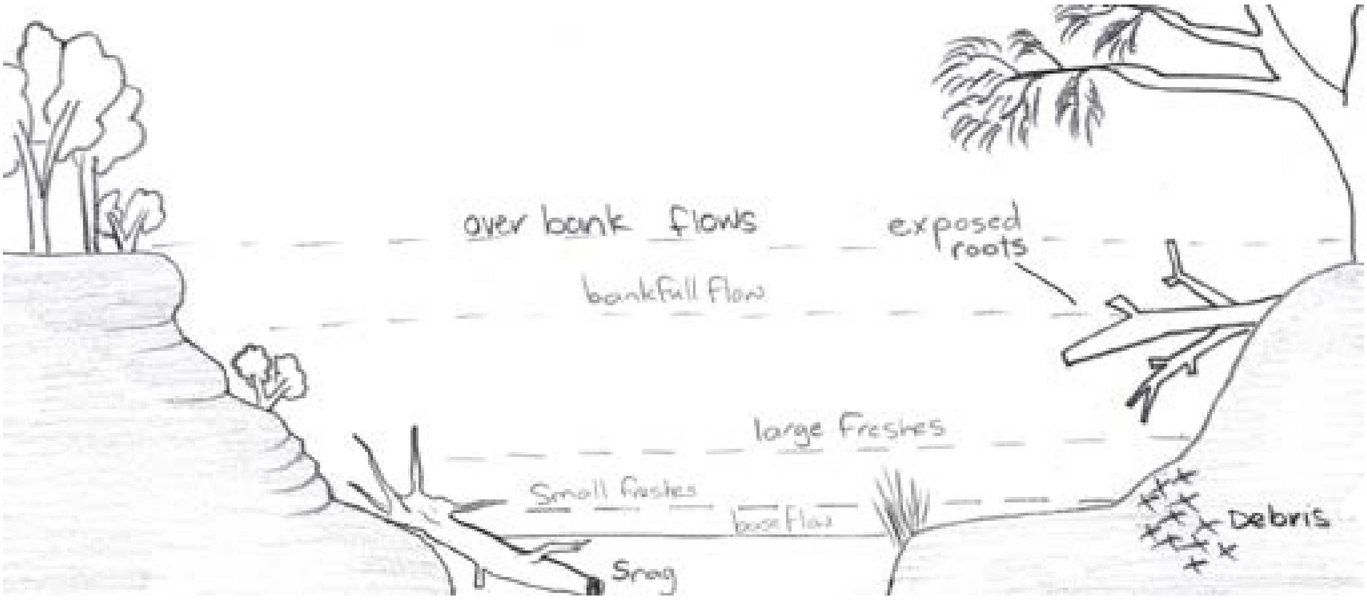
Flows

Look at your waterway and document flood levels (flows). You will find evidence of water marks on surrounding landforms where water has reached, or piles of debris have been deposited on the banks higher than the usual water level. See whether you can estimate where different types of flows might reach (cease-to-flows, base flows, small in-channel pulses/freshes, large in-channel pulses/freshes, high bankfull and overbank). Draw a rough cross-section of the site, like this example sketch, to indicate different flow levels.

Surrounding landscape

Record which direction the water flows through the system and where it enters and exits.

Observe the overall surrounding landscape. Can you see any higher landforms (hills or mountains, etc.)? If so, is this where the waterway that feeds your site comes from?



Example sketch of types of flows.

Geology

Are the banks of your site made up of loose, smaller rocks; huge rock monoliths (blocks); or loose soil/mud? Or are they a combination?

Do you think the type of banks might affect the clarity of the water?

Can you identify what type of rocks or soil the banks are? Ask your teacher/instructor or make some notes and research this after the field study.

Habitat

Does your waterway and the surrounding area have anything you think would provide habitat structure for ecosystems?

Look at things like plant life in and out of the water, submerged logs, rocks, soils, roots, aquatic plants and vegetation areas on the banks.

Teacher notes for Fieldwork: Site observations

Run through this section before you go on the field study to make sure students understand what they are being asked to observe.

The most important thing to remind students about when making site observations is that the more detailed observations they make on-site, the easier it will be to write their report. Encourage students to record as many photos, sketches and videos as possible.

While in the field, students could be given a designated amount of time to make their site observations independently and then a group/class discussion could occur to highlight some of the features observed.

Fieldwork: Biotic components (biosphere)

The biotic components of your waterway are all the living things that make up the aquatic ecosystems. Use a combination of notes, drawings and photos/video to document the plants and animals of your site.

Species documentation and identification

Yarradda Lagoon wetland plant.
Vince Bucello Midstate Video Productions.

Plants

Photograph or video plants you can see in the water and in the surrounding riverbank area (riparian zone). Make notes so you can remember the relative position of the plants you photograph (in the water, close to the edge of the water or further back in the zone that floods).

For aquatic plants, note whether they are floating, submerged or emergent (root part is in the water, but a large part is also above water). Note the type of leaves they have – broad, narrow, feathery, or any other description. If plants are submerged or you are unable to photograph them, make a sketch for later identification.

Ask your teacher or other instructor whether they can identify any plant species for you on-site. Otherwise use your documented evidence to research and identify them afterwards.

Animals

Spoonbill, *Platalea regia*. John Spencer/DPIE.

Animals can be a bit tricky as they often hide when people are present (especially noisy students). They may also be submerged in the water or only come to the waterway at night. See whether you can document (photograph/video) evidence of animals using the waterway. For example:

- Scats – animal droppings or faeces are a good way to identify what animals have been around as they do not take them with them when they leave.
- Tracks – the best way to find tracks and impressions made by animals is to look at undisturbed muddy areas or areas with soft sediment.
- Other evidence – look for feathers, nests, hair and holes in the banks or the bottom in shallow water.

Your teacher or other instructor may be able to help you by suggesting aquatic species that can be found in your waterway (you should also have an idea from your background research).

This example of a fieldwork recording sheet for plants and animals provides a way to keep track of species you find in the field.

Date: 7 September 2020 **Field location:** Lake Mulwala, Mulwala

Species	Description	Landscape location	Evidence	Photo or sketch
Water plant unknown	Long strappy thin leaves fluffy flower spike	On edge of water		Photo taken
Water bird swamp hen	Dark blue, long legs, red beak and o head, long toes	Muddy bank	Footprints in mud	Photo taken, sketched print measurements

Water bugs

Resources

Fine mesh macro net
Bucket
Large white sorting tray
Magnifying glass
White ice cube tray
Spoons
Pipette/eyedropper.

Water bugs are a collection of bizarre and wonderful creatures that spend some or all of their lives in water. Some are soft and squishy, some have hard crusts on their bodies, and some carry a 'home' wherever they go.

Scientists call them aquatic macroinvertebrates. They are also known as water bugs. They are 'macro' meaning visible to the eye and invertebrates because they have no backbone.

Collecting water bugs can provide a greater understanding of a waterway's condition. Water bugs are useful indicators of water quality because:

- they are sensitive to physical and chemical changes in their habitat
- they are present in the water over extended periods of time and can thus indicate cumulative impacts
- they cannot easily escape pollution.

Surveying the diversity (types) and abundance of water bugs gives us a good understanding of the health of a waterway. If very sensitive bugs are present in good numbers, the aquatic ecosystem is more likely to be healthy. If only tolerant or very tolerant bugs are present, then the waterway is more likely to be unhealthy.

Download and use the NSW Waterwatch Water Bug Detective Guide – Freshwater to survey the water bugs in your waterway. Go to: NSW Waterwatch website > Resources > Water Bug ID Charts and Posters.

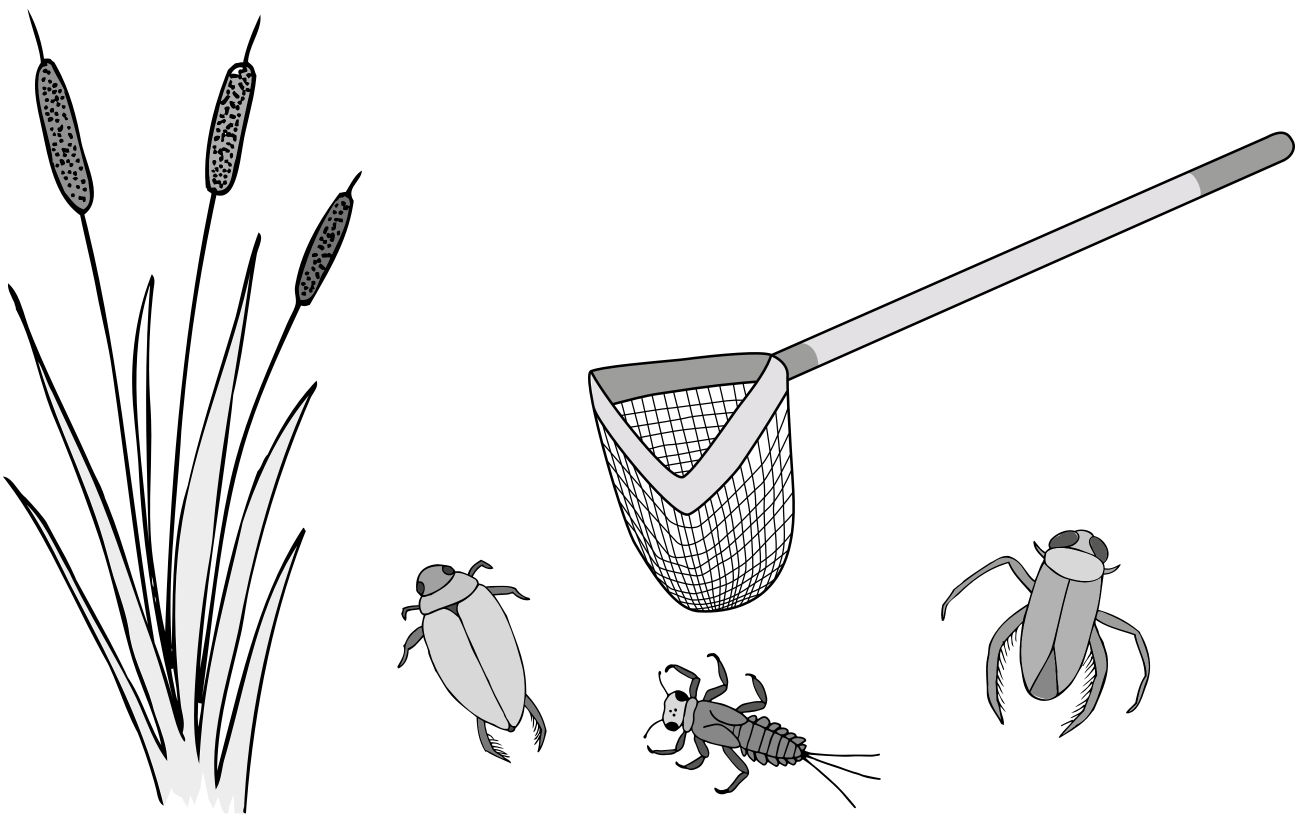
Teacher notes for Fieldwork: Biotic components (biosphere)

Students should have completed some background research to learn about species that are common in the area. This will help them when they are out in the field.

Students should follow the instru ctions outlined in Student activity 1.C. Documentation of plants, especially water plants, is very important as they may need to be identified by research at a later date.

Instruct students to be careful where they walk, especially around the edges of waterways, as evidence of animals may be disturbed.

When examining water bugs, make sure students have the necessary equipment and instructions so they can identify what they find.



Resources

Thermometer

pH paper (0–7–14 pH scale)

Electrical conductivity meter

Turbidity tube

Dissolved oxygen kit

Rate of flow: stopwatch, sticks, tape measure (or a flow meter).

Temperature

Safe freshwater range is dependent on the local environment (air temperature, altitude, shade/sun, vegetation, run-off) and the optimal range for the type of waterway you are testing.

pH

Safe freshwater range for most organisms in Australian freshwater systems is between 6.5 and 8.2.

Salinity

Safe freshwater range:

- **healthy is less than 300 ηS/cm (0.3 µS/cm)**
- **fair is 300–800 ηS/cm (0.3–0.8 µS/cm)**
- **poor is greater than 800 ηS/cm (0.8 µS/cm).**

Fieldwork: Physical measurements and water chemistry

To complete these measurements, you will need access to water testing equipment. Contact your schools' science department to see what water testing materials are available. Available materials will determine the tests you are able to complete.

Experiments/tests you could conduct are listed here.

Temperature

The temperature of water is measured using a thermometer. We do this because the physical, biological and chemical characteristics of a waterway can be affected by temperature in these ways:

- Warm water can lead to a build-up of nutrients and possible algal blooms.
- Oxygen is less soluble in warmer water and this can affect aquatic life.
- Salts are more soluble in warmer water, so temperature can affect the water's salinity.
- The metabolic rate (amount of energy used) of plants and animals can also be dependent on temperature. If the water becomes colder or warmer, organisms may not function as effectively and may become more susceptible to toxic wastes, parasites and diseases.
- Breeding cycles of plants and animals can be triggered by temperature.
- Sudden changes in temperature can damage aquatic ecosystems by killing fish and other organisms.
- Warm water may have a positive effect by producing productive sites that help to energise the food web, such as providing nursery habitat for young fish and feeding grounds for waterbirds.

pH

pH is a measure of how acidic or alkaline the water is. It is measured using pH (litmus) paper or with a pH meter.

Changes in pH outside the normal range will cause a reduction in species diversity. pH will vary depending on the geology of the area. For example, water flowing through limestone will be alkaline and water flowing through sandstone or basaltic soils will be slightly acidic.

Salinity

Salinity is the amount of salt in the water and this is measured using an electrical conductivity (EC) meter that records levels of salt in nano siemens (ηS) or micro siemens (µS) per centimetre (cm).

Most freshwater ecosystems are very susceptible to salt. High salinity can cause freshwater plants and animals to become sick and die.

Turbidity

Turbidity is a measure of the suspended particles in the water (cloudiness or muddiness of water). We test the level of turbidity using a turbidity tube and record the results in nephelometric turbidity units (NTUs).

High turbidity affects the amount of light penetrating the water (reducing plant growth and oxygen production), water temperature (excess particles absorb light), oxygen levels (decrease as temperature rises) and visual clarity of the water. All these factors can affect the breeding and survival of aquatic animals.

Turbidity

Safe freshwater range is less than 10 NTU. Levels above 10 NTU indicate excess sediment is washing into the waterway.

Dissolved oxygen

The volume of oxygen contained in water is called dissolved oxygen (DO). This is the amount of oxygen available to organisms that live in the water, such as fish, aquatic invertebrates and amphibians. DO is measured with a DO kit. If levels fall below 5 milligrams per litre (mg/L) it means oxygen levels are below the level required to maintain ecological health of a waterway.

Oxygen is lost from water when water temperature rises, salinity increases, plants and animals increase respiration and micro-organisms are feeding on excess decaying organic matter (e.g. sewage, leaf litter).

Dissolved oxygen

Safe freshwater range is above 5 mg/L.

Rate of flow

The speed or velocity of water movement (metres per second (m/s)) is the rate of flow. It can have a very important influence on the environment of your stream by affecting:

- oxygen levels
- the concentration of pollutants or salinity
- other environmental needs of living things.

Rate of flow can be measured by timing an object as it flows down a measured distance of waterway (using a stopwatch, sticks, tape measure). Alternatively, a flow meter could be used to measure the rate of flow in litres per second (L/s) or cubic metres per second (m3/s).

Other measurements you could consider taking are:

- total dissolved solids
- amount of nitrates
- amount of phosphates.

Measurement descriptions have been sourced from NSW Waterwatch.

Hint

The NSW Waterwatch website has excellent resources for studying water quality. Visit their website and look at their Waterwatch manuals. These manuals describe how to conduct experiments and provide further information about what each test shows. Go to: NSW Waterwatch website > Resources > Waterwatch manuals > High schools.

Teacher notes for Fieldwork: Physical measurements and water chemistry

Descriptions of the outcomes of suggested experiments/tests have been provided. Teachers and students will need to visit the NSW Waterwatch website to investigate how to properly conduct these experiments.

We recommend you prepare for conducting these tests/experiments in the field by practising skills and learning to use equipment at school before going on the field study.

Post-field study report

When you have completed your background research, field observations and data collections, your task is to prepare a report about your waterway study.

Your report should bring together all the information you have gathered to describe your site, the results of your experiments, and your own personal recommendations.

Description of your waterway

This will include information contained in your pre-field-study background research, your fieldwork site observations and your species identification. The aim is to tell the story of your waterway so anyone reading your report can get a good understanding of the characteristics of the site.

Results of experiments

These should include the results of your:

- water bug survey (abundance, diversity and what tolerance shows)
- physical measurements
- water chemistry experiments.

Your results should state what you found and whether it falls within a good range for healthy rivers and wetlands.

Personal recommendations

This section should discuss your recommendations about whether your site is healthy and factors that could be influencing waterway health.

A recommendation should also be included to indicate whether you think your waterway would benefit from more frequent flows and inundations provided by tools like water for the environment.

'Water that is allocated and managed specifically to improve the health of rivers, wetlands and floodplains is known as water for the environment.' (What is Water for the Environment webpage, Department of Planning, Industry and Environment).

Teacher notes for post-field-study report

This resource provides the tools for students to complete the Murray–Darling Waterway Field Study and encourages them to put their own stamp on how they present their information.

Encourage students to use some form of multimedia to present their information as they should have images, photos and/or video to back up their findings.

The description of the waterway should set the scene for their study and give readers a good understanding of the site in question.

The results of experiments and other observations should enable students to analyse the health of the site.

Students should make recommendations and provide their opinions on the health of the site.

If the site is found to be healthy, students should indicate the reasons why. They should also be encouraged to think of other determining factors that they may not been able to detect with their tests and observations e.g. looking at the bigger picture of the system.

If the site is unhealthy, students should indicate the reasons why and what they think is making it this way. Are there things the local community could do to help? Are the main causes coming from further away?

Answers have not been provided as they will be individual to each site.

Field study risk-management plan

Please note this risk-management plan is intended as a guide and no liability is accepted for its use. Please refer to your school's safety and risk-management policies before undertaking field trips.

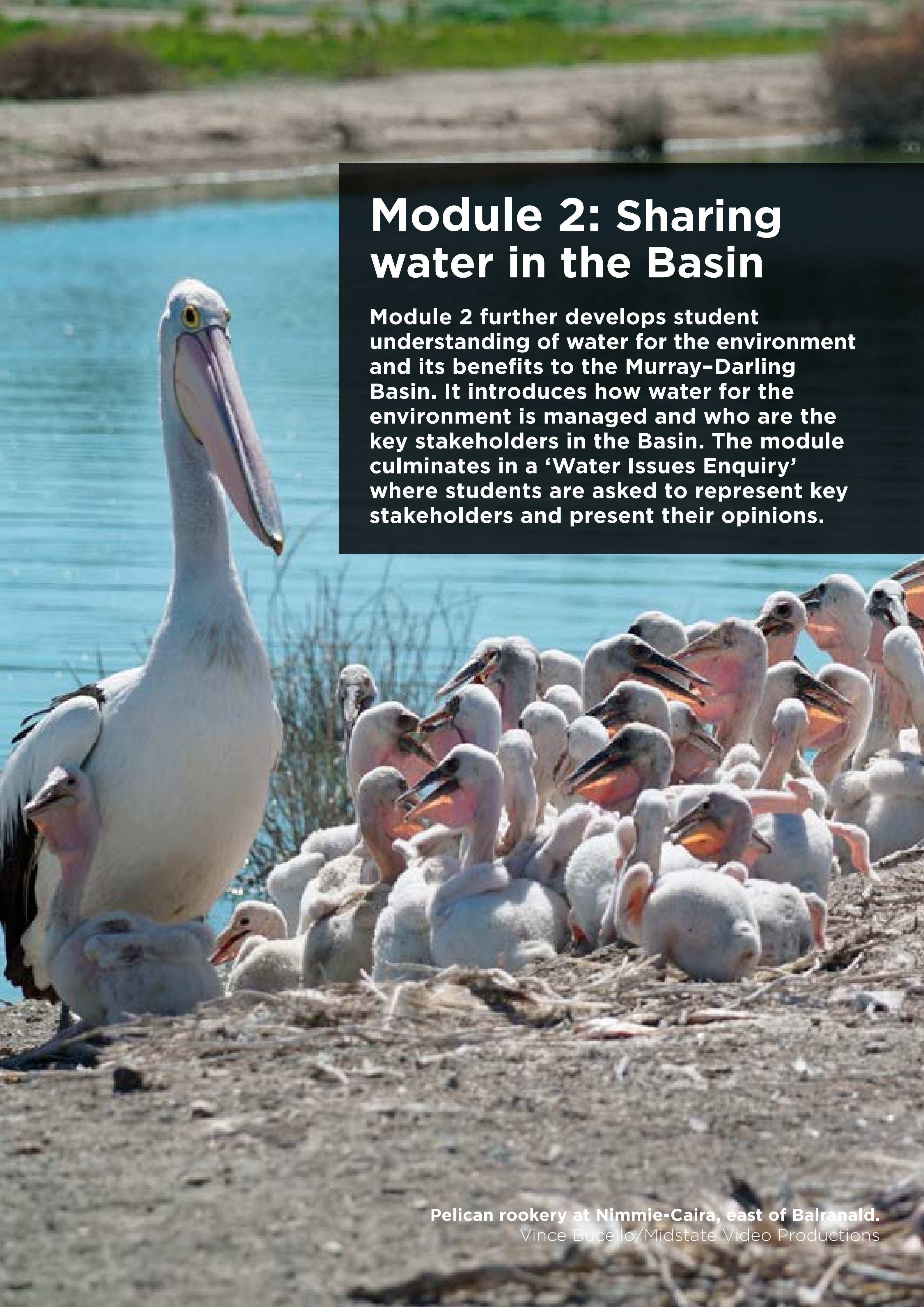
Risk levels in Table 3 have been modelled from the NSW Department of Education Excursions Policy):

- 1 and 2 – extreme risk, deal with the hazard immediately
- 3 and 4 – moderate risk, deal with the hazard as soon possible
- 5 and 6 – low risk, deal with the hazard when able.

Table 3 Field study risk-management plan

Task/activity	Hazard and associated risk	Risk level	Elimination or control measures	Who	When
Walking to and from transport and on public roads	Struck by vehicle on road Uneven footpath	4	Teachers and parent/carer volunteers attending to supervise field study	Field study coordinator	Before
		6	Brief participants on rules and behaviour		
		6	Remain on pedestrian pathways and use pedestrian crossings at all times	All	During
		6	Teachers and parent/carer volunteers 'ferry' students along the road		
Coach transport to field study location	Boarding transport Vehicle accidents	6	Ensure vehicle operators hold appropriate licence(s) and insurance	Field study coordinator	Before
		5	Check availability of seatbelts		
		6	Vehicle to be appropriate for the needs of the group (e.g. wheelchair access) and techniques		
		5	Enforce rules and monitor behaviour	Teachers	During
		5	Ensure seatbelts are worn		
Observing animals and plants	Bites and stings from insects, spiders, ticks and snakes (including allergies) Exposure to sun while observing animals and plants	4	Ensure participation of students with known allergies has been considered, implement appropriate risk controls (e.g. trained staff member can apply first aid such as Epipen for anaphylaxis)	Teachers	Before
		5	Ensure staff and students are aware of emergency response procedures		
		5	Ensure students are wearing enclosed footwear, long pants and other protective clothing and avoid walking through long grass	All	Before and during
		4	Ensure students wear hats, shirts with sleeves and sunscreen		
		4	Ensure students are provided with insect repellent on the day	All	During
		3	Bring plenty of water		
		6	Don't touch animals or hazardous plants		
		6	Carry a first aid kit	Teachers	During

Task/activity	Hazard and associated risk	Risk level	Elimination or control measures	Who	When
Walking around a wetland	Uneven ground surfaces, bites and stings, exposure to sun, wind, rain and dehydration	4	Notify appropriate site staff of expected arrival and departure times, location of walk, number of participants and students with medial conditions	Field study coordinator	Before
	Allergies to insects, reptiles and plants	3	Identify participants with known medial conditions and ensure appropriate medication/ treatment is available		
	Becoming lost or isolated from the group	3	Ensure participation of students with known allergies has been considered, implement appropriate risk controls (e.g. trained staff member can apply first aid such as epinephrine injections for anaphylaxis)		
	Change in weather conditions	4	Ensure staff and students are aware of emergency procedures, including knowing the symptoms of heat exhaustion/ stroke	Teachers	Before
		6	Check weather forecast on day of field study		
			Do not undertake physical activity in hot weather		
		6	Carry maps of the site, if applicable		
		5	Emergency plans communicated for dealing with potential accidents		
		5	Carry first aid kit		
			Teacher or other representative to lead the walk	Teachers	During
		5	Ensure adult supervision at front and back to keep the group together		
		5	Inform field study participants of safety instructions		
		3	Ensure all participants carry water bottles		
			Take extra water to refill water bottles		
		4	Carry insect repellent, additional sunscreen and ensure rest breaks are taken in the shade		
		5	Wear enclosed footwear suitable for walking, clothing to protect arms and legs and suitable for changing weather conditions	All	During
			Wear hats, shirts with sleeves and sunscreen while outdoors		
		5	Seek out shade wherever possible to avoid heat exhaustion		



Module 2: Sharing water in the Basin

Module 2 further develops student understanding of water for the environment and its benefits to the Murray–Darling Basin. It introduces how water for the environment is managed and who are the key stakeholders in the Basin. The module culminates in a 'Water Issues Enquiry' where students are asked to represent key stakeholders and present their opinions.

Pelican rookery at Nimmie-Caira, east of Balranald.
Vince Bucello/Midstate Video Productions

Overview of materials

These teaching materials include content provided for students in Rivers: Sharing our water Student workbook and additional background content, questions and resources to help teachers deliver the student activities for Module 2.

They include:

- Australian curriculum outcomes and cross-curriculum priorities addressed by the content of this module, listed in Tables 4 and 5
- Text descriptions for teachers to use when conducting student activities across the two parts of the module. This includes:
- Part A: Water stakeholders, a PowerPoint presentation and accompanying notes, and Student activity 2.A worksheet questions and answers. Student activity 2.A worksheet has been developed to go through during the PowerPoint presentation.
- Part B: Water issues inquiry Student activity 2.B worksheet, no answers provided as they will be student specific.

Eastern long-necked turtle, *Chelodina longicollis*. Rosie Nicolai/DPIE.

Australian curriculum outcomes

Table 4 Australian curriculum links for Module 2: Sharing water in the Basin

Subject	Year	Curriculum link
Geography	7	**ACHGK038:** The way that flows of water connects places as it moves through the environment and the way this affects places **ACHGK040:** The nature of water scarcity and ways of overcoming it, including studies drawn from Australia and West Asia and/or North Africa **ACHGK041:** Economic, cultural, spiritual and aesthetic value of water for people, including Aboriginal and Torres Strait Islander Peoples and peoples of the Asia region
	8	**ACHGK048:** Different types of landscapes and their distinctive landform features **ACHGK049:** Spiritual, aesthetic and cultural value of landscapes and landforms for people, including Aboriginal and Torres Strait Islander Peoples
	9	**ACHGK061:** Human alteration of biomes to produce food, industrial materials and fibres, and the use of systems thinking to analyse the environmental effects of these alterations **ACHGK062:** Environmental, economic and technological factors that influence crop yields in Australia and across the world **ACHGK063:** Challenges to food production, including land and water degradation, shortage of fresh water, competing land uses, and climate change, for Australia and other areas of the world
	10	**ACHGK070:** Human-induced environmental changes that challenge sustainability **ACHGK071:** Environmental world views of people and their implications for environmental management **ACHGK072:** The Aboriginal and Torres Strait Islander Peoples' approaches to custodial responsibility and environmental management in different regions of Australia **ACHGK073:** The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated **ACHGK074:** The application of geographical concepts and methods to the management of the environmental change being investigated **ACHGK075:** The application of environmental economic and social criteria in evaluating management responses to the change
Science	7	**ACSSU112:** Interactions between organisms, including the effects of human activities can be represented by food chains and food webs
	8	**ACSHE135:** Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations
	9	**ACSHE160:** People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities

Cross-curriculum priorities

Table 5 Cross-curriculum priorities addressed by Module 2: Sharing water in the Basin

Sustainability	
Organising ideas	
Systems	
01.1	The biosphere is a dynamic system providing conditions that sustain life on Earth.
01.2	All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.
01.3	Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.
Futures	
01.6	The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future.
01.7	Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments
01.8	Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts.
01.9	Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

Part A: Water stakeholders

Resources

Murray–Darling Basin Map

Student activity 2.A worksheet.

This section revisits water for the environment and water management, and further develops these concepts. It also introduces students to stakeholders and potential issues that may arise and need managing. Content has been developed for teachers to use in class to help guide discussion with students.

It will further develop student's understanding of:

- water for the environment
- how water flows and how patterns have changed throughout history
- why water for the environment is necessary for ecosystems in the Murray–Darling Basin
- how water is managed and delivered in the Basin and who some of the key stakeholders are in the New South Wales (NSW) part of the Basin.

The list of questions on Student activity 2.A worksheet (see Rivers: Sharing our water Student workbook for a copy of worksheet with questions only) is provided for students to answer. Discussion around issues of sustainability for both the environment and human use of water in the Basin is encouraged.

Importance of our rivers

Rivers, creeks and wetlands are the lifeblood of New South Wales (NSW). They make towns more liveable, and provide a place to relax, unwind and reconnect with nature. For Aboriginal people, healthy rivers are an essential part of spiritual, cultural and physical wellbeing.

The rivers of the Murray–Darling Basin form a huge interconnected system. Events in one part of the Basin can have a flow-on effect for other parts of the river network. For example, native fish that breed in one river may travel hundreds of kilometres in their lifetime, making use of the river network to feed and breed.

What is water for the environment?

Watch this video

The DPIE –EES What is water for the environment? webpage contains a video to use to take student through what is water for the environment.

Change has occurred rapidly since European settlement and the cycles that occurred naturally must now be carefully managed as part of a regulated system to ensure a healthy future for the river and all the communities that rely on it.

Finding a balance between the needs of the river system, its plants and animals and the communities that rely on them is complex.

Water for the environment is a share of the water in dams and rivers that is set aside specifically to support the needs of water-dependent native plants, animals and ecosystems. It is used to support the health of native plants and animals by helping to restore more natural flow patterns in rivers, creeks and wetlands.

Benefits of water for the environment

Water for the environment supports the health of rivers so they can, in turn, provide for human needs.

These water releases facilitate:

- Rivers depositing sediment on floodplains, nourishing soils and providing grazing habitat for native animals and livestock.
- River pulses that trigger fish breeding and movement, allowing juvenile fish to find safe haven in floodplain wetlands where they can feed and grow before returning to the river.
- Movement of water onto floodplains, which releases carbon that energises the food web. This connection between floodplains and the river channel is vital for maintaining food supplies for native fish and other wetland-dependent animals.
- Inundation of wetlands, which are the kidneys of our rivers (see page 7, Water for the Environment section, to revise details about the benefits of water for the environment).

Watch this video

Macquarie Marshes – environmental outcomes of the 2016/2017 floods video

Watch this video with students to see the effects water flows have on wetlands.

Importance of water to traditional owners

Aboriginal people were the first river managers. They worked with nature to provide for their families and look after the health of rivers and wetlands. Rivers were, and continue to be, a source of food, medicine, building materials and culture. The river provided a mode of transport and communication – connecting individuals, families and groups. Aboriginal connection to culture and rivers is alive today and is as important as it was before European settlement.

Changes through history

Over the past 230 years, many creeks and wetlands in NSW have had their natural flow cycles disrupted as a result of dams and weirs. While these structures have provided a more reliable water source for people, they have disrupted the natural flow cycles needed to maintain healthy rivers and wetlands.

River regulation brings more reliability to water supplies but has interrupted the natural flow characteristics of the river required by native fish and other plants and animals to breed, feed and grow.

European settlement brought with it increasing demand for land, water and wealth (see pages 1 and 2, Introduction, to revise the history of the Murray–Darling Basin and the 1800s as the 'era of harnessing water').

There was little understanding of the impact dams and water regulation would have on native plants, animals and ecosystems. Controlling flows in rivers has changed the pattern of flows.

Dams and weirs hold back water that would usually spread out across the floodplains. Floodwater plays a critical role in ecosystems by releasing carbon and other nutrients from leaf-litter on the floodplain floor to kick-start the aquatic food web. Less water over floodplains means less food in the rivers, which impacts native fish, frog and bird populations.

There are now 14 dams in the NSW part of the Murray–Darling Basin. For example:

- Burrinjuck Dam
- Hume Dam
- Burrendong Dam
- Copeton Dam.

Use the Murray–Daring Basin Map to identify more dams with students.

Impacts of changing river flows

Freshwater ecosystems rely on a range of different types of water flows (heights), durations of inundation (how long they are covered) and timing of flows (time of year and frequency of inundation) to support a diversity of plant and animal species, provide pathways for them to move around, and trigger suitable conditions for reproduction.

Changing river flows has had major impacts on ecosystems, aquatic habitat and even farming landscapes that rely on flooding events (see page 3, Introduction, to revise impacts of changes on rivers and floodplains).

Maintaining healthy rivers and wetlands is essential for the freshwater ecosystems they support.

The duration of floods that had once lasted months and allowed waterbirds to breed and plants to grow and set seed, has now reduced, sometimes to weeks. After a flood, waterbirds will breed in wetland areas. If the water recedes too quickly, there is not enough food for the birds and their chicks. Birds will often leave chicks behind to find more food and the chicks die. The minimum duration of flooding required for successful breeding of most waterbirds is about 5–7 months, but this can increase to 10 months for some waterbirds (Scott 1997).

Stands of river red gum, black box and other river-dependent plants no longer receive water as often, or for as long, as they need. This has led to the decline of these vegetation communities on floodplains. For example, river red gums require a flood every 1–3 years for forests and 2–4 years for woodlands, a flood duration of 5–7 months for forests and 2–4 months for woodlands, preferably during the winter-spring months (Murray–Darling Basin Authority 2012).

Some natural events need to occur at certain times of the year to support natural breeding and feeding events of migratory birds.

Water regulation to support flow regimes

Growing demand for river water has changed the patterns of flows and an overall reduction in the amount of water flowing through rivers and out onto floodplain habitats.

The volume of water available for the environment in the Murray–Darling Basin varies from year to year in response to:

- rainfall
- catchment conditions
- allocation announcements.

Water for farms, towns and rivers is stored in dams and then released by river operators, who are guided by rules for running the river. The water may be directed to its destination through regulators and channels, depending on its location and available infrastructure.

In NSW, the NSW and Australian governments hold a mixture of general, high-security and supplementary water licences. The use of water under these licences is subject to the same rules and availability considerations as other licence holders, including farmers. At any one time, the volume of licenced environmental water held in NSW dams accounts for less than 20% of dam capacity and is often significantly less.

River regulation is the management of rivers using dams, weirs, pipes and channels to control the flow of water.

Water is delivered via the same system of dams, weirs and channels used by other water customers. Once a target site has been identified, the water manager places an order with WaterNSW, which controls the dams and weirs. The water is released at an agreed time. Some of the process is automated. In other cases, closer to the target site, a water or land manager may be required to physically open a regulator to allow water to enter the creek or wetland. In regions where irrigation systems carry water to farms, water managers pay a fee to use these same channels to deliver water to target wetlands.

Stakeholders

Stakeholders have been divided into two groups, water users and water managers.

Water users

These are the people who use water from the Murray–Darling Basin. They include:

- community members
- businesses
- towns and cities
- tourists
- recreational fishers
- irrigation farmers
- dryland farmers
- floodplain graziers
- Aboriginal organisations
- mining and other industries.

Water managers

These are the key stakeholders that make decisions to control the release of water for the environment, how much to use, and determine the flow regime required for healthy river and wetlands.

- **Department of Planning, Industry and Environment – Environment, Energy and Science** (DPIE – EES) is the lead agency for the delivery of water for the environment in NSW. DPIE – EES has strategic and practical roles in deciding where and when to provide water for the environment to rivers, wetlands and floodplains to achieve a range of outcomes for waterbirds, native fish, vegetation, ecosystem services and system connectivity. DPIE – EES also has a monitoring role with respect to the use of water for the environment.

- **Local communities** play a key role in advising water management agencies on the use of water for the environment. Environmental water advisory groups meet regularly to help inform the decision-making process of DPIE – EES. These groups are made up of a diverse range of stakeholders including community members, recreational fishers, irrigation and farming groups, Aboriginal organisations, floodplain graziers, environment representatives, scientists and partner agencies.
- **Commonwealth Environmental Water Office** (CEWO) holds the largest portfolio of water for the environment on behalf of the Australian Government. CEWO contributes to environmental watering at sites across the whole Murray–Darling Basin, seeking basin-wide outcomes. It also has a monitoring role.
- **Murray Darling Basin Authority** (MDBA) assists with environmental watering at a whole-of-basin scale and is responsible for the development of a long-term strategy for environmental water across the basin.
- **Department of Planning, Industry and Environment – Water** (DPIE – Water) administers the *Water Management Act 2000* and leads the NSW response to the implementation of the Basin Plan. DPIE – Water determines:
- the volume of water available for allocation to water entitlements for towns, water users and the environment each year
- the water-sharing rules between users, and policies for water trading
- also has a role in monitoring ecosystem health.
- **WaterNSW** is a business unit of the NSW Government that is responsible for the operation and maintenance of dams and weirs to supply water and enhance water security.
- **Department of Primary Industries – Fisheries** (DPI Fisheries) is the lead agency for the management and protection of NSW fish populations. DPI Fisheries has a role in research, policy implementation, education and compliance.
- **Murray–Lower Darling Rivers Indigenous Nations** (MLDRIN) is a confederation of Indigenous Nations or traditional owners in the southern part of the Murray–Darling Basin. The group currently represents 24 nations.
- **Northern Basin Aboriginal Nations** – NBAN represents 22 Sovereign First Nations in the northern Murray–Darling Basin in natural resource and water management.

Stakeholder issues

There are a number of issues regarding the management of water resources in the Murray–Darling Basin – both within regional communities and across state borders. These include, but are not limited to:

- water for environmental sustainability
- industry and agricultural use
- water management requirements across varying levels of government and state borders
- location of stakeholders within the Murray–Darling Basin
- big business and small enterprises.

How can these stakeholder issues be managed? Who takes a lead role? How do Basin water managers help everyone?

State governments work together to ensure a balance is achieved between the water needs of communities, industries and the environment.

State governments determine the amount of water that can be allocated based on the total amount of water available within the Basin. This is done by determining how the availability of water may be affected by variability in rainfall and weather conditions, changes to inflows into storages and how water in storages, like dams and weirs, is managed.

This gives water users certainty around how much water they will be able to access over the year, and helps states manage water availability through unpredictable climatic conditions.

Current water management

A range of policies and plans are in place to guide the management of water in the Murray–Darling Basin (see page 9, Policies that guide water management, for more details):

- the Murray–Darling Basin Plan (the Basin Plan)
- water resource plans
- water sharing plans
- long-term water plans.

Direct students to the NSW Government's Water for the environment webpage for more information.

Watch this video

Macquarie Marshes – making decisions with water for the environment

This video covers how environmental flows and water for the environment is monitored and managed.

Student activity 2A What is water for the environment?

Question 1
Why do you think rivers are important? List as many reasons as you can.

- make towns liveable – drinking water
- agriculture
- provide a place to relax
- cultural connections
- animals and plants rely on water
- brings life to desert/dry regions.

Question 2
a. Define 'water for the environment'.

Water for the environment is a share of the water in dams and rivers that is set aside specifically to support the needs of water dependent native plants, animals and ecosystems.

b. Why do you think it is important for governments and policy makers to consider releases of water for the environment?

Students to record their own thoughts.

Question 3
a. What are the ecological benefits of water for the environment?

- animals can breed, feed and grow
- triggers reproduction in plants
- flowering plants provide food for wildlife
- wetlands filter chemicals and sediment, slowing water flow
- wetlands provide habitat for migratory birds.

b. What are the social and cultural benefits of water for the environment?

- health and wellbeing – public health
- provides greater opportunities for recreational activities.

c. What are the economic benefits of water for the environment?

- improved agriculture from nutrients in river sediment
- eco-tourism brings wealth to communities.

Question 4
a. What is the name of your local Aboriginal nation? For help to identify your local Aboriginal nation, visit these websites:

- aiatsis.gov.au/explore/articles/aiatsis-map-indigenous-australia
- collection.aiatsis.gov.au/austlang/search
- gambay.com.au.

Answer will be dependent on student's local area.

b. Do you know the Aboriginal name/meaning for your local river?

Students to investigate – based on question 4a.

Question 5

a. Why did the early settlers build dams and weirs along our major rivers?

- to provide a more reliable water source for people
- to open up areas for irrigation and provide the ability to expand farming operations inland where droughts hit hardest
- to allow farmers to cultivate nutrient-rich floodplain soil in dry times.

b. How have dams and water regulation impacted our river systems?

- changed patterns of flows
- reduced the amount of water flowing through rivers and out onto floodplain habitats.

c. The presentation identifies four dams in the NSW part of the Murray–Darling Basin. Can you think of four more?

- Blowering Dam
- Burrendong Dam
- Burrinjuck Dam
- Carcoar Dam
- Chaffey Dam
- Copeton Dam
- Hume Dam
- Keepit Dam
- Lake Mulwala
- Lake Victoria
- Menindee Lakes
- Oberon Dam
- Pindari Dam
- Split Rock Dam
- Talbingo Dam
- Windamere Dam
- Wyangala Dam.

Question 6

a. Why would shorter floods have an impact on local wildlife?

After a flood, waterbirds will breed in wetland areas. If the water recedes too quickly there is not enough food for the birds and their chicks. Birds will often leave chicks behind to find more food and the chicks die.

b. What is a snag? Why are they important?

Snags are fallen trees, tree roots or other natural structures in the water that provide habitat and protection for aquatic species. Snags also help trap sediment and slow down fast-moving water, which helps prevent erosion, especially along riverbanks.

c. What is cold-water pollution?

Cold-water pollution occurs when water is released from a dam. The water typically comes from the bottom of the dam and it is much colder than the temperature of the water that would flow in the river. Cold-water pollution prevents native fish from breeding, can affect food supplies for fish and limit their growth.

Question 7

a. The volume of water available for the environment in the Murray–Darling Basin varies from year to year in response to …

- rainfall
- catchment conditions
- allocation announcements.

b. Who releases stored water?

River operators.

c. How much water is held in dams and weirs for environmental purposes?

Less than 20% of dam capacity.

Question 8

Name four key policies or plans that guide the management of water in the Murray–Darling Basin.

- Murray–Darling Basin Plan
- water resource plans
- water sharing plans
- long-term water plans.

Question 9

Think of your local town. Who would be a stakeholder in water for the environment? Does it include you?

Answer will be dependent on student's local area.

Question 10

What are some of the issues you think would get raised at a town meeting about water for the environment?

Answer will be dependent on student's local area.

Part B: Water issues inquiry

Resources

Student activity 2.B worksheet

In this section, students will critically analyse issues regarding the management of water for the environment in the Murray–Darling Basin from the perspective of water users, managers and stakeholders. This is an inquiry-based activity that engages students to collect and analyse information (particularly through desktop research and/or fieldwork), communicate their findings in effective ways, and reach conclusions based on evidence and logical reasoning.

Prepare students

Students should complete Module 2 Part A – An introduction to water for the environment **before they do this water issues inquiry task**. Part A contains information relevant to this task.

It is also recommended that students complete Module 1 – Aquatic ecosystems so they have an understanding of water and the Murray–Darling Basin before doing this task.

Assess student knowledge

Watch this video

Watch the video located on the DPIE – EES What is water for the environment? webpage.

The main part of this section is a brainstorm session about issues relating to managing water for the environment. Before you conduct the classroom brainstorm, ask students whether they have heard of the Murray–Darling Basin Plan and if they know what it is.

Introduce students to the Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE – EES) and the role they play in managing water for the environment in NSW.

The NSW DPIE – EES Water for the Environment Team:

- manages the delivery of water for the environment in NSW
- collaborates with community stakeholders and other agencies
- undertakes and co-ordinates scientific research and evaluation of projects
- manages a portfolio of water held by the NSW Government
- manages water on behalf of the Commonwealth Environmental Water Holder
- monitors the use of water for the environment
- reports on water management activities.

Installing underground waterpipes to save water. DPIE.

Background

The Murray–Darling Basin is Australia's largest river catchment making up 14% of Australia's total land mass. It is an interconnected system of streams, creeks, rivers, lakes, dams and wetlands that come together to form an integral part of the eastern Australian landscape.

Over two million people reside within the Murray–Darling Basin, with almost four million people relying on its catchments for water and the survival of their families, communities and industries. The combination of a suitable climate and fertile land for producing food and fibre resources make the waters of the Basin one of Australia's most important natural resources.

To try and ensure water supply meets the demands of the Murray–Darling Basin population, water regulation has been necessary. This regulation is essential to support human endeavours but has changed the natural water flow patterns of the Basin's creeks, rivers and wetlands. This in turn has affected the natural ecosystems that rely on flowing water and/or periodic inundation.

Water that is allocated and managed specifically to improve the health of rivers, wetlands and floodplains is known as 'water for the environment'. It is the best tool we currently have to try and ensure a range of flows to protect and preserve our natural environment.

Due to the vast size of the Basin, the number of different states it includes and the wide range of communities and enterprises that it supports, it is difficult to get people to agree on how water is managed. There is no doubt that everyone wants the Basin to have healthy rivers and wetlands, but managing this is complex.

The management of water for the environment in the Murray–Darling Basin raises a range of difficult questions. For example:

- If the Basin is struggling to get enough water to keep its rivers and wetlands healthy, then where is the extra water going to come from?
- Are people willing to make sacrifices to reduce the amount of water they use if it could affect them?
- Who needs to reduce water use and who should decide who does?
- Are people willing to modify behaviours to reduce water use?
- Will people embrace technology to save water and will they be given access and subsidies to help them move forward?
- How can water regulations be made easier to understand?

- How can authorities more effectively monitor water use and make sure people are complying?
- Is providing water for the environment as important as providing water for industry to make prosperous communities?
- Do people upstream have a responsibility to look after rivers and wetlands downstream?

These questions (and many, many more) show the challenges that we face to try and ensure that we find a balance between our water use and having a healthy Basin environment.

Introduced in 2012, The Murray–Darling Basin Plan (the Basin Plan) provides legislation that guides governments, regional authorities and communities to sustainably manage and use the waters of the Murray–Darling Basin. The aim of the Basin Plan is to ensure that water is shared between all users, including the environment, in a sustainable way.

Differences in opinions about water management continually provide challenges for the Basin Plan during its implementation phase. This shows the complexity of dealing with so many different users with strong opinions and their own considerations throughout such a vast area.

Teacher notes for Background section

Provide students with the Water Issues Inquiry activity sheets (see Rivers: Sharing our water Student workbook for copy of Student activity 2.B Water Issues Inquiry without teacher notes).

Read through the Background section as a class. This should be a revision of knowledge students learned in Module 1 and Module 2 Part A.

Highlight the vast size of the Murray–Darling Basin – it spans five states/territories and is home to a large number of diverse communities and enterprises.

Compare the boxed list of questions on management of water for the environment in the Background section to the brainstorm session. Ask students to write any questions on the board that are not included in the boxed list.

Highlight information about the Murray–Darling Basin Plan and the challenges it is facing. Liken this to the Water Issues Inquiry students will be completing.

Explain that during this Water Issues Inquiry students will examine issues regarding the management of water for the environment through the eyes of stakeholders that have interests in their chosen waterway/system.

Student activity 2B Water issues inquiry

Inquiry task

Your task will be to examine issues regarding the management of water for the environment through the eyes of stakeholders that have interests in your chosen waterway/system. You will be required to present a report at a classroom Water Inquiry Forum where the different stakeholders will be represented.

After the forum you will reflect on the information presented by your peers, as stakeholders, and determine whether you would be willing to work more closely with other stakeholders to help keep our rivers and wetlands healthy.

For this task you will need to complete four steps:

Step 1: Choose a river system

As a class or in groups, choose a local major river or catchment to be the waterway/system that is the basis of your inquiry.

Step 2: Identify your stakeholders

Identify stakeholders in the local region, as a class or in groups, who use/manage water or have a position on providing water for the environment.

Step 3: Stakeholder report and forum

Research and prepare a report taking the position of a particular stakeholder. You will be required to present this report at the classroom Water Inquiry Forum in small groups or as individuals.

Spray irrigation. DPIE.

Step 4: Self-assessment and reflection

After presenting your report and listening to reports from other stakeholders, reflect on what you've heard and determine whether you could work more closely with other stakeholders to help keep our rivers and wetlands healthy. This is completed individually.

Step 1: Choose a river system

For the purpose of this inquiry you are to choose a particular part of the Murray–Darling Basin to study. This should be done as a class or as guided by your teacher. A suitable waterway to study should be big enough to include a range of land and water uses so you have a variety of interested stakeholders.

Research or use your local knowledge to make your decision. By having more variables, it will give a greater diversity of opinions which will make your class inquiry more complete. Some variables to consider when choosing your waterway are:

- environmentally sensitive areas like wetlands, nature reserves, national parks, conservation reserves, protected areas or Ramsar sites
- irrigation farming areas
- dryland farming areas
- infrastructure such as major dams, channels, canals, weirs or other human-made water regulation tools
- urban water users in towns and cities
- creeks, streams or other rivers that flow into your waterway (inflow)
- creeks, streams or other rivers that your waterway flows into (outflow)
- a range of elevations that suit different uses and users
- industries that depend on water or could affect what flows into your rivers (mining, forestry etc.)
- specified or protected areas for cultural purposes
- hydrological indicator sites (this will make it easier to find possible flow regime information).

Include in your report

Provide a brief description of your chosen waterway in the introduction of your report. Details should include site information, variables and possible water users/ stakeholders. Include a map highlighting the area of study.

Helpful resources

- Murray–Darling Basin map
- Catchments of the Murray–Darling Basin map
- Murray–Darling Basin Land Use map
- Murray–Darling Basin Authority geographic profile maps.

Teacher notes for Inquiry task, Step 1

Read through the information provided as a class and focus on the variables listed.

Explain to students they need to choose a local major river or catchment to be the waterway/system that will form the basis of the inquiry, and identify how water and land is used in the surrounding region.

Class brainstorm/research – On an interactive whiteboard/projector solution open the links to the maps provided to give a better idea of possible areas of study. Ask students to identify a relatively local area that contains as many of the listed variables as possible. Create a list of suggested study regions and then reach a consensus with the whole class on the region they will study.

Individual research – Alternatively, students could first be given time to research the local river themselves to try and identify a suitable study region using the variables given. The class could then be brought together and students could put forward their case for selecting particular study regions. A consensus could then be reached by the whole class on the region they will be studying.

Helpful websites – Encourage students to use the links provided to the Murray–Darling Basin map, major catchment map, land use map and geographic profile maps/graphs (elevation versus distance), plus any others they can find, to help them select a study region.

Students should provide a brief description of chosen waterway in their reports including any appropriate maps of the area.

Step 2: Identify your stakeholders

For the purpose of this inquiry you are to identify land users, water users and any other stakeholders that may have an interest in discussions about water for the environment in your chosen area. This should be done as a class or as otherwise guided by your teacher.

After creating a list of stakeholders, you will be allocated a particular stakeholder to represent at your class Water Inquiry Forum. Find more information about your stakeholder and prepare a report that represents their thoughts about water for the environment.

We've include some potential stakeholders you might find in your study region and suggestions of issues or roles to research here.

Australian government

The Australian government has a responsibility to look at the bigger picture by managing the Murray–Darling Basin as one whole system. Their aim is to try to ensure that water is shared between all users, including the environment, in a sustainable way. When making management decisions, it is the Australian government's role to:

Additional activity: waterway profiles

Create your own waterway 'profile' to show how water is used along the length of the waterway at different elevations. Your teacher can show you how to make a profile using a topographic contour map and matching it to sites along your waterway.

For an example of what you should create, view the Murray–Darling Basin Authority geographic profile maps.

- provide leadership and collaborate with state governments, agencies and communities
- facilitate engagement between regions
- encourage consideration of the integrated and connected nature of the Basin's river systems.

Department of Agriculture, Water and the Environment – Commonwealth Environmental Water Office

Department of Agriculture and Water Resources

Murray–Darling Basin Authority

State governments

State governments are responsible for dam operations and water distribution along the Murray and Darling Rivers and their tributaries within their individual states. They manage water for irrigation areas, water for urban and recreational purposes, and water for the environment and cultural purposes. The Department of Planning, Industry and Environment – Environment, Energy and Science manages the delivery of water for the environment in NSW.

NSW Department of Planning, Industry and Environment – Environment, Energy and Science

NSW Department of Planning, Industry and Environment – Water

Irrigation farmers

Irrigated agriculture in the Murray–Darling Basin makes an important contribution to the Australian economy and regional economies. Irrigated enterprises can include rice, cotton, dairy, orchards, grapes and horticulture. Farmers using irrigation want to make sure they have suitable quantities of water to achieve maximum production.

Irrigated farms in the Murray–Darling Basin

Murrumbidgee Irrigation

Coleambally Irrigation

Murray Irrigation

Dryland farmers

Dryland farming enterprises include livestock grazing, grain crops (such as wheat and barley), seed oil crops (such as canola and sunflower) and legumes (such as chickpeas). Dryland farmers need water for livestock, watering crops in times of drought and for maintaining farm equipment. These farms still need water to be pumped or carted from rivers within the Basin or from dams that store water on their properties.

Watch this video

This video about Food Production in the Murray–Darling Basin gives some examples of dryland farmers in the Basin.

Floodplain graziers

Floodplain grazing represents almost 70% of agricultural land use in the Murray–Darling Basin and is an economically and historically significant industry.

Tourists on the banks of the Darling River. Terry Cooke.

Science and technology experts

Innovation plays an enormous role in the future of the Murray–Darling Basin. Experts can provide other users, stakeholders or governments with the best advice and recommendations about managing water for the environment. Technology is especially important to the agricultural industry becoming more water efficient.

Commonwealth Environmental Water Office

Murray–Darling Basin Authority

First Peoples and Aboriginal organisations

There are many Aboriginal nations, language or community groups throughout the Murray–Darling Basin. Healthy rivers and wetlands mean healthy Country for the many First Peoples of the Murray–Darling Basin.

National Cultural Flows Research Project

Northern Basin Aboriginal Nations

Murray Lower Darling Rivers Indigenous Nations

Cultural Heritage of Lake Victoria

Mining and other industries

Mining and other manufacturing industries use about 1% of the Murray–Darling Basin water, with a large portion of this coming from groundwater in the Great Artesian Basin. Although this is a small amount compared to agricultural use, mining activities can have a large, localised impact on water use through ore production or oil and gas extraction.

Conservation groups

Conservation groups are often involved in supporting the health of local rivers and wetlands. They can range from larger statewide (or nationwide) organisations to small local groups. These groups often rely on donations and are largely supported by volunteers who help monitor and carry out on-ground tasks in the local areas.

Australian Conservation Foundation

Murray–Darling Wetlands Working Group

Community members

Members of the community who live and work in towns, cities and on rural or semi-rural properties all use or have an interest in the water in the Basin. This water is used for human consumption, in households, businesses, in gardens and having areas available for recreation.

Water in the Murray Region

Tourists

Water attracts local, regional and international tourists to witness the wildlife and scenery that comes with healthy rivers, lakes and dams. Activities can include birdwatching, fishing, skiing, photography, history or enjoying simple family gatherings. Tourism in turn provides a lot of income to local businesses.

River Murray System – River Recreation

Destination NSW state tourism statistics

Recreational fishers

There are an estimated 430,000 recreational fishers in the Murray–Darling Basin, which currently contribute around $1.3 billion each year to the Australian economy (www.dpi.nsw.gov.au). Fishers rely on having healthy rivers that support fish populations.

NSW Department of Primary Industries – Recreational fishing

Murray–Darling Basin Authority – Social and economic analysis

Teacher notes for Inquiry task, Step 2

This step is best done as a class.

Students need to identify stakeholders in the local region who use/manage water or have a position on providing water for the environment (as a class or in groups).

The idea of the Water Inquiry Forum is to replicate real-life conditions to show the complexity of dealing with many different stakeholders that all have strong opinions and their own considerations to make.

Brainstorm a list of potential stakeholders with students. They should have some idea from the variables they used to pick their waterway. Local knowledge of their area should also help identify stakeholders.

A list of possible stakeholders, with some links to relevant information, has been provided to help students get started. This is general information. Students need to choose, or be allocated, a stakeholder for their research and report, so make sure they know to be more specific and give the stakeholder they choose personality. This will also help narrow down their research and give them direction.

For example:

- Instead of ‘irrigation farmer’, choose Bruce Banner, a dairy farmer from Hulking Farm near Wagga Wagga.
- Instead of ‘State Government’, choose Diana Prince, a water manager from the Department of Planning, Industry and Environment in Albury.

The Water Inquiry Forum will be more successful if students have chosen stakeholders with a diverse range of opinions.

Step 3: Stakeholder report and Water Inquiry Forum

The idea of the Water Inquiry Forum is to replicate conditions showing the complexity of dealing with many different stakeholders that have strong opinions and their own considerations.

From Step 2, you will have been **assigned a stakeholder to research** as an individual or as part of a small group. From your research, you will **prepare a report** that represents

> **Hint**
>
> Applying the questions raised in the Background section to your stakeholder may also help with the type of information you need for the Forum.

your stakeholder's thoughts about water management in the region and managing water for the environment.

You will then give a **presentation at the Water Inquiry Forum** on behalf of your stakeholder – the length of presentations will be determined by your teacher.

Your report and presentation to the Water Inquiry Forum can be in any format that you think will impress and convince other stakeholders of your views about water for the environment. Evidence should be provided to support your report using a range of multimedia. For example, evidence could include maps, facts, quotes, statistics, graphs, video and photos.

Report structure

In the introduction, provide a brief description of your chosen waterway to set the scene in your report. Details should include:

- site information
- variables contained in the region (see Step 1)
- a list of possible water users or stakeholders.

Include evidence such as maps, river profiles and photos that highlight the area of study.

Main body – This section should represent your stakeholder and include information such as:

- Who/what organisation your stakeholder represents.
- How your stakeholder/your stakeholder's organisation supports the surrounding community.
- Why water is important to your stakeholder and their water needs.
- What are your stakeholder's responsibilities for managing water? Provide examples of how they manage water effectively.
- Whether your stakeholder has any issues relating to how water is used or managed in the chosen region. Do they have concerns with how other stakeholders use water?
- Your stakeholder's perspective on water allocation for environmental and cultural purposes.
- Are there things that your stakeholder could do differently to use less water? Do you think there is enough support given to help your stakeholder make these changes? If your stakeholder is not a water user, is there anything they could do to help others manage water?
- Should your stakeholder have to, or are they willing to, make sacrifices or modify their behaviour regarding water so there is more available to help create healthy rivers and wetlands?

Teacher notes for Inquiry task, Step 3

In this step, students are to research and prepare a report taking the position of a particular stakeholder. Reports should represent the stakeholders' water needs, and issues they have with water in the region or other stakeholders. Students should also provide their perspective on water releases designated for environmental or cultural purposes. Students will be required to present this report to the class in small groups or as individuals as part of a Water Inquiry Forum.

This is best completed in small groups (or by individuals). For a Water Inquiry Forum to be successful we suggest having at least eight different perspectives represented.

Set expectations – This activity has been designed to be flexible depending on year level, ability of students and time available. It is suggested that teachers set their own minimum page (or word) limit for the stakeholder report and determine the maximum time limit for presentations.

Report presentation – This is a chance to allow some freedom to see what individual students/groups think is important to their stakeholder. Encourage students to express themselves using a range of multimedia during their presentation. The most important thing is to keep students on task by reminding them that the aim of the activity is to examine issues regarding the management of water for the environment through the eyes of stakeholders that have interests in their chosen waterway/system.

You may choose to specify that the class pays attention to specific points to give students focus.

Evidence – In a forum of this sort, evidence to back up a presentation should be provided. Encourage students to include maps, facts, quotes, statistics, graphs, video and photos.

Seeking expert advice – As mentioned in the activity sheets, students will gain valuable insight by contacting someone who works in the field of the stakeholder they are representing. Teachers should set parameters for the class if they are contacting experts. Alternatively, you might choose to arrange for a local expert to talk about water for the environment, such as a water manager, and relate it to stakeholders throughout the region.

Conducting the forum – Teachers should act as moderators for the forum. They could even participate by acting in the role of the Australian Government, listen to all ideas and opinions, and recommend a policy regarding water for the environment for the chosen region. Alternatively, this role could be done by a suitably skilled student.

Students should be reminded to pay close attention to their peer stakeholders and take notes to help them complete the self-assessment and reflection section.

Step 4: Self-assessment and reflection

The last part of your report will be written after the Water Inquiry Forum. This will give you a chance to reflect on what you have heard and seen during the forum, as well as provide and assess the information both you and the other stakeholders presented.

During the Water Inquiry Forum, make notes on the other stakeholder's presentations to revisit when you write up this section. Use this table as a guide for each presentation.

Water Inquiry Forum stakeholder notes	
Stakeholder	....
Rate the strength of the presentation and whether it was convincing: 1 (poor) to 5 (excellent)	....
Does their water use have an effect on your stakeholder?	....
Was there anything that you strongly agree or disagree with?	....
Could you work with this stakeholder to achieve better water management outcomes?	....
Did their perspective influence or change your point of view?	....

Use your notes from the other presentations and the questions below to write a conclusion to your report

- Do you think the forum was productive?
- Do you think it gave a suitable platform for concerned stakeholders to both showcase how they manage water and raise any concerns they have with the management of water for the environment?
- Do you have any particular issues with other stakeholders? Was there anything in their presentation that you strongly agree or disagree with?

- Have you changed any of your thoughts or opinions regarding your own water use?
- Did you learn anything that could help your stakeholder manage water better?
- Do you think you could work with the other stakeholders to try and find a balance to meet everyone's needs?
- Have you any further recommendations on behalf of your stakeholder concerning managing water for the environment?

Teacher notes for Inquiry task, Step 4

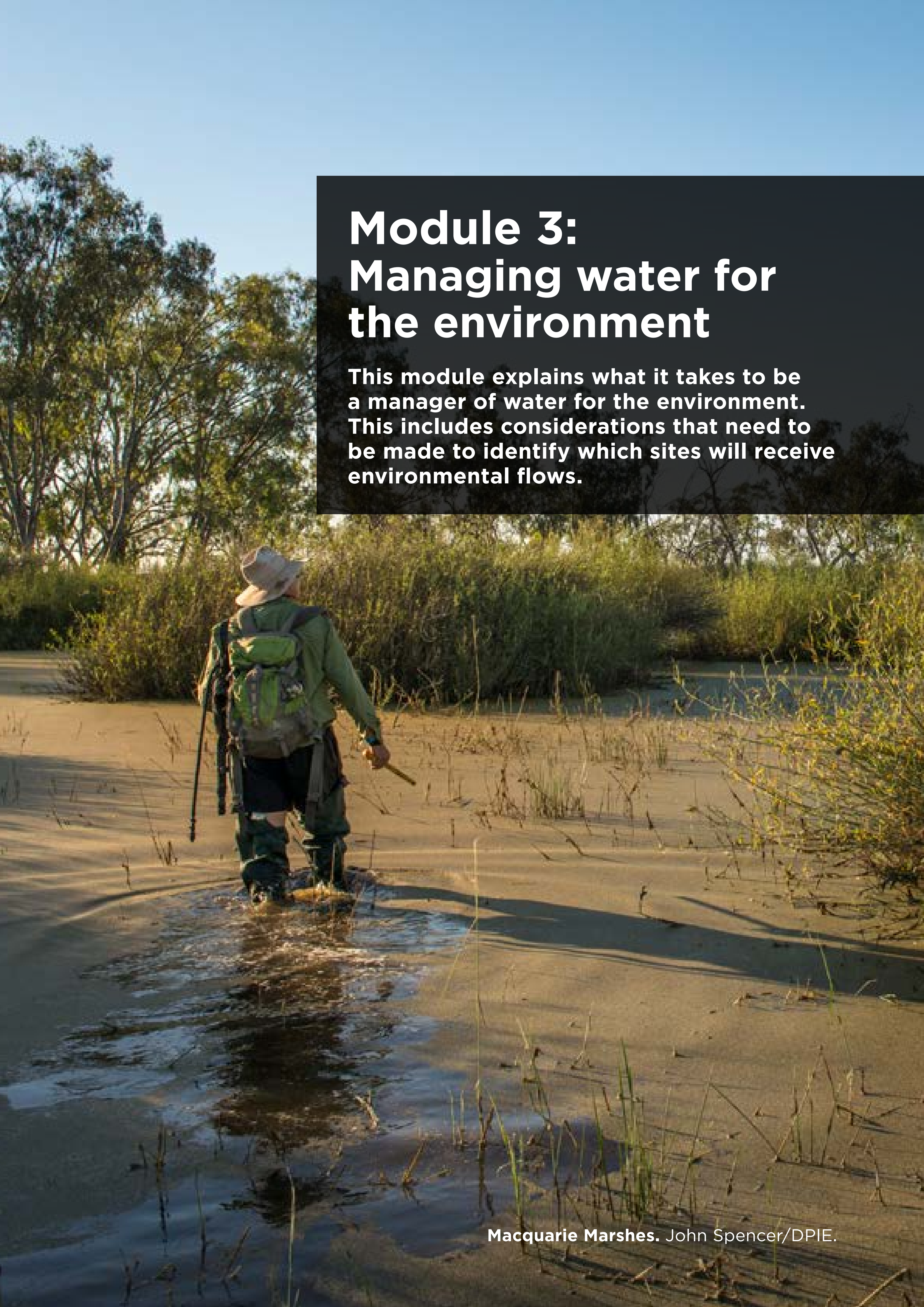
After presenting their reports and listening to reports from other stakeholders, students should reflect on their position and determine whether they would be willing to work more closely with other stakeholders to help keep our rivers and wetlands healthy.

As their stakeholder personas, would students be willing to make sacrifices or modify behaviours for the benefit of healthier rivers? Do they think that the various stakeholders represented could come to some sort of agreement or consensus?

This should be the conclusion to their report. Presenting this reflection to the rest of the class should be optional.

Module 3: Managing water for the environment

This module explains what it takes to be a manager of water for the environment. This includes considerations that need to be made to identify which sites will receive environmental flows.



Macquarie Marshes. John Spencer/DPIE.

Overview of materials

These teaching materials include the overview information and activities provided for students in Rivers: Sharing our water Student workbook plus additional background content, questions and resources to help teachers deliver Module 3.

They include:

- Australian curriculum outcomes and cross-curriculum priorities.
- An introduction that describes managing water for the environment for teachers.
- The 'Overview: Managing water for the environment information' content provided to students with teacher notes for each section to help teachers make sure students understand the topic.
- The content for Student activities 3.A–3.E and 'teacher notes' on each activity for teachers to use to guide students through each task. Teachers notes are included at the end of each task. Answers for each task have been included with teacher notes.
- 'Resources' boxes highlight what resources students will need to complete each task.

Yarrawonga Weir. Natasha Childs/DPIE.

Australian curriculum outcomes

Table 6 Australian curriculum links for Module 3: Managing water

Subject	Year	Curriculum Link
Geography	7	**ACHGK038:** The way that flows of water connects places as it moves through the environment and the way this affects places explaining how the movement of water through the environment connects places (for example, the melting of snow in spring feeding rivers and dams downstream) investigating the environmental, economic and social uses of water and the effects of water as it connects people and places (for example, the effects of water diversion in the Snowy Mountains) investigating the importance of environmental flows
	8	**ACHGK051:** Human causes and effects of landscape degradation describing the effects of river regulation including dams, locks, channel straightening and drains, on riverine and wetland landscape quality
	9	**ACHGK061:** Human alteration of biomes to produce food, industrial materials and fibres, and the use of systems thinking to analyse the environmental effects of these alterations investigating ways that the production of food and fibre has altered some biomes (for example, through vegetation clearance, introduction of exotic species, drainage, terracing and irrigation) identifying the differences between natural and agricultural ecosystems in flows of nutrients and water, and in biodiversity **ACHGS065:** Represent multi-variable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies creating a diagram to illustrate the flows of nutrients and energy within a biome, and the alterations to these flows produced by agriculture
	10	**ACHGK070:** Human-induced environmental changes that challenge sustainability discussing the concept of sustainability in relation to environmental functions identifying human-induced environmental changes (for example, water and atmospheric pollution; loss of biodiversity; degradation of land, inland and coastal aquatic environments) and discussing the challenges they pose for sustainability **ACHGK073:** The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated **ACHGK074:** The application of geographical concepts and methods to the management of the environmental change being investigated proposing geographical management strategies for the environmental change being investigated (for example, establishing reserves and corridors to preserve biodiversity (a spatial strategy), ecosystem-based management (an environmental strategy), urban planning to reduce energy consumption (a spatial strategy), and addressing underlying as well as immediate causes of environmental change (holistic thinking)) **ACHGK075:** The application of environmental economic and social criteria in evaluating management responses to the change explaining how communities and governments attempt to balance environmental, economic and social criteria in decisions on environmental programs, and the extent to which there can be trade-offs between them discussing the extent to which achieving sustainability in one place should take account of the effects on environmental conditions in other places in the context of the environmental change being investigated

Subject	Year	Curriculum Link
Science	9	**ACSSU176:** Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems examining factors that affect population sizes such as seasonal changes, destruction of habitats, introduced species investigating how ecosystems change as a result of events such as bushfires, drought and flooding

Cross-curriculum priorities

Table 7 Cross-curriculum priorities addressed by Module 3: Managing water

Sustainability	
Organising ideas	
Systems	
OI.1	The biosphere is a dynamic system providing conditions that sustain life on Earth.
OI.2	All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.
Futures	
OI.8	Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts.
OI.9	Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

This module supports students to expand their knowledge of water for the environment by assuming the role of someone who has been recently employed by the Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE – EES). In this scenario they have become part of the team that manage water for the environment. Their first task in their new position will be to complete a series of activities to demonstrate they understand relevant concepts.

It is recommended that students complete Module 1: Aquatic Ecosystems and Module 2: Sharing Water in the Basin before starting this module. Module 3 expands on the information contained in the first two modules and applies it to a practical workplace scenario.

This module has been designed as a student-driven project/assignment. Teachers can give this module to students to work through at their own pace. However, it is strongly recommended that teachers go through the overview and each of the student activities for this module as a class to make sure students understand the topics and activities involved.

Module 3 is designed as one assignment task, but each activity (i.e. Student activities 3.A, 3.B, 3.C, 3.D and 3.E) can be completed individually.

Joining the water for the environment team

Welcome to your new job!

Resources

Student activity 3.A worksheet

String.

You have now become part of the Water for the Environment Team that manages water for the environment at the NSW Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE – EES).

As our newest member you will be required to demonstrate your understanding of concepts relating to water for the environment by applying your knowledge to a series of tasks.

Why does water need to be managed throughout the Murray–Darling Basin?

Watch this video

What is water for the environment?

Rivers, creeks and wetlands play a vital role in sustaining healthy communities and economies. They provide connections across the landscape for people, plants and animals with benefits that extend well beyond the riverbank. Healthy rivers and wetlands support native wildlife alongside a range of industries, including irrigation, dryland agriculture, fishing, tourism, timber production and beekeeping.

To try and ensure water supply meets the demands of the population, water regulation in the Murray–Darling Basin has been necessary. This has seen the construction of many large water storages (dams) and diversion of water resources to support the survival of the Basin's families, communities and industries.

Fields studies at Macquarie Marshes. John Spencer/DPIE.

While these storages are essential to supporting human endeavours, this regulation has changed the natural water flow patterns through the Basin's creeks, rivers and wetlands. This in turn has affected the natural ecosystems that rely on flowing water or periodic flooding.

Water that is allocated and managed specifically to improve the health of rivers, wetlands and floodplains is known as water for the environment. It is the best tool we have to try and ensure a range of flows to protect and preserve our natural environment.

The Water for the Environment Team uses the best available science, management expertise and experience to identify watering sites and provide the right amount of water where and when it is needed to maintain the health of the Basin's rivers and wetlands.

Your roles and responsibilities as a manager of water for the environment

Water for the environment is one of the most effective conservation tools to achieve the environmental outcomes of health, recovery and maintenance for our rivers and wetlands in the Murray–Darling Basin.

An environmental water manager needs to:

- Consistently monitor the recent and current water situation in the catchment (and nearby catchments). This includes:
  - monitoring where and when any rain has fallen
  - knowing how much water made it into the system
  - understanding recent, current and predicted flows – this includes rainfall, irrigation, environmental flows and any other water that contributes to or moves through the system
  - finding out where the flows go (e.g. were they stored or extracted for other purposes)
  - determining whether any rain is forecast for the short and long-term future
  - knowing how much water is currently available to be used for environmental purposes.
- Know what the natural environmental assets of river systems in their region are (geographical region and features) and the values they have to the health of the aquatic ecosystem (fish, frogs, birds, yabbies, vegetation and natural processes and functions). Part of this is knowing where these natural assets are, how significant they are (so they can be prioritised) and what are their general environmental water requirements.
- Know what the natural flow regime for different environmental assets was like before regulation and redistribution – different types of water flows (height and rate), durations of inundation (how long they are covered) and timing of flows (time of year and frequency of inundation).

- Know the current health condition of assets. This includes knowing the recent watering history and observations of the health of the aquatic ecosystem, such as whether the vegetation looks healthy or is dry/dying.

Know what the rules are that apply to the water/waterway being managed – carryover, delivery constraints, consideration of other users (e.g. channel capacity constraints).

Managers of water for the environment consult with environmental water advisory groups to determine priorities and the desired actions for the next 1–3 years. Recommendations are put forward to the DPIE – EES Water for the Environment Team and partner agencies. Managers of water for the environment then make decisions and adapt to changing conditions over the allotted time period. Monitoring and reporting on outcomes achieved then helps inform all parties on the success of the flows released and helps to improve management decisions about future deliveries of water.

Peron's tree frog, *Litoria peronii.* John Spencer/DPIE.

What you are required to do

Your first task in your new job is to prepare a report to demonstrate to colleagues and the community your skills in managing water for the environment.

The report will be based on a series of tasks that have been designed to demonstrate your knowledge and understanding of water for the environment. The tasks require you to examine different aspects of the Murray–Darling Basin and its catchments and identify priorities for providing water for the environment.

Your report will include:

Student activity 3A: Environmental assets and values

- Task 1: Identify environmental assets. A profile of one of the rivers of the Murray–Darling Basin.
- Task 2: Assets with high values. Explain three of the Basin's assets describing a particular high-value feature.

Student activity 3B: Flows

- Task 1: Decipher flows and seasons. Examine flows through a regulated system at a particular point.
- Task 2: Summarise the flow. Explain a flow graph for colleagues and the wider community.

Student Activity 3C: Weather and planning

- Task 1: Resource availability scenarios. Define the resource availability scenarios that DPIE – EES and partner agencies use to determine priorities for water for the environment releases.
- Task 2: Resource availability scenarios and flow events. Use a conceptual flow hydrograph and the flow regime to help determine priorities for water for the environment releases.

Student Activity 3D: Examine natural versus regulated flows

- Task 1: Natural versus regulated flows. Research appropriate river data, interpret data and create a hydrograph to compare flows through a natural and a regulated system.
- Task 2: Analyse the data. Through analysing the data, identify the effects of regulation on a waterway.

Student Activity 3E: Counting flows

- Task 1: Count all flows. Map points in the upper Murray River region and analyse river flow data to determine the amount of water that continues through the system and the amount held in storage by regulation.

Tree trunks along the Darling River indicate past water heights. Terry Cooke.

Teacher notes

Welcome to your new job!

This first section provides an overview of Module 3, introduces students to the idea of working with the Water for the Environment Team and includes a summary of the five activities students need to complete.

Why does water need to be managed throughout the Murray–Darling Basin?

This section introduces the theme of Module 3: Managing water. Students assume the role of someone who has been recently employed by the Water for the Environment Team at DPIE – EES. Revise why water in the Murray–Darling Basin needs to be managed with students.

Your roles and responsibilities as a manager of water for the environment

This section summarises the roles and responsibilities that their new job entails. Use this section to set the scene for Module 3.

What you are required to do

This section outlines the report that students are being asked to prepare in their role with DPIE – EES. It summarises the activities they will be required to complete for Module 3. Each activity has been divided into tasks. Go through this section and make sure students understand the activities involved.

Part A: Environmental assets and values

Common yabby, *Cherax destructor*. Carmen Amos/DPIE.

Water is life, and is useful for both human use (drinking, agriculture, recreation, mining), and for river and floodplain health. Where a conflict in the use of this natural resource occurs, things need to be managed or one use will prevail at the expense of others. This is especially necessary when some assets and values are not monetary or economic, such as natural or environmental assets.

Each river system that makes up the Murray–Darling Basin has different areas that are particularly significant to the health of the natural landscape. These are what managers of water call environmental assets.

Water is a precious resource. Decisions must be made to prioritise how, when and where it is used. The higher the significance of these environmental assets to aquatic ecosystems and the overall health of the system, the more important it is to make sure they receive sufficient water.

Environmental assets can include any part of the aquatic ecosystem, such as the geography/topography of an area, wetlands/swamps/billabongs, water storages/dams, lakes, flood plains and river channels themselves. These areas are considered important assets because their health may help:

- improve connectivity of rivers, creeks and wetlands
- maintain the condition and diversity of lowland floodplain forests and woodlands
- support plant species in wetlands and rivers
- maintain current species diversity and support breeding success of permanent and migratory waterbirds
- improve distribution and breeding success of native fish and other aquatic species
- provide pathways for species to move throughout the Murray–Darling Basin
- hold water for later redistribution
- increase river and wetland health supporting cultural purposes.

The values of these environmental assets are a way of determining and prioritising how important they are to the natural processes and functions of the biotic components of the aquatic ecosystem (fish, frogs, birds, yabbies, vegetation etc). An asset is deemed to have a high value if it is essential to the ability of these creatures to flourish and survive.

An environmental asset with high values is considered more significant and higher priority when deciding where to supply water for the environment.

Teacher notes

The introduction for Part A is a fact sheet designed to revise some information about water for the environment from previous modules and introduce the idea that environmental assets have values that make them a priority to receive water. Focus on:

- water being a resource that is in-demand and needs to be managed
- the dot points that outline desired outcomes of water for the environment
- that assets are given different values and priorities.

Relate this information to a waterway close to your school by asking students questions like:

- Does the waterway have water in it all the time?
- Where and how does it connect to the local major river catchment and the Murray–Darling Basin?
- Is it regulated (storage dams)?
- Is it used for human purposes – drinking water, agriculture, industry etc.?
- Could any parts of the waterway be considered environmental assets (wetlands/swamps/billabongs, water storages/dams, lakes, floodplains and the river channels themselves)?
- Are there any native plants and animals that use the waterway (values)?

Egret, Macquarie Marshes. John Spencer/DPIE.

Student activity 3A Environmental assets and values

Task 1: Identify environmental assets

This activity will test your ability to identify possible significant environmental assets along a waterway. You are to create a profile line of a waterway with labels identifying its environmental assets. This may be completed using a ruler and piece of string or appropriate computer software – see example below.

Step 1: Choose your waterway

The activity can be done on any waterway within the Murray–Darling Basin, but it is best to choose one of the major rivers that has regulation (water storage), a diverse range of uses and a range of identifiable environmental assets.

Step 2: Obtain maps of your waterway

Use a range of printed or digital maps and resources to develop the most accurate and informative representation of your waterway. Maps can be found in your library, on the internet, or will be provided by your teacher.

It is important for accuracy to use only one map for reference to measurement, as different maps may use different scales. Confining the scaled map to an A4-size page will keep the task manageable. The other maps will help you identify the environmental assets along the waterway (estimate where they are if not on the main map).

Geographic profile maps for Basin catchments produced by the Murray Darling Basin Authority (MDBA) may help with this task.

Step 3: Create a base profile line for your waterway

On your main map, take a piece of string and mould it so it follows the path of the river you have chosen, from its beginning to where it ends and becomes part of another river or goes out to sea. This string equals the length of your waterway.

Mark the beginning and end of your waterway on the string, use different colours to distinguish between the beginning and the end. Stretch out the piece of string in a straight line on a blank A4 sheet of paper and mark out your waterway profile line.

Step 4: Work out the scale for your map

Maps use scales to represent distance. Using the scale of your main map, the string and a ruler, work out and mark the distance from the beginning to the end of your waterway. First, measure the piece of string and use the map scale to work out the length of your stretch of river.

For example, if the scale is 10 millimetres (mm) = 50 kilometres (km) and the string is 137 mm long, then the river length is 685 km (137 mm ÷ 10 mm = 13.7 x 50 km = 685 km). Then mark the beginning of the waterway profile line you've drawn with 0 km and the end with its length (e.g. 685 km).

Step 5: Identify environmental assets

Use the scaling map and string to mark potential environmental assets along the profile line of your waterway. Label each asset with its name and a brief note on why it is an asset. You may also wish to label places (maybe in a different colour) where you think high water consumption for human use will occur on your river profile.

Teacher notes for Task 1

For this task, students will use a piece of string, ruler and map to create a basic profile line of a river. They will need to:

- choose a river from the Murray–Darling Basin
- research on the internet (or in the library) to find a suitable map
- use a piece of string and ruler to work out the waterway's length.

It is best to choose a longer, more major river that has regulation (dams) along its length.

Students will:

- use the scale on the map to calculate the length of their river
- create a profile line for the chosen river
- research a range of points that are considered environmental assets and mark them on the profile line
- mark other features of environmental or geographical significance.

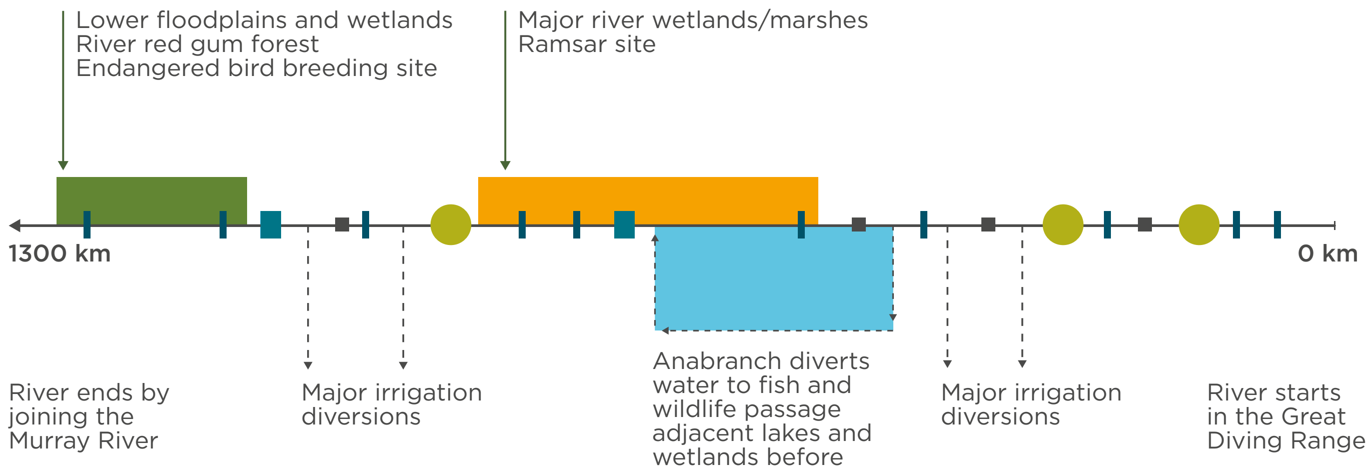
Environmental assets can include any part of the aquatic ecosystem, such as the geography/topography of an area, wetlands/swamps/billabongs, water storages/dams, lakes, floodplains, tributaries and the river channels themselves.

The Murray–Darling Basin Authority's river profiles will be a helpful reference.

An example of a river profile is provided with the student task.

Answer for Task 1

See the example river profile provided with this task.



Example river profile.

Task 2: Assets with high values

There are many important assets spread throughout the Basin that have high values when it comes to the processes and functions of the plant and animal species that live there. These are priorities when it comes to decisions regarding water for the environment as water managers only have a limited amount of water available to use.

Six environmental assets with high-value biotic features that are important to consider when managing water for the environment are pictured here.

Lake Brewster, pelicans.
Vince Bucello, Midstate Video Productions.

Barmah–Millewa Forest, river red gums.
Kelly Coleman Photography.

Yanga Creek and Yanga Lake, golden perch.
Vince Bucello, Midstate Video Productions.

Gwydir Wetlands, view from the Bunnor bird hide.
David Preston/DPIE.

Macquarie Marshes, vegetation communities.
John Spencer/DPIE.

Edward–Wakool rivers, Murray cod.
Natasha Childs/DPIE.

Choose three of the six assets and write a 100–150-word description for each explaining why the item specified is considered high value and worth providing environmental flows through the system to protect.

In your description include:

- details of the river system where the asset occurs
- whether the asset has recognition nationally/internationally for its importance
- why the processes and functions of the species/item are considered high value
- the time of year it is important that the asset/s have different flows
- details of recent environmental flows that have been released to support them.

The DPIE Water for the environment webpage may be a helpful reference.

Teacher notes for Task 2

Managers of water for the environment have only limited amounts of water to use for environmental flows so they must prioritise how and when they use water. Environmental assets considered to have a high value are more likely to be given environmental flows. Raise the point that these flows also benefit the whole system that they flow through. For example environmental flows released from Hume Dam and Lake Mulwala that are for the Barmah–Millewa wetlands have a positive impact on habitats between the two water storage reservoirs and the Barmah–Millewa wetlands – a stretch of around 150 kilometres of river environments.

Students are to research three environmental assets and the particular features that make them high value and write a 100–150-word summary on each of the points provided. The water for the environment section of the DPIE – EES website has useful information about flows and their outcomes from the last few years.

Encourage students to conduct other searches online or in the library for assets, asset values, priorities, water for the environment and environmental flows to find extra information to support their research.

Answers for Task 2

These are examples of the types of information students can find through their research.

Lake Brewster – pelicans

Lake Brewster is in the Lachlan River catchment and sits adjacent to Mountain Creek and the Lachlan River east of Hillston. Lake Brewster was originally a natural ephemeral wetland. It was developed in the 1950s into a secondary storage to re-regulate the delivery of water to the lower Lachlan. More recently, work has been undertaken to restore wetland habitats in the lake.

Lake Brewster is an important site for pelicans. It is one of the few sites in the Murray–Darling Basin where pelicans breed in large numbers on a semi-regular basis. Pelicans are known to have nested at Lake Brewster since 1984 when records were first kept. In recent years the size of the pelican colonies has increased, having as many as 8000 birds in the summer depending on water availability. WaterNSW manages water storages and delivery in the Lachlan Valley, and NSW DPIE – EES manage the water for the environment program. These two organisations have been working together to enable waterbird breeding events at the lake to complete successfully.

In 2017–18, for the first time since the construction of the outflow wetlands, water for the environment provided the trigger for extensive beds of water milfoil, ribbon weed, rushes and water grasses to establish. This flow also supported a pelican breeding colony of 4500 nests with over 3000 juveniles ready to fledge.

A tagging (or banding) program has been established at Lake Brewster to help scientists track bird movements and learn more about their needs.

Barmah–Millewa Forest – river red gums

Barmah–Millewa Forest is situated on the NSW/Victorian Border stretching from the small township of Tocumwal to Barmah. The Murray and Edward rivers wind through the forest, as well as numerous smaller creeks.

Barmah–Millewa Forest is listed as a Ramsar site, meaning it is a wetland of international importance. To be listed as a Ramsar site, an area needs to meet certain criteria. For example, the Barmah–Millewa Forest meets Criterion 1: Representative or unique wetlands, as it is Australia's largest area of river red gum forest. The forest has trees that are more than 200 years old and areas that are structurally equivalent to undisturbed forest. This is despite parts of the forests being harvested for timber for 150 years. The site also has other wetland types such as floodplain lakes, moira grass plains, meadows and reed swamps.

Unless natural flooding events occur, the Barmah–Millewa Forest is a priority site to receive water for the environment each spring to help replace flows that are harvested through regulation.

There are 4 high-level ecological objectives of water for the environment for the Barmah–Millewa Forest:

- restore the extent and distribution of healthy wetland and floodplain vegetation communities
- provide suitable feeding and breeding habitat for a range of waterbirds, including colonial nesting species
- support successful breeding and recruitment of native fish species
- provide high-quality feeding, breeding and nursery habitat for native frogs, turtles and crayfish.

Yanga Creek and Yanga Lake – golden perch

Yanga Lake is situated south of Balranald on the edge of the Murrumbidgee Valley State Conservation Area and connected to the Murrumbidgee River by Yanga Creek.

The lake and creek provide critical habitat for native fish in the Murrumbidgee region and Yanga National Park. The lakes of the lower Murrumbidgee, including Yanga Lake, can be a great nursery environment for the fish to grow and a food source for thousands of pelicans and other birds that feed on the fish.

Late winter/spring flows in 2017 and 2018 helped to ensure fish had suitable conditions to breed. Scientists say it is important to ensure priority sites such as Yanga National Park are protected during dry times, providing refuge habitat so native fish and other wildlife are ready to respond when the dry conditions ease. Yanga Lake is an important monitoring site to research the effect of water for the environment on fish populations.

Gwydir Wetlands – the Bunnor bird hide

The Gwydir Wetlands are situated on the Gwydir River in north western NSW, west of the township of Moree. They are an example of terminal delta wetlands, which are found when a river delta occurs in an inland valley. They are among the few inland wetlands of this kind remaining in the Murray–Darling Basin.

The Gwydir Wetlands are listed as a Ramsar site, meaning it is a wetland of international importance. The site meets a number of criteria listed under the Ramsar Convention, including Criterion 2: Threatened species or ecological communities. This recognises that the Ramsar site supports threatened species including the Australasian bittern and Australian painted snipe. This site is an important breeding and feeding site for these species as well as supporting other processes and functions.

In the Gwydir River system, managed flows from December to January help to restore a more natural flow regime, with these flows aimed at assisting and extending ecological processes.

Macquarie Marshes – vegetation communities

The Macquarie Marshes is situated about 100 kilometres north of Warren in central west NSW. It comprises wetlands associated with the floodplains of the Macquarie River and its tributaries.

The Macquarie Marshes are listed as a Ramsar site, meaning it is a wetland of international importance. The site meets a number of criteria in order to be listed under the Ramsar Convention including:

- Criterion 1: Representative or unique wetlands, which recognises the Macquarie Marshes are one of the largest remaining inland, semi-permanent wetlands in the Murray–Darling Basin and have a high diversity of wetland types. This Ramsar site is an example of a wetland that relies on runoff from high rainfall in the upper catchment. The Macquarie Marshes site has extensive and changeable wetlands in its semi-arid lowland reaches.

- Criterion 3: Populations of plants and/or animals important for maintaining the biodiversity of a particular bioregion, which recognises the Macquarie Marshes contain a variety of habitat types, and consequently the plant and animal species of the site are particularly diverse.

Flows in spring help to inundate semi-permanent wetland vegetation communities including reedbeds, water couch, mixed marsh and river red gum forest. These vegetation communities are essential to the health of the Macquarie Marshes, supporting the processes and functions of the diverse species that rely on them.

Edward–Wakool Rivers – Murray cod

The Edward–Wakool River system is a large anabranch of the Murray River in south-western NSW, comprising a complex network of interconnected streams, ephemeral creeks, flood runners and wetlands. An anabranch is a section of a river or stream that diverts from the main channel or stem of the watercourse and rejoins the main stem downstream.

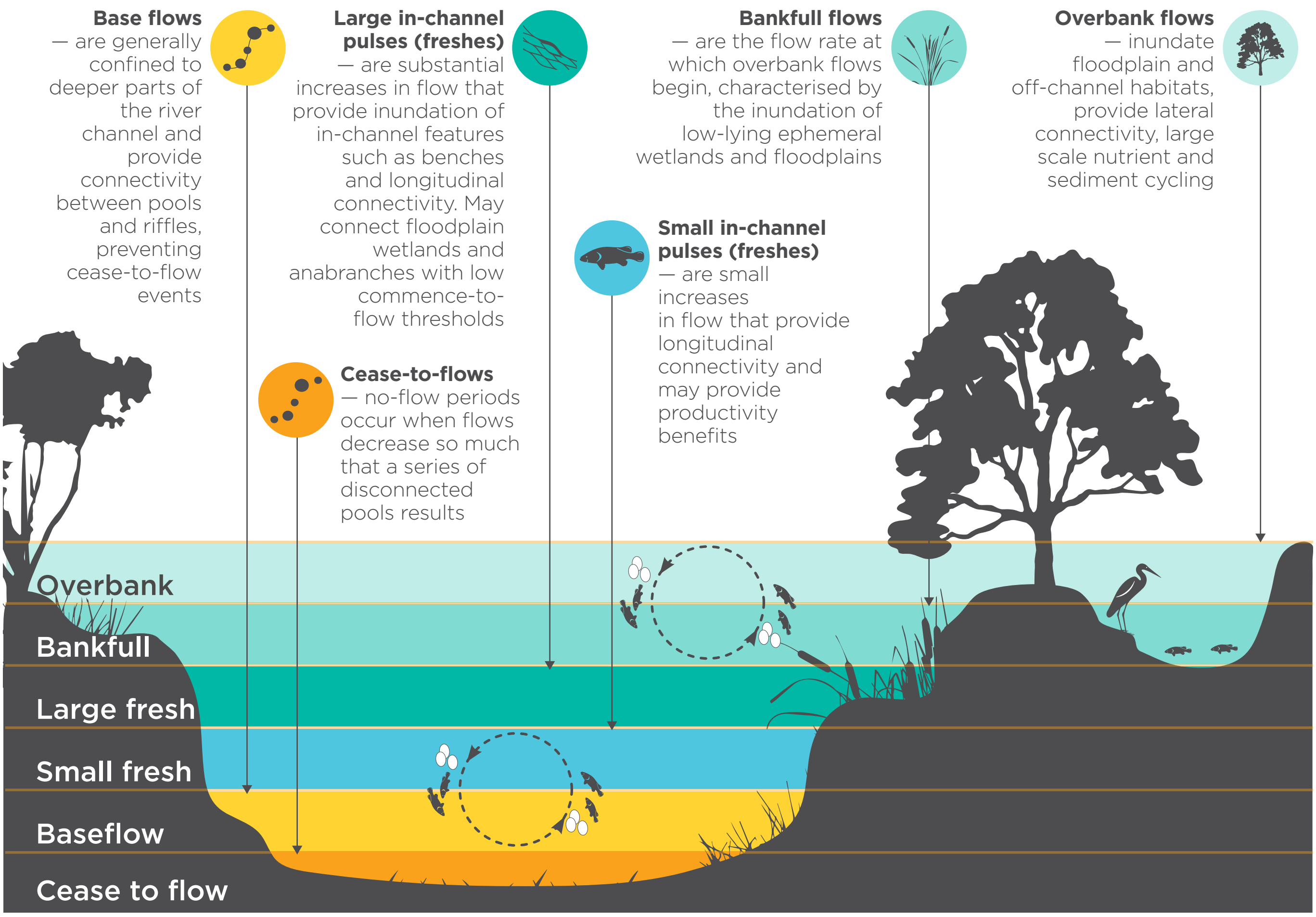
The Edward–Wakool River system supports important ecological values including 20 significant plant and animal species. The system is particularly important for fish spawning, especially Murray cod. Water for the environment is essential to river connectivity, providing pathways for Murray cod to move throughout the system. Flows release and carry essential nutrients that provide food for native fish. Flows also recharge groundwater reserves, supporting a myriad of wetland plants and provide important habitat for Murray cod and other species both instream and across the surrounding floodplains.

Part B: Flows

Water for the environment is a share of the water held in dams that is used to support the health of native plants, animals and ecosystems. It is a transient state in many cases, where water might be held in a dam (giving an environmental benefit), delivered down a river (another benefit) and then extracted where rules permit. River systems use water at all times and all of these flows must be considered when managing water for the environment and determining how to use managed environmental water accounts and allowances.

In regulated systems some water is caught by dams, which changes the type and timing of flows that would be released into the river under pre-regulation conditions. Flows are still provided by dams, but they might occur in a different season to support farming, mining, townships and other human uses. These changes mean the environmental assets and values get different water volumes, events, season and frequency than what is natural. Managers of water for the environment try to use the water in their accounts to reduce the effects of these changes by having flows released that reflect a more natural flow pattern.

Maintaining healthy rivers and wetlands is essential for the freshwater ecosystems they support. These ecosystems rely on a range of different types of water flows (heights),



Components of the flow regime.

durations of inundation (how long they are covered) and timing of flows (time of year and frequency of inundation) to support the diversity of plant and animal species. Water provides pathways for plants and animals to move around and triggers suitable conditions for reproduction. The type and timing of flows combined with the duration of inundation is what we call the flow regime.

Teacher notes

Resources

Student activity 3.B worksheet.

Use this introductory section to Part B to revise concepts of the different types and timing of flows that students should have learnt from previous modules.

Focus on these points:

- River regulation is necessary to support human interests, but this has interrupted natural flows.
- Maintaining healthy rivers and wetlands is essential for the freshwater ecosystems and sustainable communities they support.
- Ecosystems rely on a range of different types of water flows (heights), durations of inundation (how long they are covered) and timing of flows (time of year and frequency of inundation).
- Managers of water for the environment use their allotted water to reduce the effects of regulation.

The key concept introduced in activity 3.B is that river systems use water at all times and all of these flows must be considered when managing water for the environment and determining how to use managed environmental water accounts and allowances.

Relate this information to a local waterway and ask your class questions like:

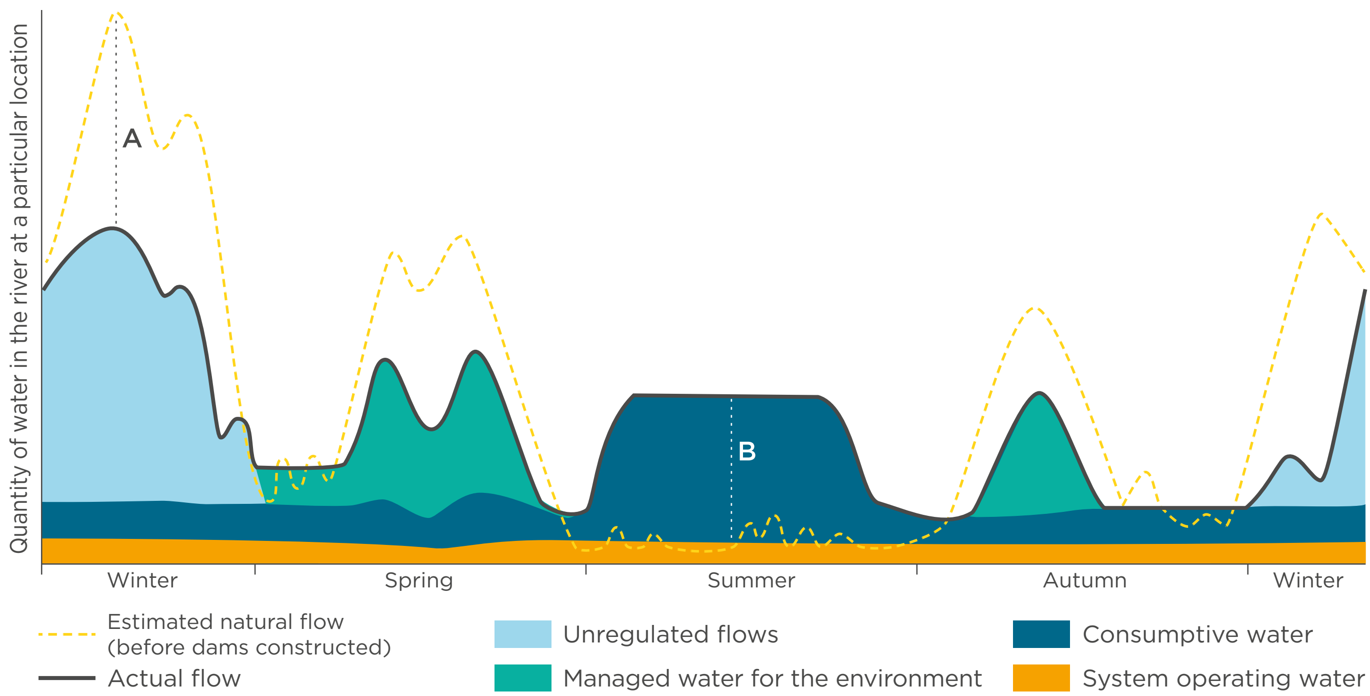
- Is this waterway regulated by storage dams, for example?
- Can students recall this waterway having a range of different flows (changes in water levels – flood events, etc.)?
- What usually happens before a rise in the water level – rain?
- Does the waterway have any marks of record flow/flood events?
- Can they recall what time of year any of these different flows occur (are they more likely in the winter)?
- If it is a regulated waterway it does not necessarily need to rain – in this case where does the water come from (storage dams)?
- What season do flows from storage dams tend to occur in (summer/ hot times for irrigation)?

If suitable, you could go on an excursion to your local waterway and see if students can see any evidence of different flows. These will be visible as debris strewn in the bushes and trees, undercutting of the bank, flood markers etc. See whether students can associate different flow markers/levels with the flow regime – cease-to-flows, base flows, small in-channel pulses (freshes), large in-channel pulses (freshes), bankfull flows and overbank flows.

Student activity 3B Flows

Task 1: Decipher flows and seasons

This graph shows seasonal river flows and it is used by the Water for the Environment Team to represent flows occurring along a regulated (dammed) Murray–Darling Basin river system. Use the questions included with this task to help you decipher what the graph means. Record your answers in your workbook.



Seasonal river flows.

Teacher notes for Task 1

The chart included with this task interprets seasonal flows through a regulated system at a particular point. Questions provided in the task will help students decipher the chart.

The focus of this activity is for students to understand that flows of water for the environment are used to try and restore some of the natural flow patterns that help to maintain river and wetland health.

Relate this to previous discussions about your local waterway. Do students know of any specific environmental flows that have been released into the waterway?

Question 1
The first step is to be able to understand any graph is to identify the y- and x-axes.

a. What does the y-axis represent?

Quantity of water in the river at a particular location.

b. What does the x-axis represent?

Seasons throughout the year.

c. So, we would call this graph Quantity of water in the river at a particular location versus Seasons throughout the year (Y vs X).

Question 2
a. Why do you think the label of the y-axis specifies 'at a particular location'?

The label of the y-axis specifies 'at a particular location' because different spots along the river would have completely different variables. To effectively analyse the flow, readings must be from the same location.

b. Why is it important to point this out?

To make sure people who view the chart realise that all the flow data was taken at the same point along the river and therefore will have the same variables influencing it.

Question 3
a. What does the dotted yellow line represent?

The black dotted line represents the 'estimated natural flow' before dams were constructed.

b. Give a further explanation of what you think this means.

Rivers in the Murray–Darling Basin used to have a complete range of flows and natural timing. This line gives the best indication of what the natural flows would have been like before regulation by storage dams disrupted the natural flow pattern – the flow regime.

Question 4
What seasons do the main peaks of the dotted line (natural flows) occur in?

Winter, spring and autumn.

Question 5
The solid black line represents the actual flow. What does 'actual flow' mean? Is it:

a. The actual amount of rain that fell during the year.

b. The actual flow this system is experiencing passing this particular point, taking into consideration all flows released.

[B] The actual flow this system is experiencing passing this particular point, taking into consideration all flows released.

c. The actual best quantities of flow that the river system has ever experienced.

Question 6
a. Winter has an area of light-blue colour that is labelled unregulated flows. This shows that during winter there is a lot more rainfall and most of the water is allowed to flow down the river to the point where it is measured. But is it truly unregulated?

No.

b. Point A on the graph could be defined as showing:

The difference between the natural flow and the actual flow during winter.

c. Do you think that this means that some of the water flows are still being captured during winter?

Yes.

Question 7
The dark-blue coloured area on the graph is labelled 'Consumptive water'. Think about the words consumptive/consume and give a brief description of what you think the dark-blue area represents.

Consumptive water are the flows used for human consumption to support human endeavours throughout the Murray–Darling Basin. It includes all the flows of water consumed by agriculture, mining, industry, towns and communities.

Question 8
a. When is the highest consumptive water peak?

Summer.

b. Why do you think it occurs during this season?

Summer is the driest time of year and people need water to support agriculture (growing season) and other human endeavours.

Question 9
a. Point B on the graph could be defined as showing:

The difference between the natural flow and the consumptive flow during summer.

b. Explain why there is such a difference between the quantity of those flows in this season.

Water is captured at other times of year so it can be supplied when we need it to support human endeavours during summer.

Question 10
a. What does the green-coloured area show?

Managed flows of water for the environment.

b. When during the year do these peaks occur?

Spring and autumn.

Question 11
What do you notice about the green coloured peaks compared to the natural flows at these times?

The aim of water for the environment is to restore some of the natural flows that would have occurred before regulation. These flows have been released to mimic or extend the peaks of these natural flows.

Question 12
Why do you think that managed water for the environment is released during these seasons in particular?

The natural flow regime for this particular spot would have been dependent on the rainfall during the different seasons. According to the chart there were wet winters, good flows/freshes in spring and autumn, and lower base flows in summer. A lot of the spring and autumn flows are now regulated and stored by dams/water storage reservoirs for human use at times we need them. These flows are released to mimic the natural flows in times of the year that are important to the processes and functions of our plants and animals.

Task 2: Summarise the flow

Now you have answered all the questions about the graph showing quantity of water at a particular location versus the seasons throughout the year. Your job is to write up a summary of these in a way that would explain what the graph is showing to your colleagues and the wider community. You may wish to add more labels to your graph to point out areas of interest.

Teacher notes for Task 2

In this task, students are to use the background information and their answers to the questions to summarise the concepts of the chart in a way that they could explain what it means to others. Encourage students to be as creative as possible with how they present their summary.

Answers for Task 2

Summaries should contain the information included in Student Activity 3B in students' individual styles.

Part C: Weather and planning

Dry riverbed at Paroo River. Terry Cooke.

Over millions of years the native plants and animals of the Murray–Darling Basin have developed adaptations which help them survive and flourish through the variable climatic conditions and natural weather patterns of the Basin. They persist through periods of drought and rain, using the natural timing and frequency of flows, seasons and other weather events to indicate when it is best for them to be active, conserve energy or to breed.

Regulation and extraction of the water has changed the natural flow patterns within the Basin. Supplying water for environmental purposes helps to restore some more natural flow patterns and provide the cues that are absent from a regulated river system.

In your role as a manager of water for the environment, planning for variations in the climate and weather is incredibly important. Outcomes from the supply of water for the environment are tied closely to the range of weather, water availability and the amount of water needed to help aquatic ecosystems flourish and survive.

To help support your planning and decision-making you need to familiarise yourself with the management outcomes that apply to the resource availability scenarios used by the Murray–Darling Basin Authority and DPIE – EES to determine water for the environment priorities.

Resources

Student activity 3.C worksheet

Guidelines for the method to determine priorities for applying environmental water (Murray–Darling Basin Authority 2012)

Annual environmental watering priorities in the Murray and Lower Darling catchments

Restoring native fish populations

Teacher notes

The focus of this activity is our variable climate, which means managers of water for the environment need to plan for a range of weather events and subsequent flows (or lack of flows) to make sound decisions.

Read through the parts of the two reference documents provided in 'Task 1: Resources availability scenarios' with your class to clarify concepts.

Relate this information to a local waterway that your students would be familiar with. Ask students to think about the weather and when their area has been in times of drought, flooding rain, and average rain. Ask them to relate 'resource availability scenarios' to their selected waterway. For example:

- When we have been in drought and the waterway has been dry/very dry, the desired outcomes of water releases for the environment would be to…
- When we have had an average amount of rain and the waterway has been moderate (average), the desired outcomes of water releases for the environment would be to…
- When we have had lots of rain and the waterway has been wet/very wet, the desired outcomes of water releases for the environment would be to…

Student activity 3C Weather and planning

> **Hint**
>
> Is everywhere in the Basin likely to be experiencing exactly the same conditions at once, or should each environmental asset be looked at individually to make sure localised conditions are taken into account?

Task 1: Resource availability scenarios

Read through these two documents and summarise the management outcomes for the resource availability scenarios presented.

Guidelines for the method to determine priorities for applying environmental water (Murray–Darling Basin Authority 2012)

Pay particular attention to:

- Step 2: Determine the management outcomes that apply to the Resource Availability Scenarios
- Table 2: Management outcomes for each RAS.

Murray and Lower Darling catchments – Annual Environmental Watering Priorities 2019–20 (DPIE 2019)

Pay particular attention to:

- weather and water forecast (including the Murray and Lower Darling Resource Availability Scenario information).

Explain why you think environmental water managers need resource availability scenarios to help forecast and prioritise where water is used. Represent these outcomes in a creative way that would be suitable to educate colleagues and the community about why they help guide priorities for delivering water for the environment. For example, present outcomes as a diagram, chart, cycle, poster, PowerPoint (or other digital display), etc.

Include a recommendation on whether you think that the resource availability scenarios should be applied to the Basin as a whole or to individual rivers/environmental assets.

Teacher notes for Task 1

Resource availability scenarios are important for planning. The current water availability and what is forecast helps managers of water for the environment decide where and when to deliver environmental flows.

Ask students to define the resource availability scenarios that DPIE – EES and MDBA use to determine priorities for water for the environment.

Students should understand that the availability of water as a resource determines which priority sites receive water for the environment. Water managers use resource availability scenarios as guidelines to the outcomes they wish to achieve.

In wet/very wet times, the outcomes of water for the environment are focussed on improving the health and resilience of water-dependent ecosystems. In moderately wet times, the outcomes of water for the environment are focussed on maintaining ecological health and resilience. In dry/very dry times the outcomes of water for the environment are focussed on avoiding irretrievable loss of or damage to, environmental assets.

Answers for Task 1: Resource available scenarios

Students individual representations should be based on:

Resource availability scenarios

	Very dry	Dry	Moderate	Wet to very wet
Management outcomes	**Main aim: protect** • avoid critical loss • maintain key refuges • avoid catastrophic events	**Main aim: maintain** • maintain river functioning • maintain key functions of high priority wetlands	**Main aim: recover** • improve ecological health and resilience • improve opportunities for plants and animals to breed, move and thrive	**Main aim: enhance** • restore key floodplain and wetland linkages • enhance opportunities for plants and animals to breed, move and thrive

Source: Murray and Lower Darling catchment Annual Environmental Watering Priorities 2018–19 (DPIE – EES 2019)

Resource availability scenarios

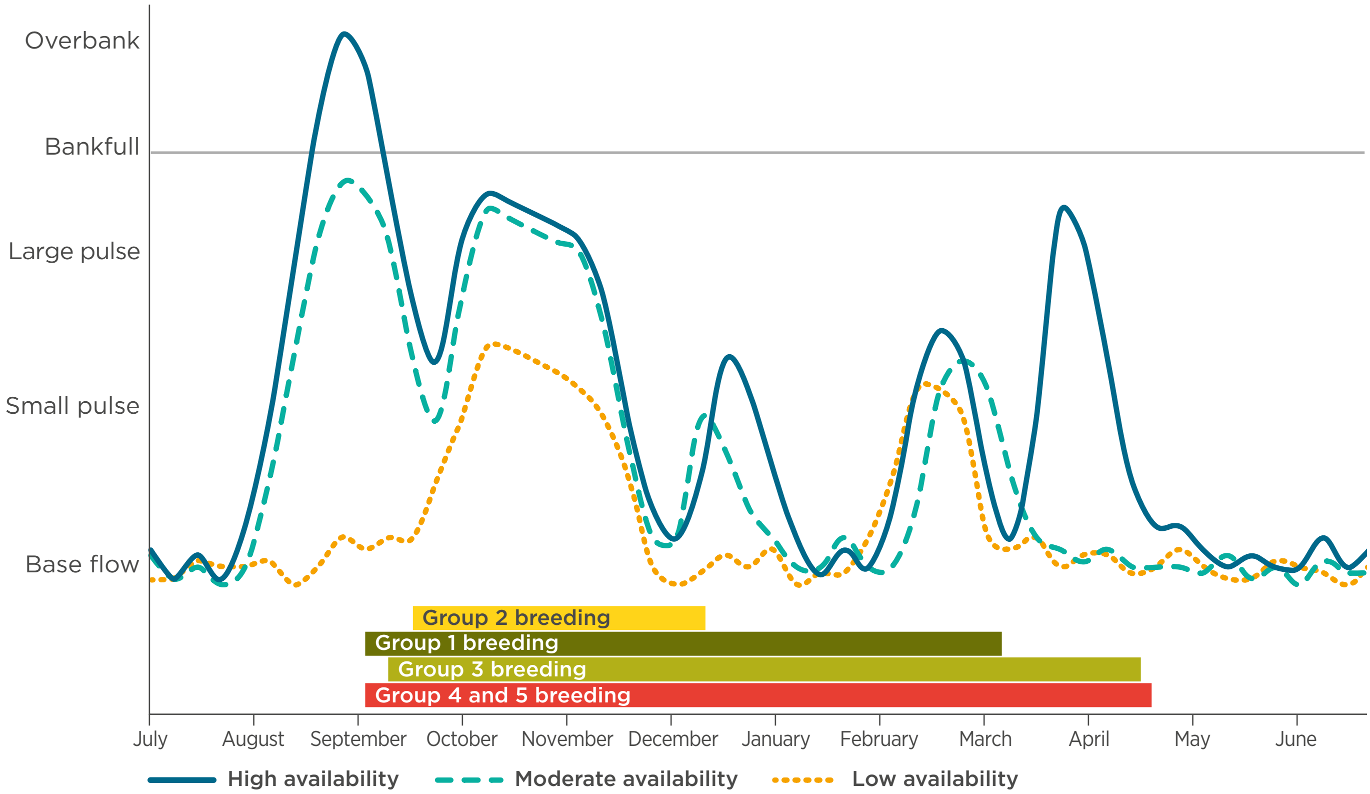
	Very dry	Dry	Moderate	Wet	Very wet
Management outcomes	**Avoid irretrievable loss of or damage to, environmental assets:** • avoid critical loss of species, communities, and ecosystems • maintain critical refuges • avoid irretrievable damage or catastrophic events • allow drying to occur, where appropriate, but relieve severe unnaturally prolonged dry periods	**Ensure environmental assets maintain their basic functions and resilience:** • support the survival and viability of threatened species and communities • Maintain environmental assets and ecosystem functions, including by allowing drying to occur consistent with natural wetting–drying cycles • maintain refuges	**Maintain ecological health and resilience:** • enable growth, reproduction and small-scale recruitment for a diverse range of plants and animals • promote low-lying floodplain–river connectivity • support medium-flow river and floodplain functions	**Improve the health and resilience of water-dependent ecosystems:** • enable growth, reproduction and large-scale recruitment for a diverse range of plants and animals • promote higher floodplain–river connectivity • support high-flow river and floodplain functions	**Improve the health and resilience of water-dependent ecosystems:** • enable growth, reproduction and large- scale recruitment for a diverse range of plants and animals • promote higher floodplain–river connectivity • support high-flow river and floodplain functions

Source: Guidelines for the method to determine priorities for applying environmental water (Murray–Darling Basin Authority 2012).

Task 2: Resource availability scenarios and flow events

This conceptual flow hydrograph shows:

- desired flow outcomes for a number of resource (water) availability scenarios
- breeding times for a range of grouped native fish species.



Conceptual flow hydrographs for a range of water availability scenarios and functional fish group breeding seasons.

Use your knowledge of resource availability scenarios and the flow regime to explain to the best of your ability the three different flow availability lines.

Include information about the types of flows for each scenario, the number of different flows and months they occurred in, and what the desired outcomes are for the three different resource availability scenarios.

For more information read Restoring native fish populations.

Teacher notes for Task 2

The focus of this task is to further develop student's knowledge about resource availability scenarios.

Students should be able to complete this task based on knowledge acquired in previous tasks. Use the answers provided at the end of this section to guide students through this task. You may wish to analyse one of the water availability lines on the hydrograph as a class and then get students to do the other two by themselves.

Point out the different groups of fish breeding provided on the hydrograph. This is not relevant to the answers for this task, but definitely worth discussing as a class. For more information on these breeding groups download the Restoring native fish populations publication.

Ask students when the hydrograph shows most breeding occurs (spring through to autumn) Ask them what time of year all groups are breeding (during spring)? Highlight the importance of spring flows to breeding and that this is often one of the most important times for releases of water for the environment (there are releases for each resource availability scenario in spring (high, moderate and low availabilities). What is the other time of year that has a peak on the hydrograph for all three lines? Why do students think releases are important at this time? – some breeding, recovery from hottest part of the year and refreshing system leading into the time of year higher flows are expected (especially if a dry winter occurs).

Answers for Task 2

High availability (blue solid line): means that water as a resource is plentiful due to large rain events and subsequent high flows in the rivers. This provides a chance to implement a full range of managed flows to achieve adequate area and duration of saturation. The chart shows one bankfull or overbank flow in late winter and spring; large pulses (freshes) in spring and autumn; two small pulses in summer; and base flows in both summer and late autumn/early winter. During wet/very wet times, the outcomes of water for the environment are to improve the health and resilience of water-dependent ecosystems.

Moderate availability (green dashed line): means that water as a resource is available due to moderate rain events and subsequent flows. Although there are no overbank or bankfull flows, there are large pulses (freshes) during winter and spring; small pulses during summer and early autumn; and base flows during summer and autumn through to winter. During moderate times, the outcomes of releases of water for the environment are to maintain ecological health and resilience.

Low availability (orange dotted line): means that water as a resource is scarce due to lack of rain events and therefore flows are also low. Only small pulses are released in spring and late summer/early autumn and the rest of the time the system operates on base flows. During very dry times of low water availability, the outcomes of releases of water for the environment are to avoid irretrievable loss of, or damage to, environmental assets.

Part D: Examine natural versus regulated flows

Rivers have natural patterns of peak in-flows and dry periods which are closely linked to climate and season. Aquatic wildlife and plants have evolved and adapted to these natural patterns over millions of years. For some animals an inflow might trigger breeding, migration or provide connectivity between the Basin's rivers. These flows might also help to inundate low-lying floodplains or forests which moves food back into the river.

River regulation, through building storages like dams, is important as it enables us to make use of the Basin's land and water to provide the food, fibre and other resources that we need to survive. However, this regulation has changed the natural flow patterns and volume of water available to rivers and wetlands. Some of the plants and animals that are dependent on those historic flow patterns are declining because less food is available with floodplains no longer able to connect to rivers.

Environmental water managers have access to a portfolio of water available for the environment to try to reinstate some of these natural patterns.

Teacher notes

This activity revises prior knowledge that:

- river regulation is important for human uses
- river regulation has interrupted the natural flow
- plants and animals have adapted and evolved with the natural flow
- water for the environment attempts to restore some of the natural flow patterns.

Discuss with students that a manager of water for the environment needs to be able to access and analyse flow data for the rivers and throughout the Murray–Darling Basin. Charts are a great way to see a visual comparison of different points of flow and help them analyse the data. This data helps water managers to understand natural and regulated flows and make decisions on releases of water for the environment.

Resources

Student activity 3.D worksheet

Computer access with spreadsheet software

Student activity 3D Examine natural versus regulated flows

Task 1: Natural versus regulated flows

Probably one of the most important parts of your new job as a manager of water for the environment is to understand the difference between natural and regulated flows. Water managers must be able to research and find the correct river flow data and interpret it. Using data tables and graphs effectively is necessary to help make decisions about when and where to supply water flows for the environment.

The best way to get an idea of how river regulation effects the flow regime is by investigating water flow at two points along the same river:

1. Point A should occur before regulation (upstream of a dam) as this gives us an indication of what the natural flow of the river would be.
2. Point B should occur after regulation (below a dam) as this indicates what the flows continuing down a river after regulation are.

By assessing these two points water managers can see how regulation has changed the quantity and timing of water flows down a river.

For this task you will examine river flow data from the Peel River just south of Tamworth. The two points your will investigate are:

- Point A: a river gauge on the Peel River at Taroona upstream of Chaffey Dam (natural flow)
- Point B: a river gauge on the Peel River just downstream of Chaffey Dam (regulated flow).

Chaffey Dam, Tamworth. WaterNSW.

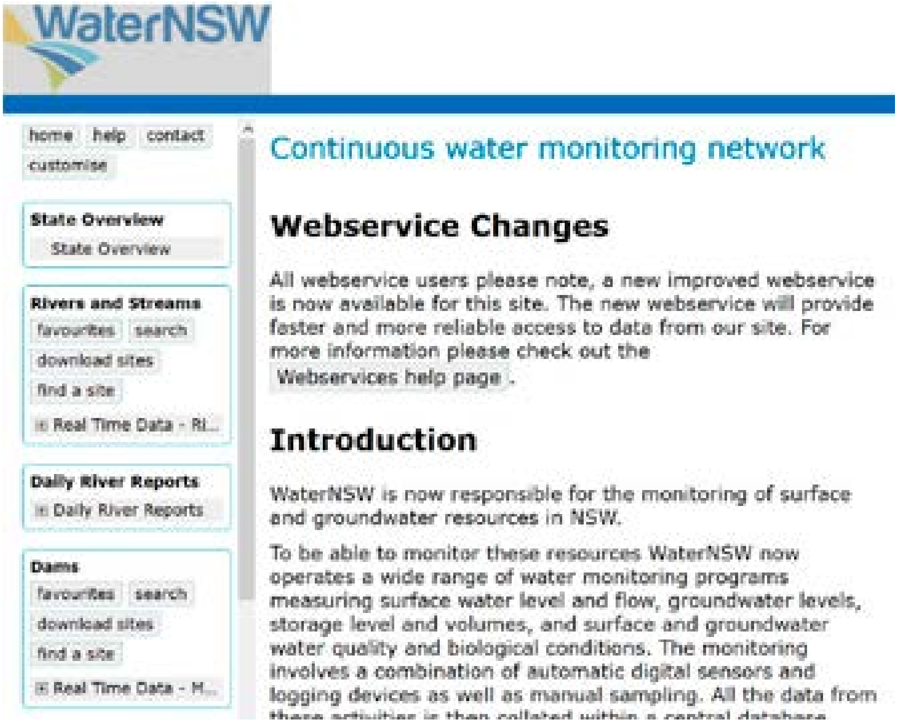
Step 1: Locate your river flow data

Go to the WaterNSW real-time data webpage. This webpage contains data for the various creeks, rivers and dams in New South Wales.

Go to the 'Rivers and Streams' menu on the left-hand side of the webpage. Under this menu individual gauge sites can be found by selecting 'search' and entering the six-digit gauge code.

Gauge codes for the two points you will investigate are:

- 419-Namoi River Basin Peel @ Taroona (419081)
- 419-Namoi River Basin Peel@D/S Chaffey Dam (419045).



Step 2: Obtain data for Point A, Taroona vGauge

1. Select 'search' under the 'Rivers and Streams' menu, type 419081 in the box that appears, then press enter.

   Click on the hyperlinked text: '419081 (PEEL RIVER AT TAROONA)' in the search results that appear. This will take you to the data page for the Taroona gauge (Peel @ Taroona).
2. Select the 'Custom Outputs' tab near the top of the page.
3. Select the box to the left of 'Discharge Rate (Megalitres/ Day)' and unselect any other boxes that are checked.
4. Select the 'Period' dropdown menu and choose 'Custom' and then choose start date: 1 January 2015; end date: 31 December 2017.
5. Click on the 'Output' dropdown menu and choose 'Download'.
6. Click on the 'Data interval' dropdown menu and choose 'Daily'.
7. Then select the 'Get Output' box at the bottom of the page to generate a spreadsheet containing the river flow data through the gauge at Taroona.

Save your spreadsheet as an Excel file with the name: Taroona 419081.

How to find a gauge site when you don't know the code

Follow these steps to find a gauge on your local river:

1. **Go to the WaterNSW real-time data webpage.**
2. **Under the 'Rivers and Streams' menu, select '+ Real Time Data – Rivers and Streams'.**
3. **Click on the catchment where the gauge is located.**
4. **Zoom in/out on the map to find a gauge on the waterway you wish to investigate.**

Step 3: Obtain data for Point B, Chaffey Dam (downstream)

Repeat Step 2 using the gauge code 419045 and then selecting '419045 (PEEL RIVER D/S CHAFFEY DAM) from your search results.

Make sure all the outputs are entered exactly the same as for Step 2.

You should now have a spreadsheet containing your river flow data through the gauge down stream of Chaffey Dam.

Save your spreadsheet as an Excel file with the name: Chaffey 419045.

Step 4: Combine your spreadsheets

To compare the data for Taroona and Chaffey Dam combine them into one spreadsheet.

Open both spreadsheets. Make sure column A is wide enough that all dates appear correctly (otherwise you may have symbols ########). The only data required is the 'Mean Discharge (ML/d)' which should be in column B.

On the Taroona 419081 spreadsheet, delete excess irrelevant data by selecting columns C to H, delete and then resave file. This should leave two columns: A = Time and Date; B = 419081 Mean Discharge (ML/d).

To combine data into one spreadsheet copy column B from the Chaffey 419045 spreadsheet and paste it into column C of the Taroona 419081 spreadsheet. Your spreadsheet should now have three columns for 2015–2017:

A = Date and time

B = 419081 Mean Discharge (ML/d)

C = 419045 Mean Discharge (ML/d).

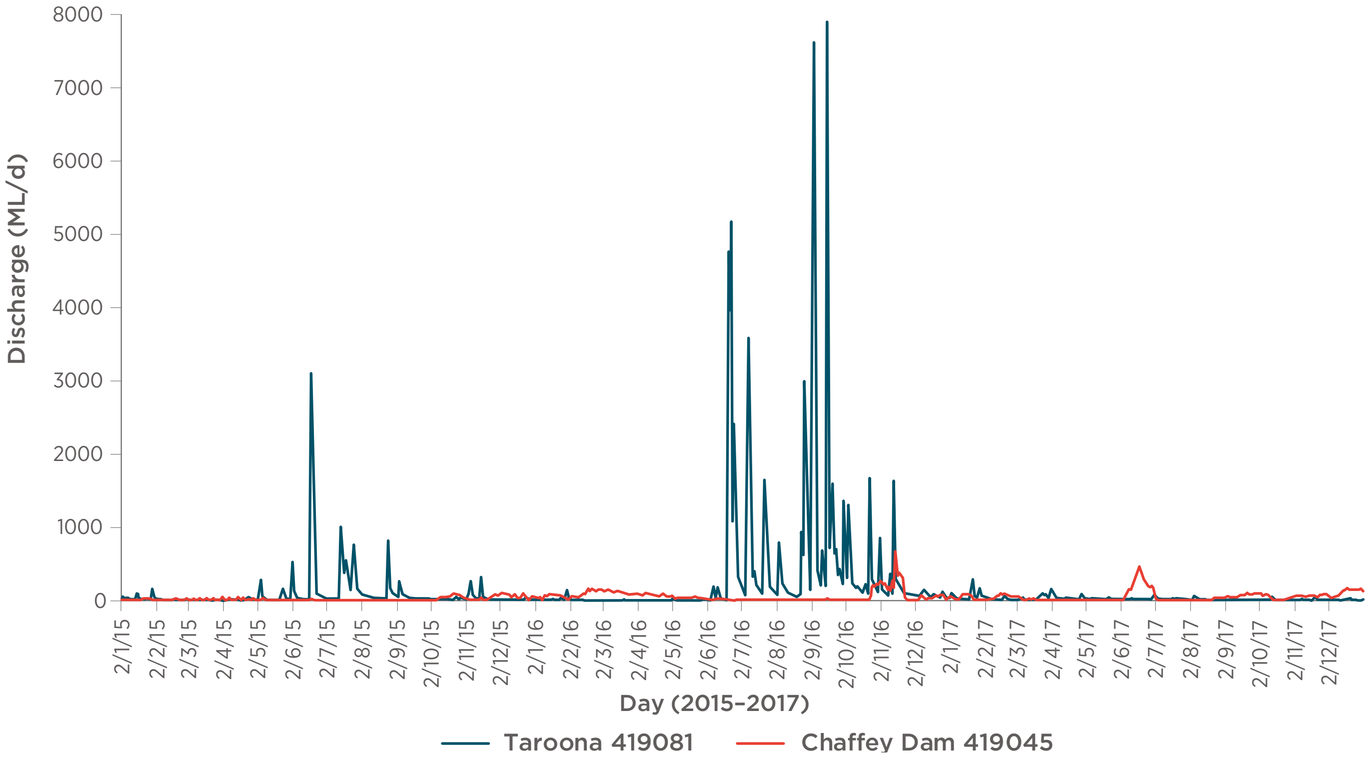
If necessary, widen the columns so you can clearly view all data. Remember that 419081 is the Taroona gauge, and 419045 is downstream of Chaffey Dam. Change or add extra titles to columns to help you remember this.

For a chart that makes a comparison of the data, highlight all data in columns A, B and C (not including the titles). Insert a line chart for this data.

Alter details of the chart:

- title (double click on 'Chart title') and change this to: Flow for the Peel River at Taroona and D/S Chaffey Dam
- legend (Chart Design/Select Data): Series 1 – Taroona 419081; Series 2 – Chaffey Dam 419045
- y-axis (+Add chart element/Axis Titles/Primary Vertical): Mean Discharge (ML/d)
- x-axis (+Add chart element/Axis Titles/Primary Horizontal): Day (2015–2017).

The chart you generate will be similar to this chart:



Flow for the Peel River at Taroona and downstream Chaffey Dam.

Teacher notes for Task 1

This task involves students analysing flow data from the Peel River upstream and downstream of Chaffey Dam. Highlight that the Taroona gauge (upstream) reflects the natural flow and the gauge downstream of Chaffey Dam represents a regulated flow. Students will need computer access to research and analyse data and create a chart. It is suggested to use Excel or another suitable program.

Discuss a local regulated waterway with your students (or an example they know of). Ask them to identify where, in the river/creek that feeds it, they would be likely to find a relatively natural flow (upstream) and where they are likely to find a regulated flow (downstream).

Highlight that Point (A) is Taroona gauge and Point (B) is downstream of Chaffey Dam.

Detailed instructions are provided for this activity are detailed, and some knowledge of spreadsheets and creating charts is required. Depending on your class ability you may get students to do the whole task themselves or work through it with them as a class and get them to analyse the data in Task 2.

After the spreadsheet and chart have been created, move on to Task 2.

Answers for Task 1

Spreadsheet data should look like this example, except the full range of data will show three years of results:

	A	B	C
1	Time	419081	419045
2	and	141	141
3	Date	Discharge (ML/d)	Discharge (ML/d)
4	Date and time	Mean	Mean
5	2/1/15 0:00	22.001	7.074
6	3/1/15 0:00	56.673	7.486
7	4/1/15 0:00	33.21	4.767
8	5/1/15 0:00	29.13	5.893
9	6/1/15 0:00	31.267	5.838
10	7/1/15 0:00	33.757	5.97
11	8/1/15 0:00	36.197	5.885
12	9/1/15 0:00	21.188	5.916
13	10/1/15 0:00	17.44	5.792
14	11/1/15 0:00	14.368	5.857
15	12/1/15 0:00	14.319	6.297
16	13/1/15 0:00	14.879	6.295
17	14/1/15 0:00	12.129	6.304
18	15/1/15 0:00	96.314	6.838
19	16/1/15 0:00	91.068	6.652
20	17/1/15 0:00	38.508	6.446
21	18/1/15 0:00	24.667	5.729

Task 2: Analyse the data

Print the chart in a landscape orientation. You can print it on an A4-size page, but A3 is larger and more easily interpreted. The questions for this task are best answered using a combination of the printed format and the digital version on a computer (where you can resize the chart to see it better).

Teacher notes for Task 2

Through analysing the data students should be able to envisage the effects of regulation on a waterway.

The main points to discuss are:

- that regulation interrupts the natural flow patterns (flow regime) of the river as water is stored for later use at a time when humans need it
- this regulated system can have a drastic effect on the aquatic ecosystems downstream of water storage reservoirs as the range and timing of flows is changed
- releases of water for the environment restore some of the natural flow pattern, providing the triggers that allow native plants and animals to complete their breeding and growth cycles.

Question 1
Clarify what the two lines (Series 1 and Series 2) show.

Series 1 is the Peel River flow through the Taroona gauge (419081) upstream of Chaffey Dam. This is natural flow in the river.

Series 2 is the Peel River flow through the Chaffey Dam gauge (419045) downstream of Chaffey Dam. This is a regulated flow in the river after a storage dam.

Question 2
The natural flows going through Taroona (Series 1) show three very different years. List them in order from the year you think was the wettest to the driest.

2016 (wettest), 2015, 2017 (driest).

Question 3
What do you think the peaks in the Taroona line (Series 1) indicate?

The Taroona line (Series 1) indicates rainfall events in the river catchment and subsequent flows down the river.

Question 4
On the Taroona line (Series 1), indicate on your chart at least one example (for each) that you think could be a base flow, freshes, high bankfull flow and an overbank flow.

See markings on chart. Overbank flow is likely to be the tallest peak in late September 2016. Bankfull flow second tallest peak in early September. Large and small freshes would make up the remainder of the peaks on the Series 1 line. Base flows occur anywhere the line is flat at the bottom of the page (due to scale).

Question 5
Look at the Chaffey Dam line (Series 2). Are many of the peaks of the Taroona line (Series 1) also reflected on the Chaffey Dam line (Series 1)? Do you think that the water flow down the river after Chaffey Dam is close to what would be a natural range of flows?

No, not many of the peaks of the Taroona line (Series 1) are shown on the Chaffey Dam line (Series 2). No, it is definitely not a natural system and is obviously heavily regulated.

Question 6
If rainfall events are showing in the flow at the Taroona gauge but not at the gauge downstream of Chaffey Dam, what do you think is happening to the water?

Any water flows at the Taroona gauge (Series 1) are being stored in Chaffey Dam for human use at a later time and therefore do not go through the gauge downstream of Chaffey Dam (Series 2).

Question 7
Ignoring the two main peaks (Nov/Dec 2016 and Jun/Jul 2017) in the Chaffey Dam line (Series 2), when does it seem that the most amount of water is flowing past the gauge downstream of Chaffey Dam?

This may be hard to see depending on the size of your chart! But if you look closely most small flows on the Chaffey Dam (Series 2) line appear in the summer months.

Question 8
What do you think the water releases you noted in Question 7 from Chaffey Dam represent?

Water being released for human purposes, especially agriculture, during the hottest time of the year.

Question 9
The two main peaks (Nov/Dec 2016 and Jun/Jul 2017) in the flow passing through the Chaffey Dam gauge (Series 2) were releases of water for environment. Which description below do you think matches each of these releases?

a. After drier than usual conditions, water resource availability was low and so water for the environment was released into the river to help ensure environmental assets maintain their basic functions and resilience.

June/July 2017.

b. After wetter than usual conditions, water resource availability was high and so water for the environment was released to improve the health and resilience of water-dependent ecosystems.

Nov/Dec 2016.

Mark both of these peaks on your chart.

Question 10.
Choose the type of flows that you would call these two water for the environment releases from this list:

a. cease-to-flow

b. baseflow

c. pulses/freshes

d. high bankfull flow

e. overbank flow.

Part E: Flows in the upper Murray River

Student activity 3E

Counting all flows

When examining the flows of a waterway it is important that a manager of water for the environment can see the whole picture. This means taking into consideration all the creeks and rivers contributing to the flow as well as the dams/water storage reservoirs that may be storing water in the system.

Task 1

Step 1

This is a list of gauges located on rivers and creeks contributing to the upper Murray River. Some flow into Dartmouth Dam, Hume Dam and Lake Mulwala. Using online maps and other resources, label points A to O on the map provided.

Note: ML/d represents megalitres per day of flow through the various gauges.

A. Murray River at Jingellic (14,495 ML/d)

B. Kiewa River at Bandiana (2780 ML/d)

C. Tallangatta Creek at McCallums (399 ML/d)

D. Ovens River at Peechelba (11,019 ML/d)

E. Mitta Mitta River at Colemans – Dartmouth release (1531 ML/d)

F. Mitta Mitta River at Hinnomunjie (1358 ML/d)

G. Gibbo River at Gibbo Park (837 ML/d)

H. Morass Creek at Uplands (144 ML/d)

I. Black Dog Creek at Dugays Bridge (27 ML/d)

J. Indigo Creek downstream Creamery Bridge (45 ML/d)

K. Murray River downstream Yarrawonga Weir – Lake Mulwala Release (14,309 ML/d)

L. Murray River downstream Hume Weir – Hume Dam Release (10,076 ML/d)

M. Dartmouth Dam

N. Hume Dam

O. Lake Mulwala.

Map of the upper Murray River.

Step 2

Complete the table by inserting the rivers and creeks in the appropriate column.

Rivers/creeks flowing into Dartmouth Dam	Rivers/creeks flowing into Hume Dam	Rivers/creeks flowing into Lake Mulwala

Step 3

Calculate the water flow entering, being captured by, and being released by each of the water storages.

Dartmouth Dam example

Sum up all the water entering Dartmouth Dam on the day gauge reading occurred.

Mitta Mitta River at Hinnomunjie (1358 ML/d) + Gibbo River at Gibbo Park (837 ML/d) + Morass Creek at Uplands (144 ML/d) = 2339 ML/d flow into Dartmouth Dam

Determine the total flow stored in Dartmouth Dam.

Subtract the release into the Mitta Mitta River at Colemans. Take 1531 ML/d from the total flow into the reservoir calculated at 2339 ML/d. This leaves 808 ML/d of flow stored by the Dartmouth Dam.

Work out the percentage of the total flow stored by Dartmouth Dam = (flow stored by Dartmouth ÷ flow into Dartmouth) x 100: (808 ML/d ÷ 2339 ML/d) x 100 = 34.54% of the total flow into Dartmouth Dam is stored.

Summary for Dartmouth

Flow into Dartmouth Dam	Flow out of Dartmouth Dam (Mitta Mitta River at Colemans)	Flow stored by Dartmouth Dam	Percentage of total flow stored in Dartmouth Dam
2339 ML/d	1531 ML/d	808 ML/d	34.54%

Using the Dartmouth example, work out the water flow entering, being captured by and being released by (a) the Hume Dam and (b) Lake Mulwala and add your calculations to the tables.

Summary for Hume

Flow into Hume Dam	Flow out of Hume Dam (Murray River D/S Hume Weir)	Flow stored by Hume Dam	Percentage of total flow stored in Hume Dam

Summary for Lake Mulwala

Flow into Lake Mulwala	Flow out of Lake Mulwala (Murray River D/S Yarrawonga Weir)	Flow stored by Lake Mulwala	Percentage of total flow stored in Lake Mulwala

Step 4

Average the percentages of water stored that travels through all three water storage reservoirs.

(Total sum of % flow stored in Dartmouth, Hume and Mulwala) ÷ 3 = % of total flow stored.

Step 5

Write a paragraph about what these totals indicate about flows into reservoirs, the amount of flow stored/captured, and the amount of flow released. Draw conclusions about the effect this has on natural flows and the plant and animal species they support.

Teacher notes and answers

Counting all flows

Examine the map provided with this task and point out to students that the upper Murray River system is regulated at three different places over a relatively short distance – Dartmouth Dam, Hume Dam and Lake Mulwala. Ask students to think about the effect this has on the flow of water through the system. Students could hypothesise a prediction about what percentage of flow entering the system makes it through regulation to the point downstream of Yarrawonga Weir (downstream of Lake Mulwala), and the percentage that is stored (i.e. if 26% is stored in the three reservoirs then 74% of flows make it through to downstream of Yarrawonga Weir).

Use these notes to support further discussion with students about each section of this task:

1. Points are marked on the map provided to make it easier for students to locate and label gauges. Highlight that managers of water for the environment need to know their catchments intimately. They must know where all water comes from, how much water is entering the system and how much is being regulated. This knowledge helps them understand their catchments and make decisions about water releases.

2. Once gauge points have been provided students should be able to trace rivers and identify flow inputs and outputs into the three reservoirs. Only the gauge at Murray River DS Yarrawonga Weir – Lake Mulwala Release (14309 ML/d) will not go into the table, but it will be needed for calculations in the questions 3 and 4.

Resources

Student activity 3.E worksheet

Computer access to use:

WaterNSW real-time data webpage

Online maps

Rivers/creeks flowing into Dartmouth Dam	Rivers/creeks flowing into Hume Dam	Rivers/creeks flowing into Lake Mulwala
Mitta Mitta River at Hinnomunjie (1358 ML/d)	Mitta Mitta River at Dartmouth release (1531 ML/d)	Murray River DS Hume Weir – Hume Reservoir release (10,076 ML/d)
Gibbo River at Gibbo Park (837 ML/d)	Murray River at Jingellic (14495 ML/d) Kiewa	Kiewa River at Bandiana (2780 ML/d)
Morass Creek at Uplands (144 ML/d)	Tallangatta Creek at McCallums (399 ML/d)	Black Dog Creek at Dugays Bridge (27 ML/d)
		Indigo Creek DS Creamery Bridge (45 ML/d)
		Ovens River at Peechelba (11,019 ML/d)

Notes: d = day; ML = megalitres

3. Students should follow the method used in the Dartmouth example to complete calculations and fill in the tables for this section. The main tricky part is to remember that the flow out of Dartmouth Dam (Mitta Mitta at Colemans) is counted as one of the flows into Hume, and the flow out of Hume Dam (Murray River D/S

Hume Weir) is counted as one of the flows into Lake Mulwala. The flow out of Lake Mulwala (Murray River D/S Yarrawonga Weir) is not in table for section but it is on the list in section 1.

Results show the percentage of the flow into them that is stored by each of the three reservoirs.

a. Summary for Hume Dam

Flow into Hume Dam	Flow out of Hume Dam (Murray River D/S Hume Weir)	Flow into Flow stored by Hume Dam	Percentage of total flow stored in Hume Dam
16,425 ML/d	10,076 ML/d	6349 ML/d	38.65%

Notes: d = day; ML = megalitres

b. Summary for Lake Mulwala

Flow into Lake Mulwala	Flow out of Lake Mulwala (Murray River D/S Yarrawonga Weir)	Flow stored by Lake Mulwala	Percentage of total flow stored in Lake Mulwala
23,947 ML/d	14,309 ML/d	9638 ML/d	40.25%

Notes: d = day; ML = megalitres

4. If students made a prediction about the percentages before the activity, you should check who was close.

   (34.54% + 38.65% + 40.25%)/3 = 37.81% of total flow stored

5. Discuss this section with this example answer:

   The flows in the upper-Murray system are heavily regulated with three major water storage reservoirs along the system. These reservoirs capture and store 37.81% of the flows shown, which means that 62.19% of the natural flows continue down the river. This stored water is important to humans because it supports agriculture, towns and industry that in turn provides drinking water, food, fibre and other resources. But this can have a drastic effect on the natural aquatic ecosystems downstream of the upper-Murray system. This stored water is often released in a different season than the natural flows would have been, preventing plants and animals receiving water that triggers breeding, migration and other natural processes and functions.

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