Kimberley edition

Water Monitoring

Produced by the Centre for Learning Technology,
The University of Western Australia, for the SPICE program

Kimberley River, photo courtesy Natalie Tapson

spice

THE UNIVERSITY OF WESTERN AUSTRALIA

Government of Western Australia Department of Education

Supported by Shell

Acknowledgements

This program owes its inception to the Shell-funded SPICE-Shell Kimberley Science Program and Shell's partnership with the Ngurrarra Rangers. Shell's social investment program, *Unlocking Potential*, aims to equip disadvantaged young people with the knowledge, understanding, skills and values to take advantage of opportunities and help solve challenges, creating a better future for all Australians.

Water monitoring (Kimberley edition) was designed and written by the SPICE program with input from Rebecca Dobbs and Fiona Tingle from the *Waterways Education program for the Kimberley* (Centre of Excellence in Natural Resource Management at The University of Western Australia and Department of Water Western Australia).

Thanks to Scitech for giving permission to use an activity from their *DIY Water* package.

Developed by the Centre for Learning Technology, The University of Western Australia. Production team: Jan Dook, Alwyn Evans, Bob Fitzpatrick, Dan Hutton, Paul Ricketts, Jodie Ween and Michael Wheatley.

SPICE resources and copyright

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Ivanhoe Crossing
photo courtesy of Robyn Bradbrook

Contents: *Water monitoring*

Digital resources for *Water monitoring* are available on CD-ROM or USB.

They include electronic copies of this teacher guide, its appendices and audiovisual resources.

Digital resources

		folder on CD-ROM or USB
Part 1: Clean water	How much of Earth's water is fresh?	procedures
Part 2: Sources of water	Where does water come from?	presentations
	Build an edible aquifer	procedures
	Build a model aquifer	procedures
	Groundwater pollution	worksheets
Part 3: Is it safe to drink?	Why monitor water?	presentations
	Measuring pH	worksheets
	Measuring temperature	worksheets
	Measuring salinity	worksheets
	Measuring turbidity	worksheets
Part 4: Field trip	Field protocols	procedures
	Data record	worksheets
	Identification key (two versions)	factsheets
	Macroinvertebrate survey (two versions)	worksheets
Part 5: Putting it together	Field report	worksheets
	Interpreting your results	factsheets
	Water quality (three versions)	worksheets

Background

Water monitoring (Kimberley edition) is a science program designed for students in year 7. The program has been written for the Kimberley but is adaptable to other areas. The program focuses on importance of water, importance of groundwater, and how water quality is measured.

Using methods of observation, measurement, recording and analysis students act as scientists to evaluate health of a local water body.

Students progressively learn to take measurements, firstly in the classroom and then in the field. Data are analysed and management strategies discussed.

This program has been developed in response to a Shell-sponsored project of the Ngurrara rangers: monitoring and understanding water flow and movement with the Canning Basin. Rangers are keen to work with students at Fitzroy Valley District High School and wanted a school-based program that would prepare students for an on-country trip to traditional water holes (jila).

The SPICE team is hopeful that other ranger groups will work with their local schools to implement this program.

Water monitoring (Kimberley edition) covers all three strands of the Australian Curriculum: Science. The program has strong links to literacy, numeracy and geography (Unit 1: Water in the World).

The program also recognises the significance of water for Indigenous Australians and is respectful of their knowledge of our natural environment.

Australia acknowledges the significant contribution of Aboriginal and Torres Strait islander people locally and globally. Aboriginal communities maintain a special connection to and responsibility for Country/Place throughout all of Australia. Their ways of life are uniquely expressed through ways of being, knowing, thinking and doing. Aboriginal peoples have unique belief systems that spiritually connect them to land, sea, sky, water bodies, flora and fauna.

There are many opportunities within *Water monitoring* to involve local Elders and Rangers in providing their perspective on water bodies.

About the Ngurrara rangers

The Ngurrara rangers are based at the community of Djugerari. They manage the Ngurrara native title area of some 77 814 square kilometres in the southern Kimberley region, which includes part of the Canning Stock Route. The rangers are instructed by their Traditional Owners to protect heritage through knowledge transfer, and to physically protect culturally important sites by managing visitors, fire, weeds and feral animals.

Through Working on Country, a number of rangers undertake training in conservation and land management, relevant occupational health and safety training, conduct biodiversity surveys and record species abundance across representative habitat types within Ngurrara country.

The Ngurrara rangers undertake cat, fox and camel management work, based on biodiversity survey monitoring results, traditional and local knowledge. They also undertake weed management surveys to inform control plans and management for Weeds of National Significance (WONS) along with other weeds in the region.

The rangers monitor freshwater wetland sites to prioritise and implement management actions under the guidance of traditional owners. Following identification of fire management sites through community-based planning, the ranger team also conducts annual burns.

Department of the Environment. (2013). *Working on Country funded projects – WA*. Retrieved 15 May 2015 from http://www.environment.gov.au/indigenous/workingoncountry/projects/wa/

About the water monitoring project

Ngurrara is currently working with Shell on a two-way learning project to measure water quality and quantity in the Canning Basin. The project pairs traditional knowledge about water (through tracing the living water in paintings and gathering stories from Ngurrara Elders) with Western scientific knowledge.

It's a project that both Ngurrara Rangers and Ngurrara Traditional Owners are undertaking and it has significant benefits. Foremost, it is providing Yanunijarra Aboriginal Corporation [manager of the Ngurrara native title claim in the Kimberley region of Western Australia] with a wealth of baseline data about the connection of jumu and jilas (waterholes) with our groundwater and about how water moves. This means we are well-placed to understand, measure and control any possible impacts of new developments or mining on Ngurrara country.

Through the project, Rangers and Traditional Owners have also been presenting to and engaging students at Yakanarra Community School, Djugerari Remote Community School and Fitzroy Valley District High School. Already, there has been an improvement in school retention, students are learning traditional knowledge and they're exposed to possible employment and training outcomes post year 12.

Yanunijarra Aboriginal Corporation. (n.d.). *Shell 2-Way learning*. Retrieved 15 May 2015 from http://www.yanunijarra.com/shell-2-way-learning/

Learning pathway

The program is structured around a constructivist model, based on the 5-Es, where teachers may:

- **Engage** student interest in water issues through two videos that highlight importance of water to communities;
- provide opportunities for students to **Explore** where their drinking water comes from;
- guide students to **Explain** how various measurements are taken to assess water quality;
- **Elaborate** on what data mean and how management decisions are made regarding water; and
- **Evaluate** student progress through completion of activities.

	PURPOSE	DESCRIPTION
Part 1: Clean water	ENGAGE	This resource is intended to **Engage** students' interest in water by learning about the importance of fresh, clean water.
Part 2: Water sources	EXPLORE	This resource is intended encourage students to **Explore** where drinking water comes from by investigating aquifers. Students build aquifer models and consider how aquifers provide water to communities; how aquifers recharge; and how they may be contaminated.
Part 3: Is it safe to drink?	EXPLAIN 1	Students are introduced to a range of water monitoring techniques.
Part 4: Field trip	EXPLAIN 2	Students learn how to sample and record data, in the field.
Part 5: Putting it together	ELABORATE	How do scientists use data to plan water management strategies?

Technical requirements

The teacher guide requires Adobe Reader (version 5 or later). This is a free download from www.adobe.com.

Presentations are supplied in Microsoft PowerPoint and PDF format. Procedures and worksheets are supplied in Microsoft Word and PDF format.

An Internet connection is required to view the videos in **Activity 1.1**.

A computer with Adobe Flash is needed to play the *Gnasty Gnomes* game in **Activity 2.4**.

Links to Australian curriculum

SCIENCE UNDERSTANDING (YEAR 7)
Earth and space sciences Water is an important resource that cycles through the environment (ACSSU222) • Investigating factors that influence the water cycles in nature • Exploring how human management of water impacts on the water cycle
SCIENCE AS A HUMAN ENDEAVOUR (YEAR 7)
Use and influence of science Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management (ACSHE121) People use understanding and skills from across the disciplines of science in their occupations (ACSHE224)
SCIENCE INQUIRY SKILLS (YEAR 4)
Questioning and predicting Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124) **Planning and conducting** Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125) In fair tests measure and control variables and select equipment to collect data with accuracy appropriate to the task (ACSIS126) **Processing and analysing data and information** Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships including using digital technologies as appropriate (ACSIS129) Summarise data from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS130)
GEOGRAPHY (YEAR 7)
Geographical knowledge and understanding The classification of environmental resources and the forms that water takes as a resource (ACHGK037) • describing how water is an available resource when it is groundwater, soil moisture (green water), and surface water in dams, rivers and lakes (blue water), and a potential resource when it exists as salt water, ice or water vapour The ways that flows of water connect places as it moves through the environment and the way this affects places (ACHGK038) The quantity and variability of Australia's water resources compared with those in other continents (ACHGK039) The economic, cultural, spiritual and aesthetic value of water for people, including Aboriginal and Torres Strait Islander Peoples and peoples of the Asia region (ACHGK041) **Collecting, recording, evaluating and representing** Collect, select and record relevant geographical data and information, using ethical protocols, from appropriate primary and secondary sources (ACHGS048)
CROSS-CURRICULUM PRIORITIES
Aboriginal and Torres Strait Islander histories and cultures OI.2 Aboriginal and Torres Strait Islander communities maintain a special connection to and responsibility for Country/Place throughout all of Australia. OI.3 Aboriginal and Torres Strait Islander Peoples have unique belief systems and are spiritually connected to the land, sea, sky and waterways.

Overview

	IN THE CLASSROOM	IN THE FIELD	DIGITAL RESOURCES
PREPARATION			
	Contact Rangers, Elders about the program, including participation in the field trip.		
	Discuss possible sites for field trip.		
WEEK 1			
Part 1: Clean water (page 11)	Show two short YouTube videos (**Activity 1.1**). Discuss importance of water.		
	Demonstrate **Activity 1.2** *How much fresh water?*		procedure: *How much fresh water?*
Part 2: Water sources (page 15)	Show presentation, *Where does water come from?* (**Activity 2.1**)		presentation: *Where does water come from?*
	Students complete **Activity 2.2** *Build an edible aquifer*.		procedure: *Build an edible aquifer*
WEEK 2			
	Demonstrate/conduct **Activity 2.3** *Build a model aquifer*.		procedure: *Build a model aquifer*
	Play *Gnasty gnomes* and complete worksheet (**Activities 2.4** and **2.5**).		worksheet: *Groundwater pollution*
WEEK 3			
Part 3: Is it safe to drink? (page 27)	Show presentation, *Why monitor water?* (**Activity 3.1**)		presentation: *Why monitor water?*
	Conduct practical activities in class, **Acivities 3.2** to **3.5**.		worksheets: *Measuring pH* *Measuring temperature* *Measuring salinity* *Measuring turbidity*

Overview

	IN THE CLASSROOM	IN THE FIELD	DIGITAL RESOURCES
WEEK 4			
Part 4: Field trip (page 33)	Preparation for field trip: plan site and procedures (Activity 4.1)		
		Field trip: conduct water monitoring, record data, identify and draw macroinvertebrates. (Activities 4.2 and 4.3)	procedure: *Field protocols* worksheets: *Data record*, *Identification key*, *Macroinvertebrate survey*
WEEK 5			
Part 5: Putting it together (page 41)	Analyse data with spreadsheets. Compare results to guidelines. Enter results into summary table. (Activity 5.1)		worksheets: *Field report*, *Interpreting results*
	Consider management strategies for different scenarios. (Activity 5.2)		worksheet: *Water quality*
	Design a sign/poster. (Activity 5.3)		

Preparation for all activities

Choose a site for the field trip

Identify a suitable water body where students may safely take water samples and conduct water quality tests.

If you are working with a local Ranger group or community members, site selection should be done based on their knowledge and experience.

Otherwise you may wish to contact Department of Parks and Wildlife.

- Broome: Phone (08) 9195 5500
- Kununurra: Phone (08) 9168 4200

Be CrocWise

These websites from Northern Territory and Western Australia governments have information on the ***Be CrocWise*** program.

- http://www.parksandwildlife.nt.gov.au/becrocwise
- http://parks.dpaw.wa.gov.au/sites/default/files/imce/Be%20CROCWISE%20Factsheet.pdf

Watch the following YouTube movie, Be CrocWise — Don't risk your life.

- https://www.youtube.com/watch?v=m7qnpUISoMA

Recording

Recording data is an important part of doing science. Original data obtained by scientists are the basis for analysing and predicting.

Ensure students record field measurements, either on paper or electronically.

Equipment suppliers

Prices as of June 2015 (GST excluded). Delivery charges may apply.

Vendart Pty Ltd
vendart.com.au

LaMotte Earth Force low cost water monitoring kit (3-5886)	$93.65
replacement pH TesTabs, 50 pack (6459A-H)	$35.00
replacement pH TesTabs, 100 pack (6459A-J)	$63.00
replacement nitrate TesTabs, 50 pack (3703A-H)	$32.00
replacement nitrate TesTabs, 100 pack (3703A-J)	$55.00
replacement dissolved oxygen TesTabs, 50 pack (3976A-H)	$28.00
replacement dissolved oxygen TesTabs, 100 pack (3976A-J)	$40.00
replacement phosphate TesTabs, 50 pack (5422A-H)	$29.00
replacement phosphate TesTabs, 100 pack (5422A-J)	$45.00
coliform *E. coli* tablet with vial (3599)	$6.05

Perth Scientific
perthscientific.com.au

salinity and temperature probe (ADWA AD 31)	$75.00

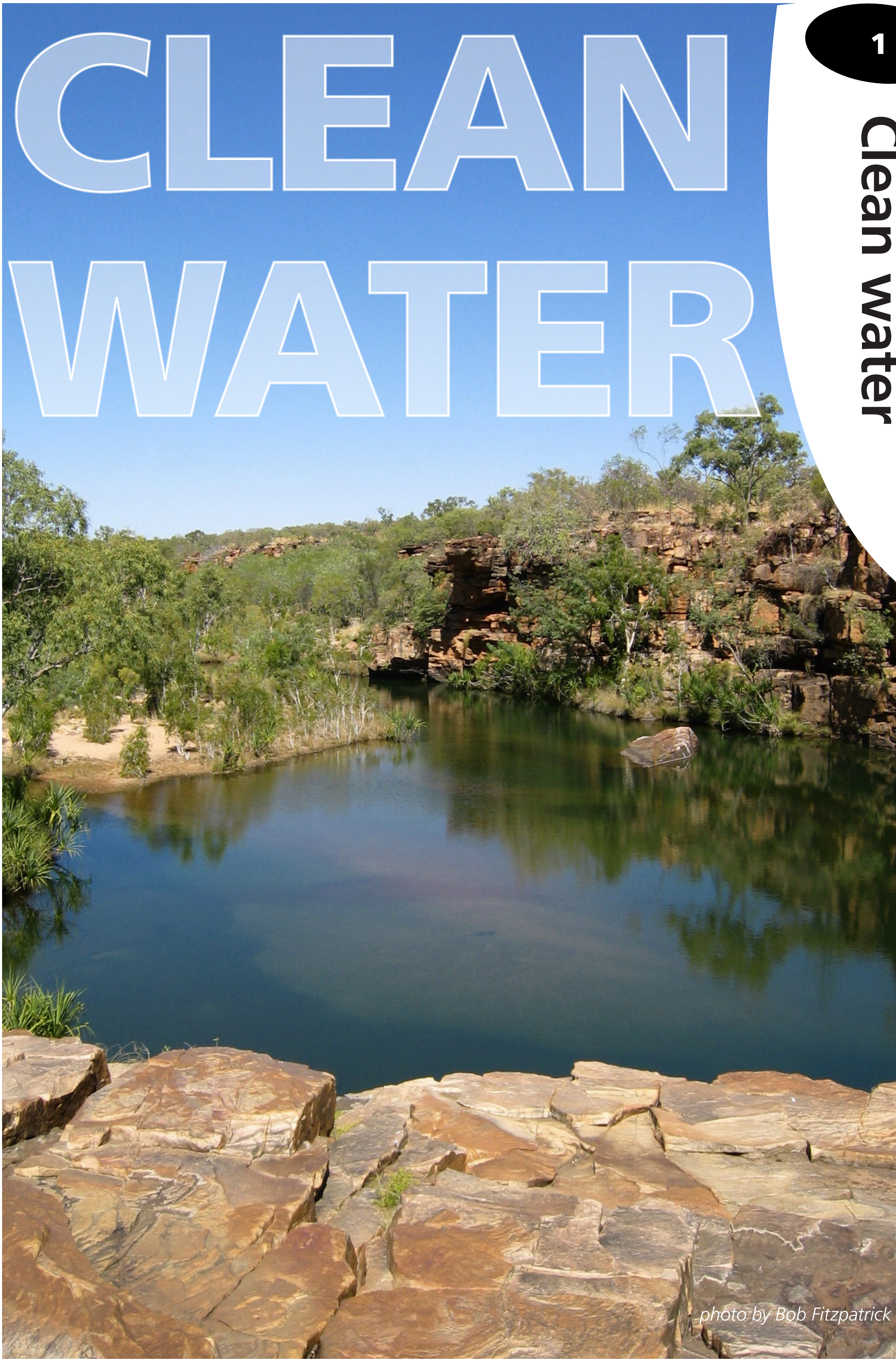
Australian Entomological Supplies Pty Ltd
entosupplies.com.au

macroinvertebrate handle (E25)	$16.30
macroinvertebrate hoop (E35)	$12.90
macroinvertebrate aquatic bag (E565)	$14.90
aquatic net complete (EANET1)	$44.10

WestLab
westlab.com.au

turbidity tube (122020-0001)	$70.20

Saltwater crocodile
photo by Bob Fitzpatrick



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Clean water

Purpose

This resource is intended to **Engage** students' interest in water by learning about the importance of fresh, clean water.

Outcomes

Students understand that:

- life without water would be impossible;
- only a small percentage of Earth's water is fresh and hence available for drinking; and
- most of the available fresh water is found in groundwater.

Materials needed

NAME	DESCRIPTION	LOCATION
Life without water	two short YouTube movies from *National Geographic*	Available from: http://voices.nationalgeographic.com/2013/08/28/life-without-water-is-awkward-new-viral-videos/
How much fresh water?	Activity to demonstrate how much of Earth's water is fresh. You will need: • 10 L water container (bucket) • 5 beakers or jars of various size: the largest amount of water to be transferred is 300 mL and the smallest amount is 1.5 mL • Pasteur pipette or eye dropper (approximately 0.05 mL/drop, 20 drops = 1 mL) • blue food colouring • labels or paper to identify water portions	**Appendix A** digital-resources/procedures

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
1.1	Teacher shows class two short YouTube movies (30 s each) to stimulate discussion about the importance of water.	class discussion	5 min
1.2	Students make predictions about percentages of Earth's water resources in various categories. Teacher demonstrates to class percentage of Earth's water that is freshwater.	board teacher demonstration	5 min 20 min

Background information for teachers

Water is important for all living things. Approximately 60 - 70% of our body (depending on age) is composed of water. It's found in cells, between cells and in blood. A 70 kg person will have about 42 L of water in their body.

Some properties of water

Water molecules are composed of three atoms: two hydrogen atoms bonded to one oxygen atom (H_2O). Although water molecules as a whole are neutral in charge, hydrogen atoms are slightly positive and oxygen atoms are slightly negative. This means that each end of the water molecule is attracted to the opposite end of another water molecule. As a result water molecules stick together (water is cohesive).

Water also sticks well to other substances: adhesion. If adhesive forces are stronger than cohesive forces then water spreads out. Water is also known as the universal solvent because it dissolves more substances than any other liquid.

Most substances become denser when in a solid form however, ice is less dense than water. This is why ice-blocks float and lakes freeze from the top. If ice sank, lakes would freeze from the bottom up killing most aquatic life.

Figure 1.1 water and ice
Paul Ricketts

Fresh water

Although Earth is known as the 'Blue Planet', only a small percentage (approximately 3%) of the Earth's water is fresh.

Water is vital to life, but there are potential problems with water. There are a number of water-borne diseases, including diseases:

- caused by microorganisms and chemicals in water that people drink;
- caused by organisms that have part of their life-cycle in water, such as bilharzia; and
- that have water-related vectors, such as malaria.

People can also drown in water.

Some statistics from the World Health Organisation

- Diarrhoeal disease accounts for the deaths of 1.8 million people/year.
- Diarrhoeal disease accounts to an estimated 4.1% of the total global burden of disease.
- It is estimated that 88% of the disease burden is attributable to unsafe water supply, sanitation and hygiene.
- Seven hundred million Indians do not have access to a toilet.
- Ninety percent of groundwater in Chinese cities is polluted.

Figure 1.2 Moochalabra Dam
photo courtesy of Water Corporation

Sources of fresh water

Surface water

Surface water is found in rivers, streams, lakes, dams (barrier that holds water back) and reservoirs (man-made lake to store water). Surface water is more exposed to natural or anthropogenic (human-caused) contaminants.

Anthropogenic contaminants include chemicals such as petrol, fertilisers, pesticides and industrial waste.

Natural contaminants include floating and suspended material from plants and animals, natural biological activity such as decay of organic matter by bacteria, metabolic activity of algae and protozoa, and excretions by fish and other aquatic organisms

Groundwater

Groundwater is water stored in pores and crevices of soil and rock beneath the ground. Rock and soil layers beneath the ground that are saturated with water are called aquifers.

Groundwater is less susceptible to anthropogenic contamination although leaking underground storage tanks or septic systems may contaminate groundwater systems. Groundwater, however, often has high levels of dissolved minerals due to long-term contact between rocks and minerals. Salinity of groundwater may also be quite high.

Seawater

Approximately 97% of Earth's water is in oceans and 75% of people live in coastal locations. For these reasons desalination is becoming a viable option. Desalination is a term for the process that removes salt from seawater to produce fresh water. This process takes considerable energy as ocean salinity ranges from 34 000 to 38 000 mg/L, while water regulations in WA for drinking water require salinity to be less than 500 mg/L.

Figure 1.3 Borefield
photo courtesy of Water Corporation

Figure 1.4 Perth seawater desalination plant
photo courtesy of Water Corporation

Activity guide

Activity 1.1 Life without water

To stimulate discussion about the importance of water, show two short YouTube movies (30 s each) from *National Geographic*.

- http://voices.nationalgeographic.com/2013/08/28/life-without-water-is-awkward-new-viral-videos/

While American in flavour they introduce the importance of water in a fun style. The first movie shows a swimming pool with no water. The second shows rafting down a dry river.

Brainstorm the importance of water from different perspectives including biological function, physical properties and recreation.

Activity 1.2 How much water?

Two thirds of Earth is covered with water.

- Ask students to predict how much of Earth's water is fresh. Ask students to think about where fresh water may be stored.
- Write ideas on the board.
- Demonstrate the activity as described in **Appendix A: How much fresh water?**
- Return to students' original predictions on the board and discuss.

WATER SOURCES

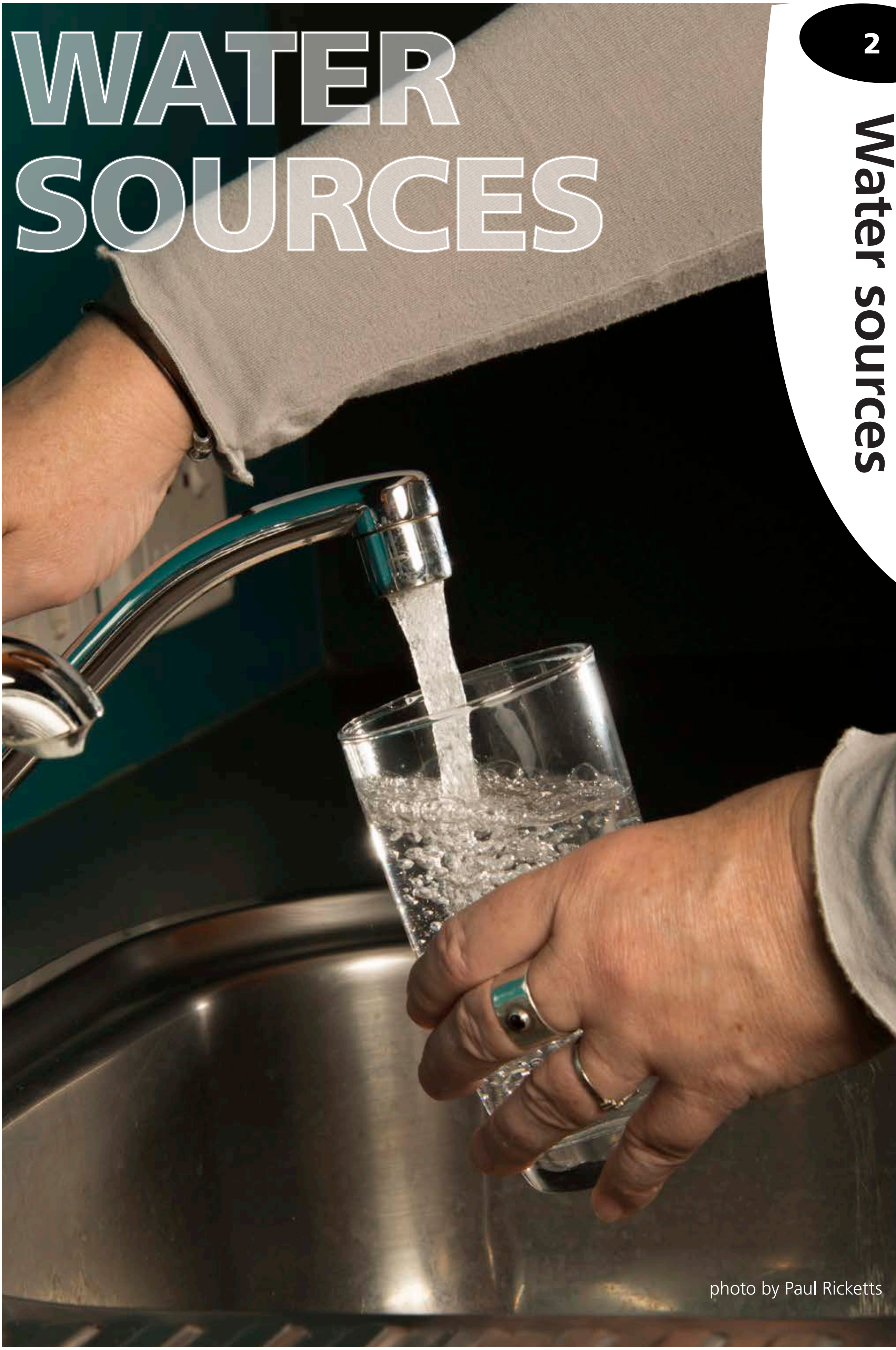


photo by Paul Ricketts

Purpose

This resource is intended encourage students to **Explore** where drinking water comes from, by investigating aquifers. Students build aquifer models and consider how aquifers can provide water to communities; how aquifers recharge; and how they may be contaminated.

Outcomes

Students understand that:

- a significant portion of drinking water is found in groundwater;
- most water in the Kimberley is sourced from groundwater;
- groundwater is held in structures known as aquifers;
- groundwater aquifers are comprised of different layers including surface water, water table, unsaturated zone, saturated zone and confining layer;
- water can be drawn from groundwater supplies by bores;
- groundwater in an unconfined aquifer may be recharged through rain and runoff;
- groundwater may be contaminated; and
- keeping groundwater clean is important to secure water supplies.

Materials needed

NAME	DESCRIPTION	LOCATION
Where does water come from?	This presentation may be used by teachers to introduce activities in this section.	digital-resources/presentations
Build an edible aquifer	individual practical activity and worksheet You will need: • clear plastic drinking cup, 1 per student • ice cream scoop or large spoon • plastic teaspoons, 1 per student • drinking straws, 1 per student • 2 L tub vanilla icecream or fruit sorbet • 2 L bottle lemonade • chocolate chips, small gummy bears/jubes, crushed ice or cereal • coloured cake sprinkles	**Appendix B** digital-resources/procedures
Build a model aquifer	small group/class practical activity and worksheet You will need: • clear plastic container approx 25 cm × 17 cm × 15 cm or small aquarium • 5 L pebbles or aquarium gravel • 4 packets plasticine • hand pump • food dye – 3 different colours • 1.5 L water dyed blue • 500 mL water dyed yellow • 60 mL water dyed red • 2 small beakers or containers • paper towel • cling film (optional)	**Appendix C** digital-resources/procedures

NAME	DESCRIPTION	LOCATION
Gnasty Gnomes	online game focused on contamination of groundwater Note: computers require Flash to be installed for this game.	http://www.wetrocks.com.au/games/gnasty-gnomes
Groundwater pollution	worksheet summarising aquifer contamination	**Appendix D** digital-resouces/worksheets

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
2.1	Discuss with students 'Where does our drinking water come from?' using the presentation, *Where does water come from?*	class discussion	10 minutes
2.2	Students build an edible aquifer and complete worksheet.	individual practical activity	30 – 45 minutes
2.3	Students build a model of an aquifer and complete worksheet.	small group practical activity individual activity	35 – 40 minutes
2.4	Students play *Gnasty Gnomes* game on computer. Discuss with students potential sources of contamination of groundwater.	individual computer activity class discussion	30 minutes 5 minutes
2.5	Students complete worksheet on groundwater contamination	individual activity	10 minutes

Background information for teachers

Groundwater is water stored in pores and crevices of soil and rock beneath the ground. Rock and soil layers beneath the ground that are saturated with water are called aquifers.

Aquifers

Aquifers may be broadly classified as unconfined or confined.

Unconfined aquifers are also known as water-table aquifers as the saturated zone is usually close to Earth's surface. The upper part of the saturated zone is known as the water table. These aquifers usually recharge (replenish) from surface water and rain.

Confined aquifers have an impermeable (or low permeability) layer above and below the saturated zone. They are usually deeper in the ground than unconfined aquifers and water is under pressure. Water may slowly 'leak' into a confined aquifer from above, or there may be a point where the aquifer outcrops at the Earth's surface enabling recharge. If an aquifer is completely confined it will not be recharged naturally.

Groundwater replenishment is a new practice adopted in Western Australia where a confined aquifer is recharged with water, via a well.

In the groundwater replenishment process wastewater passes through a treatment plant to create secondary treated wastewater. Then it undergoes further treatment to make it drinking water quality, known as potable water. This potable water is pumped into a confined aquifer. Due to slow flow rates in the aquifer, it will remain in groundwater for decades before it's drawn up by bores, treated again, and used.

Water Corporation launched the Groundwater Replenishment Trial in 2009.

Water in the Kimberley

Northern Australia is perceived as having a lot of water. For example various schemes have been proposed in Western Australia to transport Kimberley water to the south. In reality, northern Australia is water-limited. While there is high seasonal rainfall, high temperatures result in very high evapotranspiration (evaporation and plant transpiration) rates. There is more abstraction (removal of water) than recharge.

Figure 2.2 Aerial view of flood waters
photo by Yaruman5/Flickr, CC-BY-NC-ND-2.0

Contaminants

Groundwater contaminants are anything that makes water no longer suitable for use. They may enter groundwater through soil, sediments and rocks, or travel from surface water into groudwater.

Materials from the land surface can contaminate groundwater. Depending on land activity contaminants may be man-made (anthropogenic) such as fuels, pesticides and fertilisers, or natural such as animal waste.

Materials under ground can also contaminate groundwater. Leaking underground storage tanks, septic systems and landfill can affect groundwater.

Rainwater or surface water that comes into contact with a contaminant may transport pollution into groundwater.

In cities, urban run-off that may carry petrol, motor oil, detergents, cleaning products as well as organic waste is a big problem. In country areas, agriculture, pastoral practices and mining may be the main contributor.

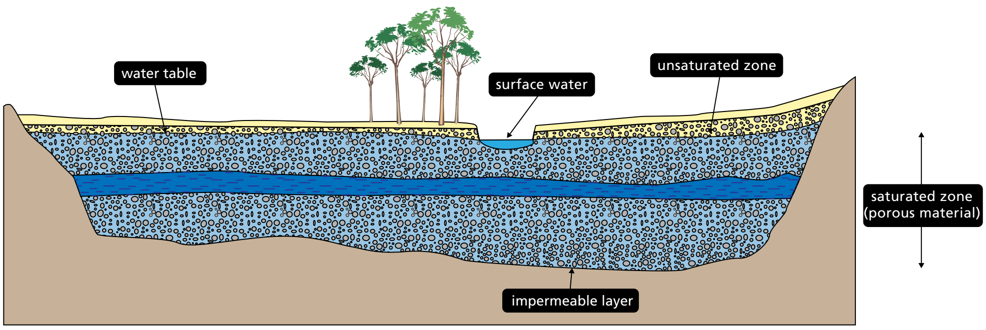


Figure 2.1 cross section of an aquifer
Dan Hutton

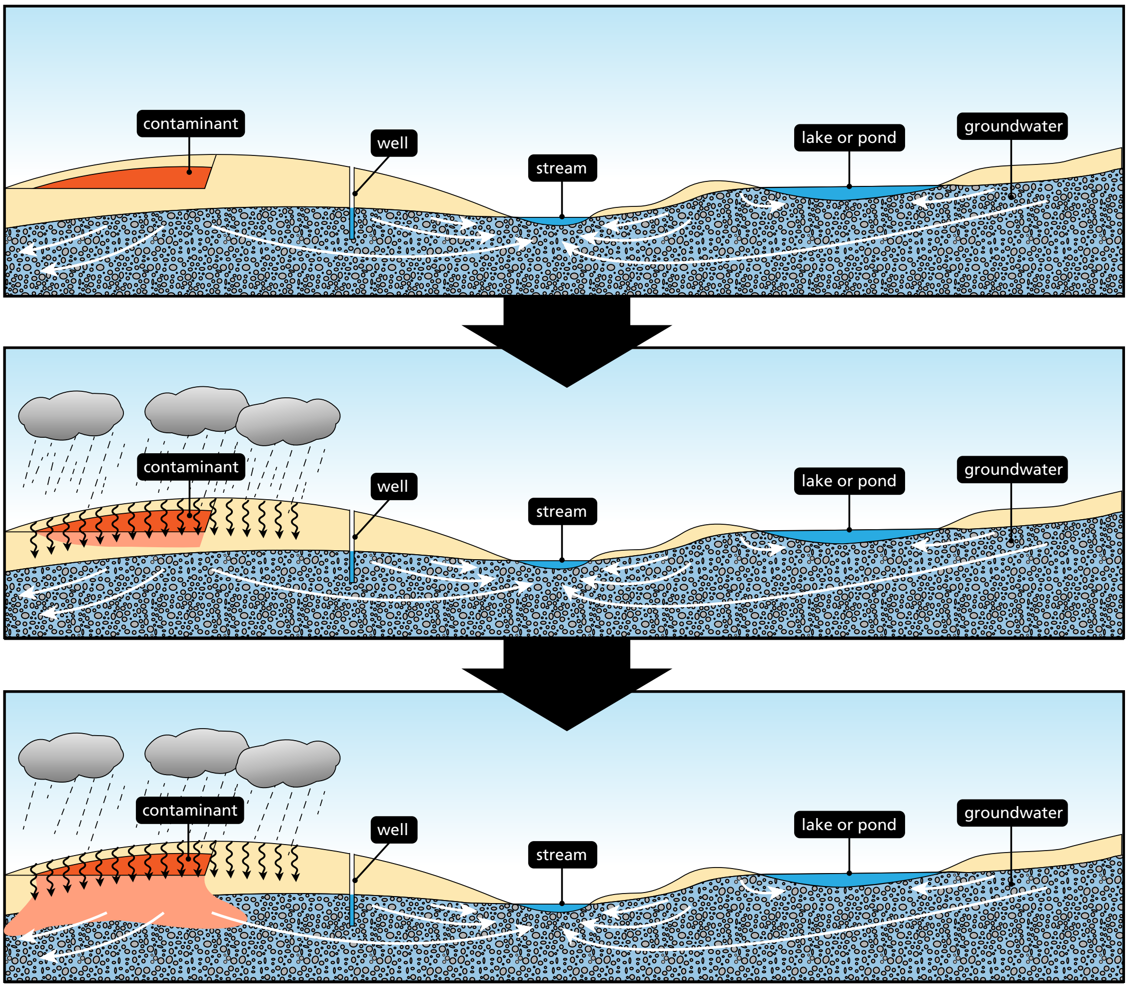


Figure 2.3 Aquifer contaminant
Dan Hutton

Fracking

Fracking began in the 1940s when vertical shafts were drilled into layers of shale and 'fracked'. That is, chemically-treated water and sand were blasted down the well at high pressure, cracking the rock and freeing natural gas (mainly methane). Technological advances now enable horizontal fracking; drilling equipment is able to make a 90° turn and drill parallel to the ground surface. Wells may be drilled to vertical depths of 2 km then a horizontal distance of 2 – 3 km. Vertical wells often pass through aquifers so wells are lined with cement casings to protect aquifers.

Fracking uses a lot of water forced under pressure into a well. Significant volumes of water return as 'flowback'. Flowback water is full of toxic chemicals used in the fracking process, and must be stored appropriately before treatment and possible re-use.

There are a number of potential risks. Fracking may open pathways between natural gas and an aquifer, contaminating groundwater with gas. The cement well-casing may fail allowing contaminants to enter groundwater. Flowback storage may be compromised through inadequate lining of storage pits and tanks, or overflow.

The following online articles contain more information about fracking.

- Mooney, C. (2011). The truth about fracking. *Scientific American, 305*, 80–85. Retrieved from http://www.nature.com/scientificamerican/journal/v305/n5/full/scientificamerican1111-80.html
- Howarth, R., Ingraffea, A. and Engelder, T. (2011). Natural gas: Should fracking stop? *Nature, 477*, 271–275. Retrieved from http://www.nature.com/nature/journal/v477/n7364/full/477271a.html

Seawater intrusion

In coastal areas groundwater flow pushes fresh water towards the ocean. Water leaves the land and enters seawater at subsea outcrops of an aquifer. If the original groundwater gradient changes, as a result of pumping, seawater may intrude into the coastal aquifer and become too salty for drinking.

Activity guide

Activity 2.1 Where does our drinking water come from?

Discuss with students the question, ‘Where does our drinking water come from?’ using presentation: *Where does water come from?* The nine slides in this presentation highlight the structure where groundwater is found: an aquifer.

Activity 2.2 Build an edible aquifer

In this activity students build an aquifer model using edible ingredients. The model demonstrates key features of aquifers.

This activity, in conjunction with the presentation and class discussion, takes around 30 - 45 minutes. As students work through the activity there are questions to answer. After completing the activity students can eat their aquifer.

All ingredients may be substituted for more appropriate or accessible items.

Things you will need for this activity, and what each item represents:

ITEM / INGREDIENT	EQUIVALENT
clear plastic drinking cups, 1 per student	aquifer
drinking straws, 1 per student	bore — used to extract groundwater
2 L tub vanilla icecream or fruit sorbet	confining layer — impermeable rock layer that confines groundwater
2 L bottle lemonade or soda water	groundwater
chocolate chips, small gummy bears/jubes, crushed ice or cereal	saturation zone — gravel, rock or sand
coloured cake sprinkles	topsoil — uppermost layer soil containing plants and animals
ice-cream scoop or large spoon	
plastic teaspoons, 1 per student	
copies of student procedure sheet, *Build an edible aquifer*	**Appendix B** digital-resources/procedures

Figure 2.4 Items and ingredients to build an edible aquifer
Paul Ricketts

Terminology

groundwater
aquifer
porous
water table
saturated zone
confining layer
topsoil

Procedure

1. Hand out a plastic drinking cup to each student.

   Explain to students that this is their aquifer.

2. Build porous gravel layer.

   Fill a third of the cup with chocolate chips.

   Explain to students this forms the bottom layer of the aquifer. Indicate that there are air spaces between particles. This layer is porous: air and water can fit between the spaces between particles.

3. Add water to aquifer.

   Pour lemonade over gravel layer — fill until gravel layer is just covered.

   Explain to students that the gravel layer is referred to as the saturated zone of their aquifer. In this zone all available air spaces are filled with water. Point out that the lemonade sitting just above the gravel layer is called the water table.

4. Build a confining layer.

   Add one scoop of ice-cream to the top of the gravel layer.

   Explain to students that this confining layer effectively traps groundwater below. This represents impermeable rock or clay that is a feature of many aquifers. Water cannot move through the rock as there are no or few air spaces in it.

5. Add topsoil to aquifer.

   Scatter cake sprinkles on top of the ice cream layer.

   Explain this is the final aquifer layer and represents topsoil and leaf litter. Plants and animals live on the surface.

6. Build a bore to extract water from the aquifer.

   Insert straw into the aquifer and pump out water by drinking.

   Explain to students that groundwater is extracted by drilling bores into the saturated zone of an aquifer. Ask students to note if there is any resistance when they insert their straw.

   The aquifer model is complete. Students photograph or sketch the layers of their edible aquifers.

Figure 2.5 Building an edible aquifer
Paul Ricketts

Discussion questions

Following completion of this modelling activity students enjoy eating their edible aquifers while reviewing what they have learned through class discussion.

- What does lemonade represent in your aquifer?
  groundwater
- What do chocolate chips/cereal represent in your aquifer?
  saturated zone: porous rock or soil
- How are aquifers recharged?
  rainfall or rivers
- What does the ice-cream layer in your aquifer represent?
  confining layer or layer of impermeable rock
- What might happen if too much water was extracted from your aquifer without recharge?
  If too much groundwater (lemonade) is pumped out of the aquifer the water table will drop, and the aquifer will become depleted.

Activity 2.3 Build a model aquifer

This procedure is based on an activity developed by the Groundwater Society.

Model aquifers allow students to investigate:

- aquifer structure;
- where groundwater comes from;
- how groundwater is extracted; and
- what happens when contaminants enter groundwater supplies.

Total time for this activity, the presentation and class discussion, is approximately one hour.

This activity is presented in a number of parts in an effort to cater for students of different abilities, and to suit different lesson times.

If required, modify activity in accordance with student age level and ability.

You may choose to demonstrate each activity to the whole class, or conduct small group (3-4) activities where groups build their own aquifer models.

Extension activities include modifying the landscape around model aquifers, and investigating different substrates and confining layers on aquifer structure.

Discussion points are included in Table 2.1.

Figure 2.6 Equipment required to build a model aquifer

Terminology

aquifer
groundwater
porous
saturated zone
water table
unsaturated zone
impermeable zone
unconfined aquifer
confined aquifer
surface water
recharge
extraction
infiltration
depletion
contaminants

Overview

- Review the presentation, *Where does water come from?*
- Point out different layers that make up aquifers
- Explain in this activity a model aquifer will be built to recreate various aquifer features.

Students complete the following activities that are described in **Appendix C: Build a model aquifer**.

Part 1: Aquifer model, extraction and recharge

- Build an aquifer that includes the following features: saturated and unsaturated zones, groundwater, and surface water.
- Extract water from the aquifer via a bore and recharge the aquifer by simulating the action of rain.

Figure 2.7 Construction of model aquifer
Paul Ricketts

Part 2: Confined aquifers

- Add a confining layer to the aquifer using plasticine.
- Investigate how an impermeable layer affects groundwater extraction and aquifer recharge.

Figure 2.8 Addition of confining layer to model
Paul Ricketts

Part 3: Contaminants in aquifers

- Add contaminants to the aquifer and observe their effects.
- Discuss how pollution of groundwater might impact human health and industry.
- Modify topography of the landscape around the aquifer, and/or use alternate materials in aquifer models.
- Investigate how these changes impact on the water table and surface water.

Table 2.1 Discussion questions for **Activity 2.3**

QUESTION	RESPONSE
How is groundwater extracted from an aquifer?	Bores are drilled through the ground surface and into a confined or unconfined aquifer below. Bores pump groundwater out of an aquifer, using pipes and pumps.
How is an unconfined aquifer recharged?	Aquifers are recharged by rainfall. Water moves or percolates from the surface down to the aquifer. Aquifers can also be recharged artificially by building infiltration basins or by direct pumping of bores. Artificial recharge stores groundwater supplies for future use or replenishes over-exploited groundwater sources.
How is a confined aquifer recharged?	Confined aquifers are recharged by leakage of confined aquifers above them. They are also recharged in areas where the aquifer outcrops or is open at the surface.
What would happen if too much water were extracted from an aquifer?	When groundwater extraction exceeds recharge the water table declines and groundwater supplies are depleted.
What might be some problems caused by groundwater overuse?	Amount of water available for human use is reduced. Bores may no longer reach the groundwater supply, increasing costs of extracting water. In coastal areas saltwater can intrude into groundwater supplies. As groundwater and surface water supplies are connected, reduced water table levels may affect water levels in lakes, streams, rivers and wetlands. The land surface may lose support and subside or sink.
What might happen to groundwater supplies during times of drought?	Water levels in aquifers are not constant: they vary according to the amount of rainfall. In times of drought aquifers may not be recharged and the water table level will fall.
How do contaminants enter groundwater supplies?	Contamination can enter aquifers through land surface runoff, surface water contamination and contamination near aquifer outcrops. Groundwater can also be contaminated by underground sources, such as septic tanks.
What might happen if groundwater is contaminated?	It may become undrinkable for humans due to presence of harmful chemicals or pathogens.
Could a bore contaminate groundwater supplies? How could this be prevented?	Contamination of aquifers from bore sites is possible. Bores need to be built properly to reduce the risk of toxins entering groundwater supplies.
How can we protect our groundwater?	Manage waste, prevent pollution and build safe bores.

Activity 2.4 *Gnasty Gnomes*

Students play the game, *Gnasty Gnomes*, on a computer.

- http://www.wetrocks.com.au/games/gnasty-gnomes

This game, available from the Wet Rocks website, focuses attention on groundwater contamination. It's an initiative of the Teacher Earth Science Education Programme, funded by the Australian Government through the National Water Commission's *Raising National Water Standards* program.

Background to the game

Gnasty Gnomes represents a city or town that uses groundwater as its primary supply of water. Contamination is entering the soil, and ultimately the groundwater. Unless stopped, water quality deteriorates until it can no longer be used.

Key concepts for the game

- This game is designed to communicate that preventing contamination is more cost effective than fixing it.
- Many people are dependent on groundwater as their primary source of water.
- There are many things that contaminate groundwater.
- Four contamination management options are included: prevention, bioremediation (for organic contaminants), chemical treatment and drill (dig and dump).

The game set up

Firstly, it's a game, so it's intended to be enjoyed!

The basic premise is that you pick-up and flick 'gnomes' (a well-known source of contamination) off the screen *before* they can pour out contamination. Each time a gnome is flicked, you will earn cash.

Where pollution is spilt, there are three options provided to 'remediate' (or clean-up) the contamination: bugs (bioremediation), chemicals or drill (dig and dump).

Aim of the game

To protect the town's water supply for as long as possible from becoming polluted, and no longer useable.

Observations students may make include:

1. Prevention is better than clean-up.

   You can keep water quality okay longer if you stop gnomes from dropping pollution!

   Prevention is less expensive and more effective than clean-up.

2. Drilling is cool, but expensive.

   Digging and dumping basically digs up contamination and then moves it somewhere else.

   It solves the problem at one site, but what might be some consequences?

   Really this transfers the problem somewhere else. Some landfills are specially designed to take contaminated materials, but in many countries it is becoming unacceptable. Material may be taken to a treatment facility, and treated there. There's still a risk of a spill as it is transferred.

3. What do the bugs do?

   This is called bioremediation.

   Often there are really small bugs (such as microbial bacteria) that love to eat organic chemicals. If you can find the right bugs and give them the right conditions, they can eat up contamination. But be careful — what bugs produce can sometimes be as nasty as the contaminant in the first place!

Figure 2.9 *Gnasty Gnomes*, from Wet Rocks

4. What do the chemicals do?

   This is chemical treatment.

   Sometimes the best way to treat a contaminant (especially inorganic chemicals) is to add another chemical that reacts with them.

   This can assist in getting rid of a contaminant, either by creating a less hazardous chemical, or in some cases bonding the contaminant to soil so it can't dissolve into groundwater.

After students play *Gnasty Gnomes*, discuss what contaminants might occur in their region. Answers may include:

- fertilisers and pesticides,
- industrial waste,
- petrol and oil,
- urban run-off,
- sewage/septic systems,
- animal waste, and
- plant material.

Activity 2.5 Groundwater contamination

Following discussion about contaminants, students complete a worksheet focused on groundwater contamination in the Kimberley, **Appendix D: Groundwater contamination**.

IS IT SAFE TO DRINK?

3

Is it safe to drink?

image courtesy of Water Corporation

Purpose

Students are introduced to a range of water monitoring techniques.

Outcomes

Students understand that:

- scientific techniques may be used to determine if groundwater is safe to drink;
- there may be several techniques to measure the same parameter;
- measures such as pH and salinity show a range of measurement; and
- potable (drinking water) water must be within guidelines.

Materials needed

NAME	DESCRIPTION	LOCATION
Why monitor water?	This presentation may be used by teachers to introduce activities in this section.	digital-resources/presentations
Three practical laboratory activities measure things we can't see: pH, temperature and salinity.		
Measuring pH	practical activity in lab or classroom, in pairs You will need: • safety glasses • indicator paper, Universal Indicator or pH TesTabs • test solutions, e g lemon juice, vinegar, soda, tea, shampoo, washing powder, water …	**Appendix E** digital-resources/worksheets
Measuring temperature	practical activity in lab or classroom, in pairs You will need: • safety glasses • thermometer or salinity probe • 250 mL beaker • water at different temperatures, e g straight from tap; out of fridge; from a hot tap; water in a cup of tea …	**Appendix F** digital-resources/worksheets
Measuring salinity	practical activity in lab or classroom, in pairs You will need: • safety glasses • salinity probe • salt dissolved in water (0.5 g/L) • water samples, e g tap, deionized, bottled, filtered, pond, swimming pool	**Appendix G** digital-resources/worksheets
A practical laboratory activity measures something we can see: turbidity.		
Measuring turbidity	small group practical activity You will need: • turbidity tube • water monitoring kit container • test samples, e g tap water, muddy water, water from pond, lake or river …	**Appendix H** digital-resources/worksheets

Activity summary

	ACTIVITY	POSSIBLE STRATEGY	SUGGESTED TIME
3.1	Show presentation, *Why monitor water?* Discuss with students why we monitor our drinking water.	presentation and class discussion	5 min
3.2	Students measure pH in class.	practical activity in pairs	15 min
3.3	Students measure temperature in class.	practical activity in pairs	10 min
3.4	Students measure salinity in class.	practical activity in pairs	15 min
3.5	Students measure turbidity in class.	practical activity in pairs	20 min

Background information for teachers

pH

pH is a measure of acidity or alkalinity of a solution. It is generally reported on a scale of 1 to 14, although lower and higher values are possible. A pH of seven is neutral; values less than seven are acid and values greater than seven are alkaline (or basic).

Water molecules are in constant motion. When two molecules collide they may split apart (dissociate) to form a hydronium ion (H_3O^+) and hydroxide ion (OH^-).

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

This equation is often simplified to:

$$H_2O \rightleftharpoons H^+ + OH^-$$

The pH scale is a measure of the concentration of hydrogen ions (H^+) in a solution. It's a logarithmic scale as every one-unit change on the pH scale corresponds to 10-fold change in H^+ concentration.

For example, a solution with pH 4 is ten times more acidic than a solution with a pH 5; it has ten times the concentration of H^+ ions.

A solution with pH 3 is 100 times more acidic than a solution with a pH of 5. It has 100 times the concentration of H^+.

Changing temperature and addition of chemicals into water can affect pH. This is why pH is used as an indicator when determining water quality. The pH of drinking water should be in the range 6.8 – 8.5.

For information on the effects of acid rain, which lowers pH in surface waters, see:

- United States Environmental Protection Authority. (2012). *Effects of acid rain — surface waters and aquatic animals*. Retrieved 13 May 2015 from http://www.epa.gov/acidrain/effects/surface_water.html

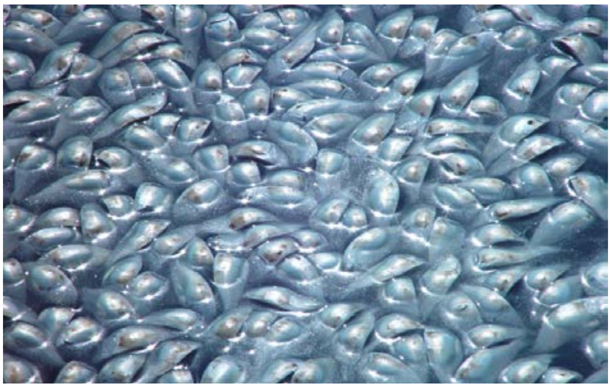


Figure 3.1 Fish kill
image by eutrophication&hypoxia/Flickr, CC-BY-2.0

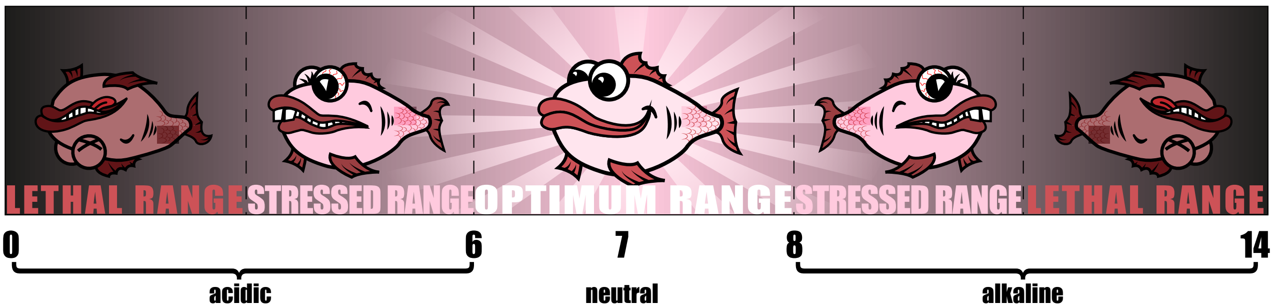


Figure 3.2 pH scale and its effect on fish

Temperature

Temperature generally refers to how hot or cold something is.

Temperature is a measure of heat energy, or the average kinetic energy of molecules. The greater the kinetic energy of molecules, the faster the molecules move and the higher the temperature will be.

Water temperature is important in water monitoring. It affects the amount of dissolved oxygen in water; it affects the rate of chemical reactions; and many aquatic organisms only function within certain temperatures.

Warm water holds less dissolved oxygen, but organisms metabolise at a fast rate in warmer water. Fish deaths may be due to a lack of dissolved oxygen if water temperatures get too high.

Water temperature fluctuates with season, water depth, latitude and surrounding environment. For example, water that's shaded will be cooler than water in full sun. There is no 'set' temperature for a particular body of water. Monitoring enables scientists to determine if temperatures are changing.

For example, if a water body is usually 20°C at a certain time of the year, but begins to measure at 23°C, it may be an indicator that something is happening. It could be a consequence of increased nutrients, due to agricultural run-off, leading to greater metabolic activity. If excessive nutrients enter water it can become over-enriched with phosphates. This can stimulate plants and algae to grow. When the plants and algae die, large populations of bacteria decompose the material, raising temperature and depleting oxygen in water.

Figure 3.3 Salt lake
photo courtesy of Rhys Lennings

Salinity

Salinity is a measure of the amount of salt dissolved in water (or soil). Salt is used here in its chemical sense that includes ions of chloride, sodium, calcium, potassium, bicarbonate, magnesium, nitrate and sulfate (not just common salt — sodium chloride). Salts are highly soluble in water. All of these ions contribute to a measured value for total dissolved solids (TDS) in water.

Too much salt in water can make it undrinkable. Groundwater is often salty as minerals from rocks and soil may dissolve in water over time.

Salinity is measured in two ways:

- total dissolved solids (TDS) — a measure of all dissolved substances in water, reported as mg/L (or parts per million, ppm)
- electrical conductivity (EC) — The amount of electricity that can pass through water is proportional to the amount of dissolved salts in water. It is reported as µS/cm (microsiemens per centimeter).

TDS may be estimated from an EC reading by using a conversion factor. There are two assumptions in using a conversion factor:

- all dissolved solids produce conductivity, and
- all solids have equal conductivity.

Conversion factors usually vary from 0.5 through to 0.6.

TDS (mg/L) = EC (µS/cm) × 0.6

A TDS up to 500 mg/L is considered suitable for human consumption.

Table 3.1 Some measured salinity values

WATER SAMPLE	SALINITY mg/L	TEMPERATURE °C
tap	415	19.7
deionised	0	20.3
bottled	72	21.7
filtered	229	19.7
salt solution	532	21.2
fish pond	682	18.6
swimming pool	> 2000	20.6

Turbidity

Turbidity is a measure of the cloudiness of water, or the relative clarity of water. The higher the turbidity, the harder it is to see through water. Turbidity is a key indicator used in assessing if water is suitable for human consumption.

Material such as suspended particles of mud, sand and microscopic organisms like algae cause turbid water.

Figure 3.4 Turbid water
photo by Ian Sutton/Flickr, CC-BY-NC-SA-2.0

Saltiness isn't related to turbidity. For example, visibility in the ocean may be very good although seawater has high TDS of 35 000 mg/L. Water with low visibility may have low TDS if particles that obscure visibility aren't dissolved. The colour of water isn't related to turbidity.

Turbidity is measured in nephelometric units (NTU) or Jackson turbidity units (JTU), depending on method and equipment used.

A turbidimeter is a sophisticated unit that uses a beam of light to measure the amount of light scattered; the more particles in the sample, the more light is scattered. It measures turbidity in NTU.

Another, easier method uses a turbidity tube. Water is slowly added until a black and white marker at the bottom of the tube (known as a secchi disk) can no longer be seen. A reading off a scale on the side of the tube is then taken.

Drinking water should have a turbidity of less than 5 NTU. This is the value at which turbidity becomes visible to the naked eye.

COMMON TERM	SCIENTIFIC TERM
acidic, alkaline, basic	pH
hot, cold	temperature
salty	salinity
cloudy, clear	turbidity

Activity guide

Activity 3.1 Water monitoring

Use presentation, *Why monitor water?* to introduce water monitoring. The presentation has 16 slides and highlights basic questions of why, what, how, when and where water monitoring is done.

Introduce a range of water measurement techniques that students will practice in class, before doing field measurements.

Activity 3.2 Measuring pH

Discuss with students what pH is (how acidic or alkaline a solution is) and why pH is an important measure in a water-monitoring program. If water pH is too high, or too low, aquatic organisms may die.

The optimum pH range for most organisms is between 6.5 and 8.5. At pH 5 most fish eggs can't hatch. pH values below 4 or above 11 may cause human skin and eye irritation. Drinking water pH should be in the range pH 6.8 to 8.5.

Addition of chemicals into water and temperature may alter pH.

Students follow **Appendix E: Measuring pH**, working in pairs, to investigate the pH of various solutions. This activity requires students to predict, measure and record data.

Activity 3.3 Measuring temperature

Discuss with students how temperature is measured (with a thermometer) and why temperature is an important measure in a water-monitoring program. For example, as temperature of water increases, the amount of dissolved oxygen decreases.

The salinity probe also measures temperature, so this probe may be used instead of a thermometer.

Students follow **Appendix F: Measuring temperature**, working in pairs, to investigate the temperature of various water samples. This activity requires students to predict, measure and record data.

Activity 3.4 Measuring salinity

Discuss with students what salinity is (how salty a solution is, or the amount of salt dissolved in water) and why salinity is an important measure in a water-monitoring program.

All organisms need a certain amount of salt in their bodies, but too much salt in water can affect aquatic organisms. Freshwater fish have mechanisms that retain salt, while saltwater fish have ways of excreting or getting rid of excess salt.

If humans drink seawater we become sick. We would have to urinate more water than we drank to get rid of the excess salt. We would quickly become dehydrated and die.

We can't see the amount of salt that's dissolved in water.

Students follow **Appendix G: Measuring salinity,** working in pairs, to investigate the salinity of various solutions. This activity requires students to predict, measure and record data.

Activity 3.5 Measuring turbidity

Turbidity is about the amount of undissolved material in water. It is a key indicator used to assess if water is suitable for human consumption.

Too much suspended material in the water may block light from getting to aquatic plants. You can see if water is clear or cloudy. In this activity students make a scientific measurement of turbidity.

Students follow **Appendix H: Measuring turbidity**, working in pairs, to investigate the turbidity of a water sample. This activity requires students to measure and record data.

4

Field trip

Purpose

Students learn how to sample and record data, in the field.

Outcomes

Students understand that:

- scientific techniques may be used to determine if groundwater is safe to drink;
- potable (drinking water) water must be within guidelines;
- sampling is a process where a water sample is used to represent a water body; and
- accurate data recording is an important part of science.

Materials needed

NAME	DESCRIPTION	LOCATION
Field trip preparation	whole class activity	A full equipment list for the field trip is included in **Activity 4.1** below.
Field protocols	description of protocols for taking samples and making measurements	**Appendix I** digital-resources/procedures
Data record	Students complete this form as measurements are made.	**Appendix J** digital-resources/worksheets
Identification key	aquatic macroinvertebrate classification key Two versions of this key are provided. A simplified version features macro-invertebrates most commonly found in the Kimberley.	**Appendix K** digital-resources/factsheets
Macroinvertebrate survey	Students use this form to assess water health, based on presence of macroinvertebrates. Two versions are supplied for the two identification keys.	**Appendix L** digital-resources/worksheets

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
4.1	field trip preparation	class discussion organise equipment	30 min
4.2	Students conduct water measurements while on a field trip.	field trip	2 hours, or full morning / afternoon
4.3	macroinvertebrate classification	field trip	included in **Activity 4.2**

Background information for teachers

Part 3 contained background information on monitoring pH, temperature, salinity and turbidity levels of water. This is extended here with information on living organisms in water (this includes microorganisms that are too small to see and visible organisms — macroinvertebrates); and other compounds that may be monitored in water.

Microorganism — *E. coli* bacteria

Escherichia coli, or *E. coli*, is a type of fecal coliform bacteria that is commonly found in the gut of humans and animals. Fecal coliform bacteria are associated with human and animal waste.

Image 4.1 *E. coli* test kit
Paul Ricketts

Infection with *E. coli* can be severe and cause fever, bloody diahorrhea or even kidney failure.

Water with *E. coli* can be disinfected with chlorine, ultraviolet light or ozone, all of which kill or inactivate *E. coli*. All systems that use surface water for drinking must disinfect it.

Aquatic macroinvertebrates

Aquatic macroinvertebrates are animals without a backbone that can be seen with the naked eye. As they live at least part of their lives in water their survival is closely linked to the health and quality of water. Examples of macroinvertebrates include snails, worms, shrimp, mosquito larvae, water mites and beetles.

Image 4.2 Aquatic macroinvertebrates
Paul Ricketts

Macroinvertebrates are an integral part of the food web as they're a food source for fish and birds.

Each type of macroinvertebrate needs particular environmental conditions to survive, grow and reproduce. Some macroinvertebrates are very sensitive to pollutants, while others are not. Scientists can tell a lot about the health of the water body by the presence or absence of various macroinvertebrates.

For example, organisms in the orders Ephemeroptera (mayfly nymphs), Plecoptera (stonefly nymphs) and Trichoptera (caddisfly larvae), collectively known as EPT are very sensitive to pollutants.

Less sensitive orders include Odonata (dragonfly larvae), Hemiptera (water strider) and Diptera (mosquito larvae/pupa). Most tolerant are subclass Hirudinea (leech), phylum Nematoda (roundworm) and subclass Oligochaeta (segmented worm).

(Note: the traditional classification of kingdom → phylum → class → order → family → genus → species is used here.)

Time of sampling is important. For example, do not sample within two weeks following a flood event. The Ausrivas sampling manual suggests sampling in northwest WA be done in the periods March to May, or September to October.

- Department of Water WA. (2009). *Western Australia AUSRIVAS sampling and processing manual*. Retrieved 13 May 2015 from http://www.water.wa.gov.au/PublicationStore/first/85677.pdf

Dissolved oxygen (DO)

Aquatic organisms need oxygen to respire. Low levels of dissolved oxygen may stress aquatic animals and plants.

Aquatic organisms respire (use up oxygen), therefore oxygen needs to be replenished. In many water systems this occurs through re-aeration, which is diffusion of gases between the atmosphere and water. Oxygen dissolves in water through mixing of surface water and the atmosphere. If water is moving rapidly oxygen can dissolve more readily than if water is still. Oxygen also enters water via photosynthesis in aquatic plants.

The level of dissolved oxygen is inversely proportional to water temperature. The lower the temperature, the more oxygen can dissolve. For example, at 0°C the maximum level of oxygen is 14.6 mg/L, and at 30°C the maximum level is 7.56 mg/L.

Most northern Australian rivers have seasonal flows and by the end of the dry season re-aeration is a problem. If water is warm then metabolic activity and oxygen consumption rates of all aquatic organisms will be high, even though less dissolved oxygen is present.

Image 4.3 Kimberley river
photo courtesy of Natalie Tapson

Dissolved oxygen needs to be between 5 and 6 mg/L for growth and activity of most aquatic organisms.

Phosphates and nitrates

These compounds are often found in fertilisers. If they are added to water, for example through agricultural run-off, they can stimulate growth of aquatic plants.

Eutrophication is a process whereby excessive nutrients cause excessive growth of algae and other aquatic plants. Often an 'algal bloom' will occur which will eventually die off and be decomposed by bacteria. Bacteria use significant amounts of oxygen during decomposition leading to a decrease in oxygen available for other organisms.

Maximum safe levels in water are 50 mg/L of nitrate and 5 mg/L of phosphate.

Image 4.4 Algal bloom
photo by Lynton Bond/Flickr, CC-BY-NC-2.0

Water monitoring

Monitoring is about making consistent observations and measurements over time. These measures are then analysed to provide information about the state of a water system. Consistent sampling methods enable comparisons to be made.

Before deciding to start monitoring, basic questions of why? what? how? when? and where? should be answered.

Why monitor?

For the Ngurarra rangers based at Fitzroy Crossing there are issues with traditional waterholes (jila). Levels of water in jila are decreasing and rangers want to find out why.

In other programs the purpose may be to gather baseline data to begin to understand threats to freshwater systems or it may be to determine if a rehabilitation activity is effective.

Monitor what?

Determining what water quality indicator measures should be used ultimately depends on why monitoring is in place. It is also useful to identify land use issues that may impact the water system. For example in a rural setting land clearing, stock (cattle/sheep) and use of fertilisers, pesticides or herbicides may impact a water system. Parameters such as turbidity, nutrient levels (nitrate and phosphate), *E. coli* and dissolved oxygen would be useful measures.

How to monitor?

Using standardised methods for data collection means that quality data are collected that can be compared and used to make decisions. Samplers should be trained and all steps in the process documented.

Monitor when?

Sampling frequency depends on purpose. Sampling may be seasonal or event driven (for example after a flood). However to determine if there's any change comparative data will be required.

Monitor where?

Site selection depends on reasons for monitoring however the site must be accessible and safe. Once the general spatial area is determined, individual sampling sites are selected. Data have to represent conditions at sampling sites accurately. For data to be complete, enough should be collected to represent conditions at the sampling site.

Measurement errors can be caused by:

- poor site selection;
- poorly calibrated equipment;
- sample contamination;
- poor sampling techniques; or
- inaccurate record keeping, data transcription and storage.

Quality control

At school level the following samples may be taken:

- **blank samples** — distilled (purified) water to detect and measure contamination in sampling technique; and
- **replicate samples** — two or more samples collected from the same site, at the same time, using the same method. Three replicates enable some assessment of precision.

Water sampling

The water sample should represent average conditions in the water body being measured. In general, a sample should be collected in the middle of the stream, at least a few centimetres below the water surface.

Be CrocWise at all times.

If wading is required, try not to disturb sediments. Stand facing upstream and collect the water sample in front of you.

For more information about water monitoring, see:

- Department of Water. (2009). *Water quality monitoring program design*. Retrieved 17 March 2015 from http://www.water.wa.gov.au/PublicationStore/first/87153.pdf
- United States Environmental Protection Authority. (2012). *Monitoring and assessing water quality — volunteer monitoring*. Chapter 5: Water quality conditions. Retrieved 13 May 2015 from http://water.epa.gov/type/rsl/monitoring/vms50.cfm

Image 4.5 Taking a water sample
Paul Ricketts

Figure 4.6 Be CrocWise at all times.
photo courtesy of Tim St Pierre

Activity guide

Activity 4.1 Field trip preparation

Discuss with students possible reasons for monitoring water in your area.

Consider the why, what, where, how and when of sampling. Discuss what parameters your class will measure on the field trip (see below).

Students may all use water from one water sample, or different water samples could be collected from different areas at the water body (for example, near the edge, in the middle of a stream, still water, running water …).

The LaMotte water monitoring kit, turbidity tube and salinity probe may be used to measure: pH, salinity, temperature, turbidity, nitrate, phosphate, dissolved oxygen and *E. coli*.

Figure 4.7 LaMotte water monitoring kit
Paul Ricketts

Students also measure aquatic macroinvertebrates and consider riparian (close to water's edge) vegetation. Together these measures provide an indication of water health.

Conducting field measurements

- Students may work in small teams with each team measuring all parameters.
- Students may work in pairs with each pair measuring a specific parameter.
- Different teams of students may take water samples from different parts of a water body to make comparisons between sampling sites.
- Before starting, discuss where aquatic macroinvertebrates might be found (see background information).

Students need to be prepared BEFORE the field trip so all know what their tasks are.

Equipment required for the field trip

For each team:

- 3 x 10 mL test tubes with tops (for pH, nitrate and phosphate)
- 1 x 5 mL tube with screw lid (for dissolved oxygen)
- test tube rack
- 1 *E. coli* test tube (special LaMotte tube with screw-on lid and tablet for *E. coli*)
- pencils
- **Appendix I: Field protocol**
- **Appendix J: Data record** or iPads
- **Appendix K: Identification key** for aquatic macroinvertebrates
- **Appendix L: Macroinvertebrate survey**

For the class

- salinity and temperature probe
- turbidity tube
- buckets, beakers
- clean container, attached to a pole for a 1 L water sample
- measuring cylinder to measure 10 mL volumes
- TesTabs from LaMotte kit for chemical measures (pH, nitrate, phosphate, dissolved oxygen and *E. coli*)
- aquatic macroinvertebrate sampling kit:
  scoop net on a handle
  2 white sorting trays
  4 ice cube trays
  plastic spoons to sort macroinvertebrates
  hand lens or magnifying glass
- camera
- umbrella/shade
- chairs
- two small card tables (depending on class size)

Activity 4.2 Field trip

Preferably the field trip should be conducted at a surface water setting, although it could be conducted at a bore or within school grounds. Depending on location, aquatic macroinvertebrate sampling may or may not be an option.

If possible, invite a ranger group to participate in the field trip. They should be able to help with knowledge of a suitable site, equipment and sampling technique.

In the Kimberley it is important to be CrocWise.

Sampling order should be as follows:

- Take water sample to be used for all measures.
- Measure: temperature, salinity, pH, nitrates, phosphates, dissolved oxygen, *E. coli* bacteria, turbidity (all measured from the same water sample).
- Observe habitat variables.
- Conduct macroinvertebrate sweep.

Students follow sampling and measurement protocols as outlined in **Appendix I: Field protocols**. Data may be recorded by students using **Appendix J: Data record** or electronically in a spreadsheet application.

Collecting a water sample

If wading is required, try not to disturb sediments.

Stand facing upstream and collect the water sample in front of you. If the sample is collected from the shore, be sure to pick a site where there's enough current to ensure adequate mixing.

Don't sample from stagnant, slow-moving water if it's not representative of the stream segment.

All containers should be washed and rinsed with distilled water prior to sampling. A clean, wide-mouthed jar or container (approximately 1 L) with a cap is suitable.

Perform each test within an hour of collection.

How to sample macroinvertebrates

Good sampling is found near stones, logs and vegetation. These areas are usually near the edge of a water body.

Use **kick sampling** in running water:

- Select an area within the water body that is shallow enough to stand in: about knee-deep.
- Establish a clear path of approximately 5 m that can be walked upstream in a straight line.
- Face *downstream*, submerge the net so it is in front of your feet on the floor of the river bed. Position the mouth of the net so it is facing *upstream*.
- Shuffle and kick the ground so the sediment, rocks etc are disturbed.
- Slowly walk backwards for 5 m continuing to kick and shuffle the ground.

Use **sweep sampling** in slow moving water:

- In slow moving water and pools, sweep the net across the surface and drag it through the water in a figure of 8 motion.

Use **beat and scrape sampling** near vegetation, rock and logs:

- Beat and scrape your net against the base of aquatic plants.
- Pick up smaller rocks and logs and rub surfaces.

Adapted from *Waterwatch South Australia*. http://www.waterwatchadelaide.net.au/index.php?page=sampling-techniques

Figure 4.8 This sample holder uses a bicycle drink holder attached by two screws to a pole.
Paul Ricketts

Activity 4.3 Macroinvertebrate classification

In the field, find out what macroinvertebrates were netted and determine their pollution sensitivity.

Sorting techniques

- Pre-fill white sorting trays with water from the water body and place in the shade.
- Turn your net inside out and empty the sample into the sorting tray.
- Pick through for at least 10 minutes.
- When you spot a bug, use a spoon to scoop it out and place it into the ice cube tray – make sure there is water in the tray.
- Don't mix up different bugs in the trays.
- Identify animals using **Appendix K: Identification key** and add to **Appendix J: Data record**.
- Return macroinvertebrates to the water body.

Calculate pollution index and taxa richness using information in **Appendix L: Macroinvertebrate survey**. These data will be added to the field trip summary back in the classroom.

Note that the quoted pollution sensitivity values on the macroinvertebrate identification keys (Appendix K) and survey sheets (Appendix L) are typical values for these organisms. In some cases species most commonly found in the Kimbeley have different sensitivities.

COMMON NAME	POLLUTION SENSITIVITY (GENERAL)	POLLUTION SENSITIVITY (KIMBERLEY)
mayfly nymph	9	5
caddisfly larva	8	6
giant water bug	1	2

PUTTING IT TOGETHER

Display poster by Derby District High School

version 1.0
developed for the Department of Education WA

Purpose

This resource is intended to summarise collected data into a coherent picture: what do the data reveal about water quality in the investigated water body?

Outcomes

Students understand that:

- data are collated and presented to show meaning;
- data are used to inform management strategies; and
- communicating information to the public is an important part of science.

Materials needed

NAME	DESCRIPTION	LOCATION
Field report	This form summarises data from the field trip.	**Appendix M** digital-resources/worksheets
Interpreting your results	This fact sheet helps students determine if a water body is healthy.	**Appendix N** digital-resources/factsheets
Water quality	Three scenarios, in the form of newspaper headlines, promote understanding of connections between monitoring parameters. Three versions of this worksheet, for advanced (worksheet 1), intermediate (worksheet 2) or basic students (worksheet 3), are provided.	**Appendix O** digital-resources/worksheets

Activity summary

ACTIVITY		POSSIBLE STRATEGY	SUGGESTED TIME
5.1	Enter data into a master spreadsheet. Add results to **Appendix M: Field report**. Students use **Appendix N: Interpreting your results** to determine if the water body is healthy, based on field measurements.	small group activity	30 minutes
5.2	Teacher or students read a short newspaper story. Three stories are included in **Appendix O**. Individually or in pairs, students use a guided mind-map or create their own mind-map to show how the scenario could impact a water body.	class activity in pairs	30 minutes
5.3	Students select an appropriate key message and design a poster or sign to display at a water body.	individual activity	40 minutes

Background information for teachers

Science communication

The two most fundamental questions to ask in any communication activity are:

- 'Who is your target audience?' and, as a result of the answer to that question,
- 'What is your key message?'

Target audience

A target audience is the main group of people at which your message is aimed. There are different 'types' of audience. For example:

- Mass audience: a social unit in which people are bound together by something that attracts their attention or is the focus of their interest. For example, the nightly news attracts a mass audience.
- Segmented audience: a mass audience is divided into more homogenous subgroups that may have similar demographic characteristics such as gender, ethnicity, age, income or education.

A campaign against drink-driving is an example of a segmented audience. Such a campaign is best targeted towards a segmented audience consisting of males between the ages of 16 – 25. This age group represents only 5% of the population, but is the high-risk age group for that behaviour.

Most communication works best when the message is focused on a segmented audience. Messages that suit one particular audience may miss the mark with another.

Key message

The key message is also called the take-home message; it's what you want your audience to remember, understand or do. The target audience drives the key message, as the key message must be relevant to the target audience.

Posters and signs

A poster or sign is visual combination of bold design, colour and message intended to catch and hold the attention of a passerby long enough to implant a significant idea in their mind.

Posters and signs are visual communication tools. They:

- stand alone;
- speak for themselves;
- are a hybrid of visual and written ideas; and
- have one key message.

Visual elements are a key component of a poster or sign. One study[1] found that 66% of positive comments about a set of posters related to non-textual elements.

It's important to have a strong connection between visual elements and text. They should combine to drive home the key message.

[1]Scibus: Science on the Buses. Report to the European Commission. (2003). Graphic Science, Faculty of Applied Science, University of the West of England. Retrieved from www.uwe.ac.uk/fas/graphicscience/projects/evaluations/scibus_eval.htm

The poster above is very busy. It contains too many messages: four where there should only be one key message.

- WHY wash your hands?
- WHEN must you wash your hands?
- HOW to wash your hands
- USING gloves

The poster also has too much text. Most people will give a poster or sign just a few seconds of their time, UNLESS the message is very relevant to them.

The posters below (both done by students) have one major message: wash your hands with soap to stop the spread of infection. There is a strong connection between text and visual elements.

To get people to look at your poster you must engage their attention. If you can't engage attention then your effort is wasted!

Remember, the key message needs to be relevant to the target audience, NOT YOU!

Activity guide

Activity 5.1 Data entry

Set up a master spreadsheet for students to enter their field data. The form of the spreadsheet will depend on how and what data were collected.

If teams of students collected data on all variables, calculate average results for each variable. There will be no need to do this if small groups measured one variable each.

Enter results into **Appendix M: Field report**.

Use **Appendix N: Interpreting your results** to determine if the water body is healthy or not.

What do data show? Students may write or orally present their results. Is the water body healthy or not. Why? Are there any concerns?

Activity 5.2 Scenario activity

In this activity students investigate impacts of three scenarios upon water quality. It helps students understand that consideration of all water quality measures is necessary to determine the health of a water body.

Students review single or multiple scenarios and make decisions about impacts on physical, chemical and biological characteristics of water quality.

Students indicate if water quality characteristics, such as pH or dissolved oxygen, increase, decrease, or do not change as a result of each scenario. They are encouraged to consider how water quality characteristics are connected. For instance, animal activity around waterholes directly impacts water quality by increasing turbidity, which leads to increases in temperature and decreases in dissolved oxygen.

To represent the impacts of each scenario students use a mind map format to display interactions between water quality parameters.

Three versions of the activity are included in **Appendix O**.

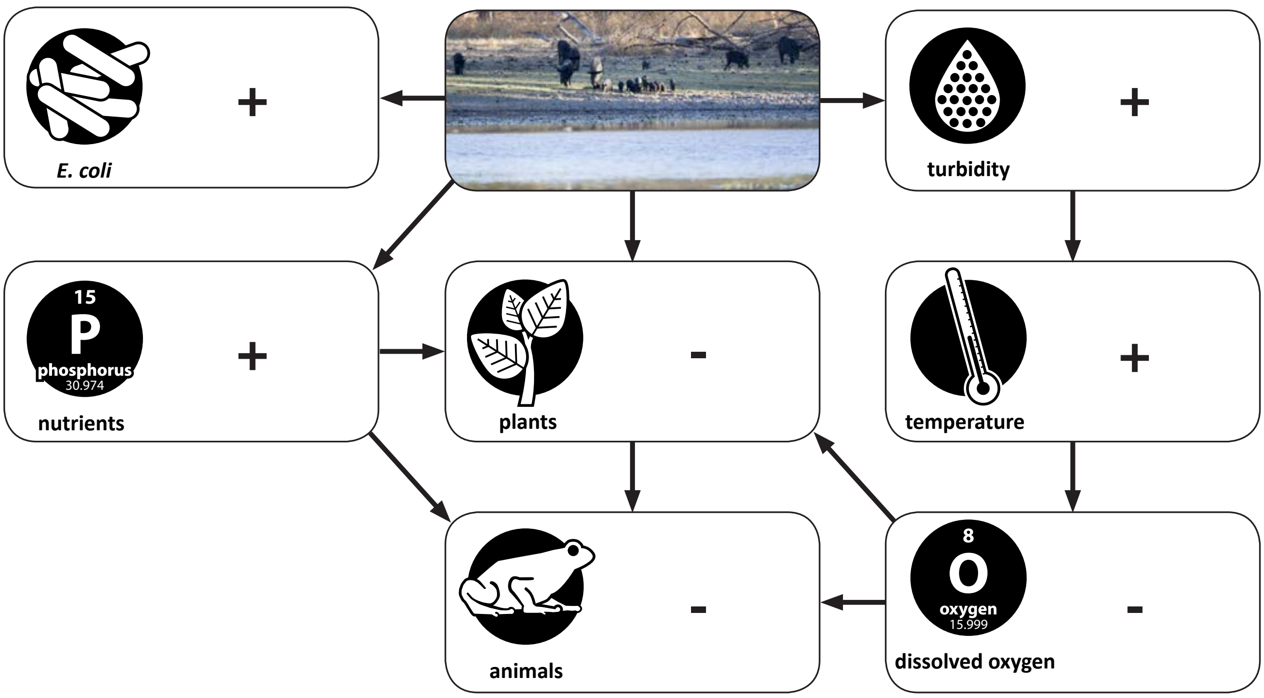
Advanced students develop their own mind map or other diagrammatic representation of these interactions, using the worksheet, *Water quality 1.*

Water quality 2 presents the same information with reduced text.

Less advanced students may label partly completed mind maps provided to guide their decision-making, using *Water quality 3.*

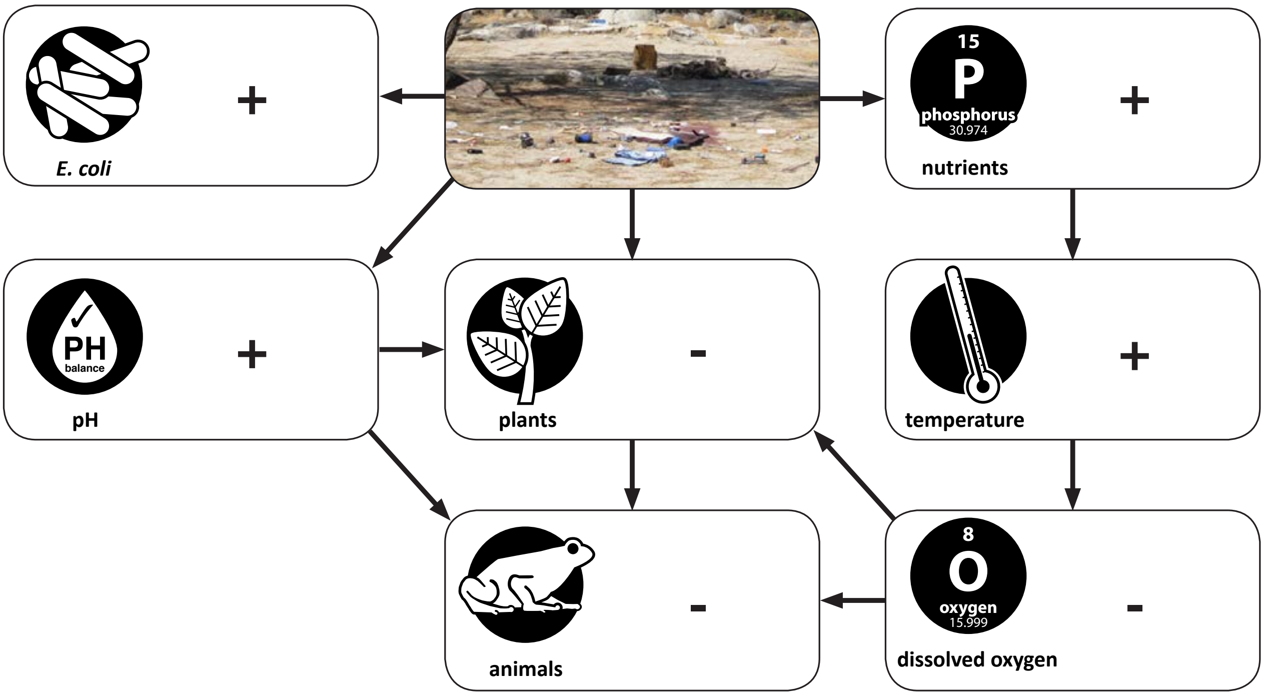
Students may also be encouraged to conduct additional investigations into remediation, prevention and management strategies to maintain water quality.

Feral animals damage waterhole.



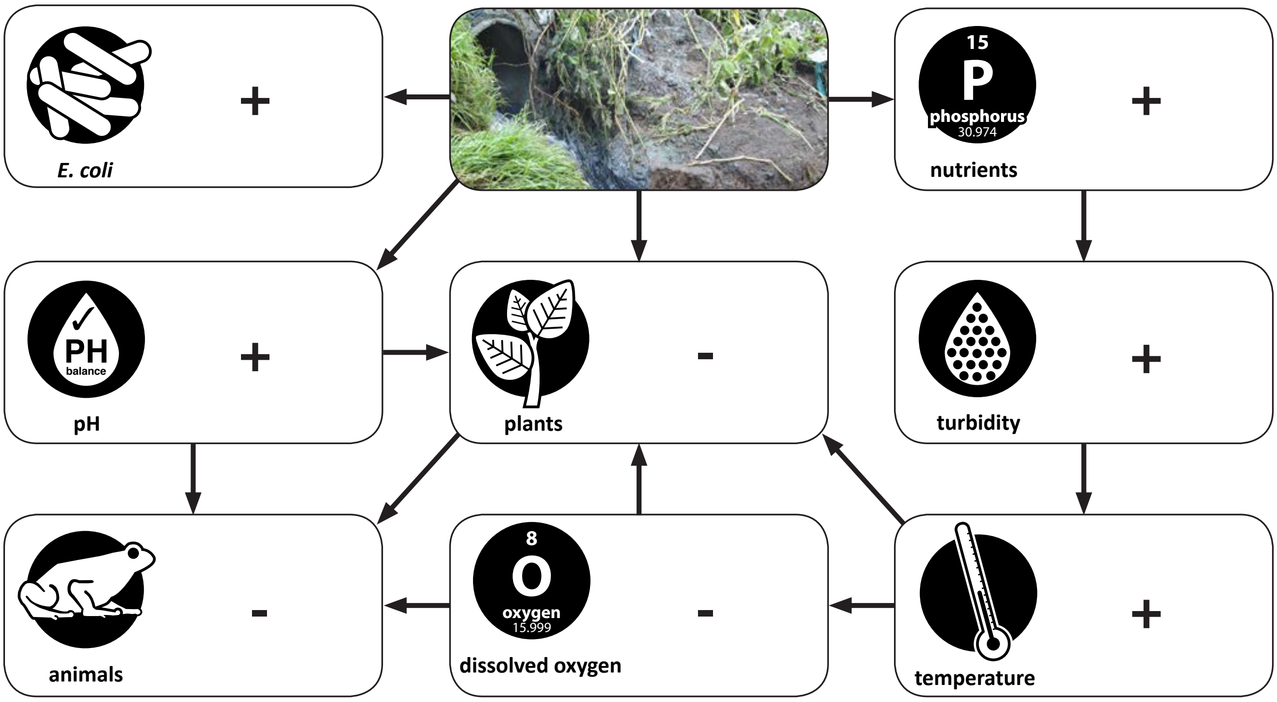
Suggested answer for scenario 1

Campers leave litter.



Suggested answer for scenario 2

Sewage contaminates local river.



Suggested answer for scenario 3

Activity 5.3 Communication

Discuss what management strategies could be used at a water body to maintain health or to improve health.

Write idea(s) on a post-it note and stick onto the front board.

Select one idea and design a poster or sign to display at a water body to give a target audience (community member, tourist …) a specific message about keeping the water body healthy.

Suggestions include:

- Restrict numbers of people using the water body.
- Ban fires.
- Fence area.
- Improve signage.
- Install rubbish bins.
- Cull feral animals.
- Manage septic tanks.

Appendices


worksheet
School name
Sample plot GPS
A:
B:
Sample date
Sample time
Ambient temperature
Weather conditions
number of mites / sample
climate
worksheet
The learning object Virtual telescope: resolution com
through different telescopes.
Telescope resolution
Object:
Moon
Telescope:
backyard telescope
The moon is the Earth's only natural satellite. It orbits some 384,000 kilometres from us.
It is possible to see the larger craters when looking at the moon through a backyard telescope.
Back

Appendix A: How much of Earth's water is fresh?

This activity is adapted with permission from Activity 3.4 in *Science DIY Kit: Water*, published by Scitech and supported by Water Corporation.
http://www.scitech.org.au/education/at-your-school/diy-science/1602-diy-science-kits

Outcomes

Students:

- identify the amount of water on Earth available for consumption, and
- visualise and understand the percentage of drinkable water on Earth.

Duration

- 20 minutes

Safety and disposal

- Do not drink water used in this demonstration. Dispose of water wisely.

Materials

- bucket
- water
- 5 beakers, various sizes
- measuring cylinder
- Pasteur pipette

Method

This is a teacher-led demonstration to showcase the availability of Earth's water supplies.

You may like to start this activity as a guessing game to see if students can predict how much water is available to drink, proportionally, when given an amount of water. Encourage students to discuss what water is used for, where we might find it and in how many different forms (states).

Introduce students to the concept of 'proportions'. What does this mean and why do we use them?

1. Fill a 10 L bucket with water. This represents all water on Earth.
2. Ask a student to remove the amount of water they think is fresh.
3. To demonstrate what the actual percentage looks like (3% of total water on Earth), use a container to take 300 mL of water from the refilled 10 L bucket. This represents the proportion of fresh water on Earth. Compare it with the student's estimate and what's left in the bucket.
4. Colour the 300 mL water sample to make it easier to see. Then divide it amongst 4 labelled containers to represent the amount of fresh water in each of the following: polar ice caps and glaciers, underground, permafrost, and finally surface water. Ask different students each time to guess the amount (you may need a second container containing 300 mL of water for the guesses).
5. The table below summarises how 300 mL of water should be divided up. A very small (<0.1%) proportion of fresh water is also present in the atmosphere.

Where does all the water go?

10 L	all of the water on Earth	100% of the **total** water on Earth
9.7 L	seawater	97% of the **total** water on Earth
300 mL	fresh water	3% of the **total** water on Earth

Divide up the 300 mL that represents fresh water:

300 mL	fresh water	100% of **fresh** water on Earth
204 mL	ice caps, glaciers	68% of **fresh** water on Earth
90 mL	groundwater	30% of **fresh** water on Earth
4.5 mL	permafrost (underground ice)	1.5% of **fresh** water on Earth
1.5 mL	fresh, liquid, surface water	0.5% of **fresh** water on Earth

Now we've discovered there isn't much surface water, ask students to:

- brainstorm how we use this water; and
- tell you what type of water is represented in the bucket we used earlier (salty water).

This has been a visual representation of the water that we have to use on Earth. Ask students to:

- explain why it is so important to save water;
- discuss what happens to fresh water once it disappears down the drain (It travels to oceans and rivers and becomes salty water.); and
- discuss whether there are ways to make use of other sources of water.

Explanation

Most of the water on Earth is salty. Humans can't use this water for drinking. Instead, we use fresh water. Unfortunately, only a small percentage of the total water on Earth is fresh. Of this, an even smaller amount is readily accessible surface water. Therefore, it's very important both to save the fresh water we have and experiment with ways to use salty water. Scientists have now developed desalination plants that remove salt from ocean water, making it appropriate to drink. Advances in technology have made this process much faster and more cost effective.

Real world relevance

Almost half of Perth's water needs in 2015 are supplied by two desalination plants (in Kwinana and Binningup). The balance comes from groundwater and surface water.

Appendix B: Build an edible aquifer

Build a model aquifer from food and drink.

What you will need

- clear plastic drinking cup
- ice cream scoop or large spoon
- plastic teaspoon
- plastic drinking straw
- vanilla ice cream or fruit sorbet
- lemonade
- chocolate chips or cereal
- coloured cake sprinkles

What to do

1. Get a plastic drinking cup.

2. Put some chocolate chips in the cup.

   This stands for sand and gravel at the bottom of an aquifer.

3. Pour in lemonade so it just covers the chocolate chips.

   This stands for water in an aquifer.

4. Add a scoop of ice cream on top of the chocolate chips.

   This stands for a layer of rock or soil that traps groundwater. It's called a confining layer.

5. Add a teaspoon of sprinkles over the ice cream.

   This stands for soil and leaves near the surface.

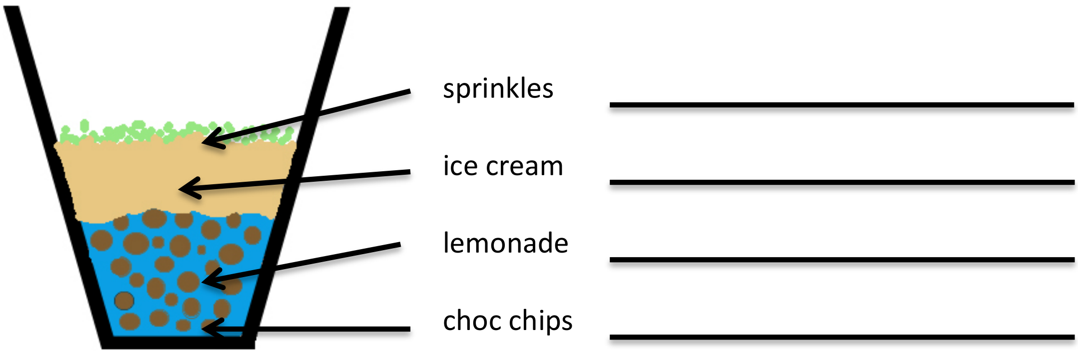
6. Push a straw through the ice cream into the chocolate chips.

Drink the lemonade.

This stands for a bore that pumps up water from an aquifer.

Questions

1. Name the parts of a real aquifer the food and drink stand for.



2. The lemonade fills spaces between the chocolate chips. We say the chocolate chip layer is porous. What fills the spaces in a real aquifer?

....

3. You used a straw to get to the lemonade. How can you get to water in a real aquifer?

....

....

....

3. What happened when you drank the lemonade?

....

....

4. What happens to a real aquifer when water is pumped out?

....

....

5. Does your model help to show what a real aquifer is like?

What parts help?	What parts don't help?

Appendix C: Build a model aquifer

You will need

- small glass aquarium or clear plastic container (L 25 cm x W 17 cm x H 15 cm)
- 5 L gravel, white or light colour
- 1.5 L water dyed blue
- 1 L water dyed yellow
- 60 mL water dyed red
- hand pump (from soap dispenser or lotion)
- 4 packets plasticine
- 2 small beakers or containers
- 100 mL sand or soil (optional)
- paper towels

What each item stands for

ITEM	AQUIFER EQUIVALENT
glass aquarium	aquifer
gravel	saturated zone and unsaturated zone
water (dyed blue so it is more visible)	groundwater
water (dyed yellow)	another groundwater source
hand pump from lotion or soap dispenser	bore — to pump out groundwater
plasticine or plastic wrap	confining layer — impermeable rock layer confining groundwater
100 mL beaker of water (dyed red)	contaminants getting into the aquifer
sand or soil	topsoil layer

What to do

Part 1: Aquifer model, extraction (pumping out) and recharge (refill)

1. The base of the aquarium stands for the bottom of an aquifer. It stops groundwater going deeper. It's called an impermeable layer.

   Pour 3 L gravel onto the base of the aquarium.

2. Smooth the gravel to make a 5 cm deep layer.

3. Add 1.5 L blue-dyed water until most of the gravel is covered.

   Groundwater fills spaces between bits of gravel because the layer is porous.

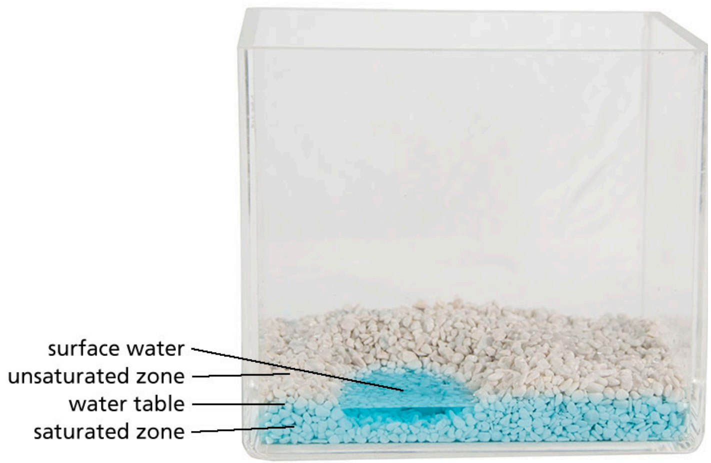
   This is a model of an unconfined aquifer. It has different zones layers or zones:

   - gravel with water is the saturated zone;
   - dry gravel is the unsaturated zone; and
   - the top of the water is the water table.

4. Now, move some gravel to make a pool of water.

   A lake at the surface is called surface water.

   Water in the saturated zone is called groundwater.



5. Put the hand pump in one corner of the aquarium.

   Put a beaker under the pump and extract (pump out) the water.

   Watch what happens to the water table and surface water as you extract water.

   Bores extract groundwater from the saturated zone for us to use.

6. Near a corner of the aquarium pour back the water you extracted.

   Aquifers need to be refilled. This is called recharging.

   Watch what happens to the surface water and water table as you recharge the aquifer.

   Where do you think recharge comes from?

Part 2: Confined aquifers

7. Smooth the gravel so there's no surface water.

8. Flatten plasticine over the gravel.

9. Fix the plasticine to the sides of the aquarium. Try to make it watertight.

10. Pour a little yellow-dyed water over the plasticine. It should collect in a pool on the surface.

    The plasticine stands for a confining layer. In a real aquifer this kind of layer is rock or clay that won't let water through (it is impermeable).

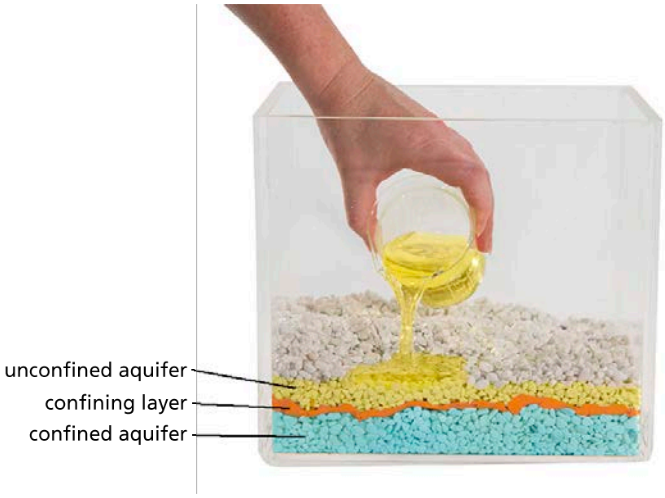
    If groundwater is trapped below an impermeable layer, the aquifer is called a confined aquifer.

11. Pour 2 L gravel onto the plasticine layer.

12. Move some gravel until you have a pool of surface water.

    If you like you can sprinkle sand or dirt on the gravel layer to create topsoil.

13. Pour 800 mL yellow-dyed water on the gravel layer.



The different layers of the model aquifer are:

- **confined aquifer**, shown by blue-dyed groundwater below the plasticine.
- **confining layer** (impermeable rock that traps groundwater), shown by the plasticine.
- **unconfined aquifer**, shown by porous gravel with yellow-dyed groundwater.

Challenge: How are confined aquifers recharged?

14. Make a hole in one corner of the plasticine.

    Push the pump through the hole.

15. Put a beaker under the pump and pump out water.

    Watch what happens to the water table as water is pumped out.

    Water table and surface water levels drop as you pump out 60 – 100 mL of water from the aquifer.

16. Pour the water you pumped out back, through the hole you made.

    This hole is called the recharge site of the confined aquifer.

    Sometimes the recharge site of a confined aquifer is in an area where the aquifer is unconfined. This may be a long way from the confined aquifer area.

Part 3: Contaminants (things that pollute water) in groundwater

17. In one corner, slowly pour 60 mL red-dyed water to unconfined aquifer.

    For best results add this water near the recharge site.

    This water stands for contaminants.

    This shows how contaminants get into unconfined and confined aquifers.

18. Put hand pump into the recharge hole.

19. Put a beaker under the pump.

20. Keep pumping out water until you see contaminants in the extracted water.

    These contaminants are in the water supply.

    Runoff from landscape around aquifers can carry contaminants into the groundwater.

    What might contaminate groundwater?

    Challenge: How might contamination affect humans, industry and the environment?

21. **Extra activity:** Change landscape around the model aquifer, building mountains, streams and wetlands. See what happens to the water table and surface water levels.

    Experiment with different materials, such as sand and larger rocks.

22. Clean up!

Appendix D: Groundwater pollution

Gnasty Gnomes is set in a town that gets its water from groundwater.

Pollution is getting into the water. This must be stopped or the town won't be able to use the water.

How to play

1. Flick 'Gnomes' off the screen *before* they pour out pollution. Each time you flick off a Gnome you get cash.

2. If Gnomes pour out pollution there are three ways to clean it up. Cleaning up water is called remediation.

3. To remediate pollution use your cash to buy:
   - bugs — this is called bioremediation;
   - chemicals — this is called chemical remediation; or
   - drill (dig and dump pollution somewhere else).

After the game

Think about your town or community.

Could any activities in these pictures be a problem where you live? Write a sentence about any problems you can think of.

US Department of Agriculture, PD

pesticides and fertilisers

....

....

....

....


Calistemon, GFDL

industry and mining

....

....

....

....

Sustainable sanitation alliance, CC-BY-2.0

leaking sewers or septic systems

Cezary P, GFDL 1.2

landfill

Javier Ignacio, CC-BY-NC-2.0

animal waste

Fernost, PD

petrol and oil

Peterpans Adventure Travel
ultimateozholiday.com

fishing

Bob Fitzpatrick

swimming

Bob Fitzpatrick

camping

Appendix E: Measuring pH

The pH of a solution tells how acid or how alkaline it is. The pH scale goes from 1 to 14.

Acid in a car battery is very acidic. It is about pH 2.

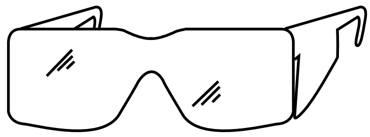
Caustic soda, which is used to clean drains, is very alkaline. It is pH 14.

Pure water is neutral (neither acid nor alkali). It has pH 7.

You can measure pH of solutions with pH paper, Universal Indicator (UI) solution, or a pH meter.

You will need

- safety glasses
- pH paper, UI solution or pH meter
- 100 mL beaker
- test solutions: lemon juice, soft drink, washing powder, shampoo, tea, tap water, pool water …



Safety

Wear safety glasses.

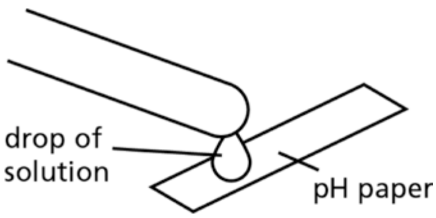
Take care with liquids!

What to do

1. Put 25 mL of tap water in the beaker.
2. Predict the pH and write it in the table below.
3. Measure the pH and write it in the table below.
4. Predict, then measure the pH of test solutions.
5. Write all your results in the table below.

Tech tip

If you have pH paper, use a pop stick or glass rod to put a drop of solution on the paper. The colour the paper goes, shows pH.



If you have a pH meter, rinse the probe with distilled water after every use.

Results table

Fill in all columns of this table.

WATER SAMPLE	PREDICTED pH	MEASURED pH
tap water		

Questions

1. Did the pH of any solutions surprise you?

   ....

   ....

   ....

2. What did all the samples have in common?

   ....

   ....

   ....

3. Gardeners and farmers often measure pH of their soil. How would you measure pH of soil?

   ....

   ....

   ....

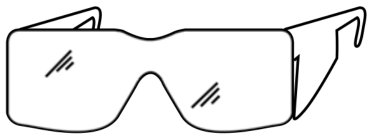
Challenge

Does pH of a soft drink change when it goes flat?

Appendix F: Measuring temperature

How hot is water from a tap, river or swimming pool?

Scientists use thermometers to measure temperature.

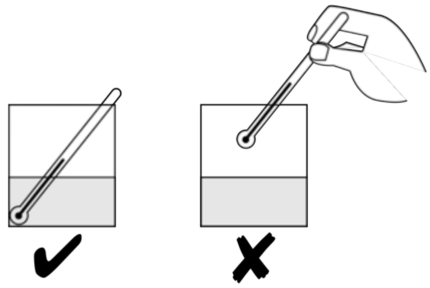


You will need

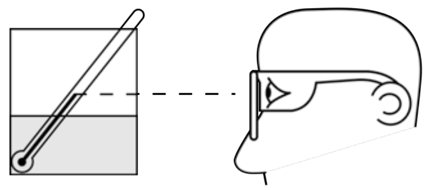
- safety glasses
- thermometer that reads 1 – 110°C
- 250 mL beaker
- hot and cold water from different places
- cup of tea or coffee

Tech tip

Make sure the thermometer stays in the liquid.



Always make sure that your eye is level with the thread in the thermometer.



Safety

Wear safety glasses when using liquids.

Take care when using hot liquids!

What to do

1. Put 150 mL of cold tap water in the beaker.
2. Predict its temperature and write it in the table.
3. Measure the temperature using a thermometer, and write it in the table.
4. Predict, then measure and write the temperature of each of these test solutions.
    - washing-up water
    - cup of tea or coffee
    - water from a fridge
    - water from the hot tap
    - water from a pond or pool

Results table

Fill in all columns of this table.

WATER SAMPLE	ESTIMATED TEMPERATURE	MEASURED TEMPERATURE
cold tap water		

Questions:

1. How close were your predicted temperatures and measured temperatures? Did your predictions get better?

   ....

   ....

   ....

2. What unit is temperature measured in?

   ....

   ....

   ....

3. Do you know at what temperature water freezes or boils? If not, find out.

   ....

   ....

   ....

Challenge

Does the shape of a container affect how quickly hot water cools?

Use an open-investigation planning sheet to help you answer this challenge.

Appendix G: Measuring salinity

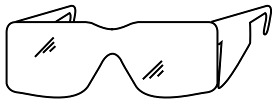
Salinity is the amount of salt dissolved in water.

You measure salinity with a salinity probe.

The probe records the number of salt particles dissolved in water as parts per million (ppm). It also measures water temperature.

You will need

- safety glasses
- salinity probe
- 250 mL beaker
- water samples such as: tap, deionized, bottled, filtered, pond, swimming pool



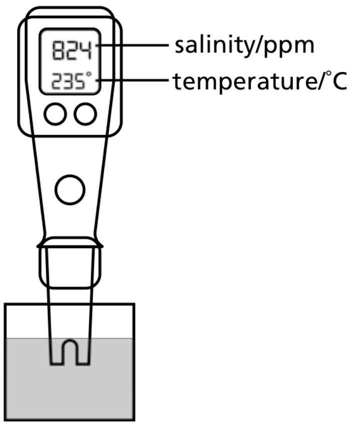
Safety

Wear safety glasses when using liquids.

Take care when using hot liquids!

Tech tip

Make sure the probe stays in the liquid.



What to do

1. Put 150 ml of tap water in a 250 ml beaker.
2. Take cap off the probe, and turn it on.
3. Put probe in the water sample.
4. Gently stir sample with the probe.
5. Read the ppm measurement and write it in the table.
6. Read, and write in temperature of the sample (temperature affects salinity).
7. Rinse the probe with tap water (keep away from the sample) to stop contamination.
8. Repeat for all samples.

Results table

Fill in all columns of this table.

WATER SAMPLE	SALINITY (ppm)	TEMPERATURE (°C)
tap water		

Question:

1. Use **Appendix N: Interpreting results**, and write a comment about the quality of your water samples.

....

....

....

....

....

....

Appendix H: Measuring turbidity

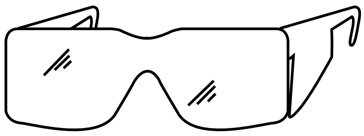
Cloudy water can harm animals and plants in water. It can raise water temperature, block sunlight and suffocate small animals and plants.

Scientists use the word ‘turbidity’ to measure cloudiness. They use the NTU scale (on a turbidity tube) as units of measurement.

Turbidity is caused by very small solid particles of clay, algae or small animals, spread or suspended in water.

You will need

- safety glasses
- turbidity tube
- 250 mL beaker
- samples of cloudy water
- cold tea



Safety

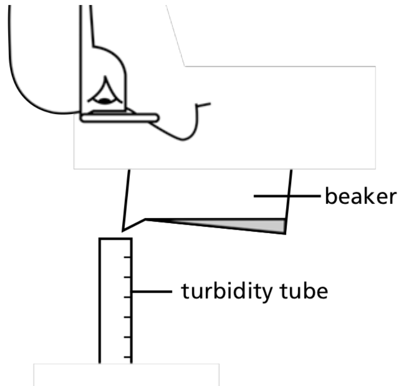
Wear safety glasses when using liquids.

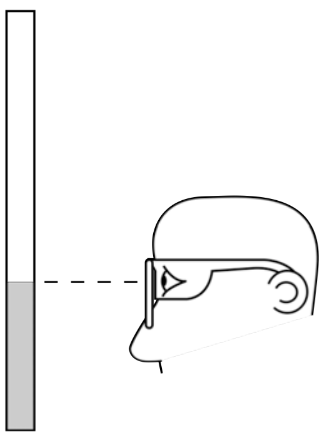
What to do

1. Work with a partner.
2. Put 250 mL of tap water in a beaker.
3. Put the two parts of turbidity tube together.
4. Person A holds the tube vertical (straight up) and looks at the pattern on the bottom.
5. Person B slowly pours the tap water sample into the tube.
6. Person A says ‘Stop’ when they can’t see the pattern any more.
7. Person B stops, reads the measurement on the NTU scale, and writes it in the results table.
8. Repeat these steps and measure the turbidity of different samples. (You may need to shake the samples.)

Tech tip

Make sure your eye is level with the water level in the turbidity tube.





Results table

Fill in all columns of this table.

WATER SAMPLE	NTU MEASUREMENT
tap water	

Questions:

1. What did you notice about turbidity measurements for tap water and cold tea?

    ....

    ....

    ....

    ....

2. Why did you have to shake your cloudy water samples?

    ....

    ....

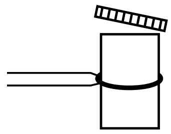
    ....

    ....

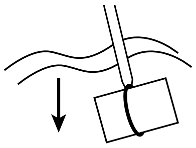
Appendix I: Field protocols

Collect water sample

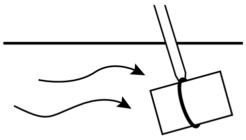
A. Surface water



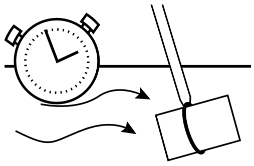
Remove the cap from container.
Wear gloves.
Connect container to a handle.
Rinse container with stream water.



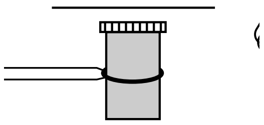
Push container, upside down, below the water surface.



Turn container away from you, so it faces current.

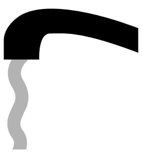


Let water flow into container for 30 seconds.

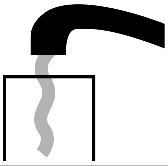


Cap container while still underwater.

B. Bore or well



If there's an aerator remove it.
Run water for a few minutes.



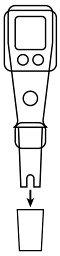
Put water sample from tap or pump into container

Physical and chemistry field test: temperature and salinity

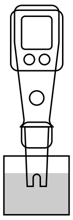
Use your water sample.

Wear gloves and safety glasses.

A. Using LaMotte monitoring kit



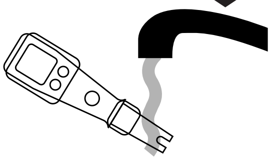
Take cap off probe and turn it on.



Put probe in water sample.

Write salinity as ppm on **Data record** sheet.

Write temperature as ˚C on **Data record** sheet.



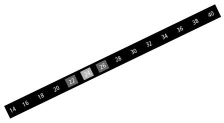
Rinse probe with tap water.

Put cap back on.

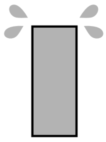
Chemistry field test: dissolved oxygen

Use your water sample.

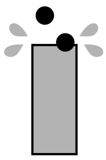
Wear gloves and safety glasses



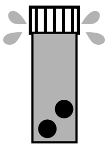
Record temperature of your water sample on the **Data record** sheet.



Put small tube (0125) underwater into your sample.
Carefully take out tube, keeping it full to the top.

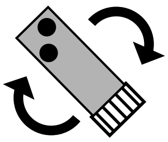


Put **2** dissolved oxygen TesTabs in full tube. Water will overflow.

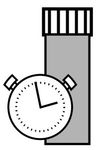


Screw cap on tube. More water will overflow.

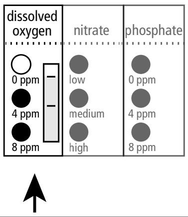
Make sure no air bubbles are in it.



Turn tube over and over until tablets dissolve – about 4 minutes.



Wait 5 more minutes for colour to show.



Compare colour of sample to the dissolved oxygen chart.

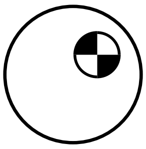
Write result as ppm dissolved oxygen on **Data record** sheet.

Physical field test: turbidity

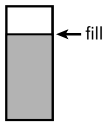
Use your water sample.

Wear gloves and safety glasses.

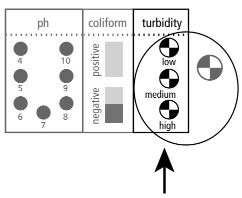
A. Using LaMotte monitoring kit



Stick the secchi disk sticker on inside bottom of the large white jar.



Fill jar to 'turbidity fill line' on the outside label.



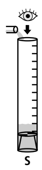
Hold turbidity chart next to top edge of container.

Look into container from above.

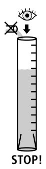
Compare the secchi disk there with the chart.

Write result as turbidity as NTU on **Data record** sheet.

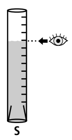
B. Using Turbidity Tube



Look into tube from above and slowly pour in water from your sample.



Stop when you can't see the disk on the bottom.



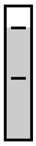
Read measurement on side of tube.

Write result as turbidity in NTU on **Data record** sheet.

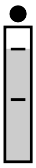
Chemistry field test: phosphate

Use your water sample.

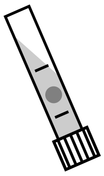
Wear gloves and safety glasses.



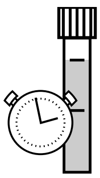
Fill test tube (0106) to the 10 mL line water sample.



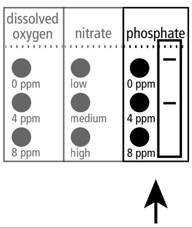
Add one phosphorus TesTab.



Cap and shake until tablet dissolves.



Wait 5 minutes for colour to show.



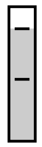
Compare colour to the phosphate colour chart.

Write result as ppm phosphate on **Data record** sheet.

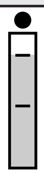
Chemistry field test: pH

Use your water sample.

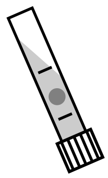
Wear gloves and safety glasses.



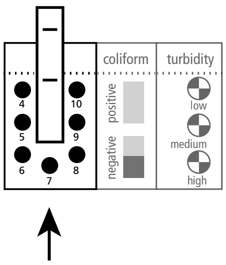
Fill test tube (0106) to 10 mL line with water sample.



Add one pH TesTab.



Cap and mix.



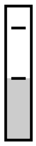
Compare colour to pH chart.

Write result as pH on **Data record** sheet.

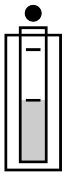
Chemistry field test: nitrate

Use your water sample.

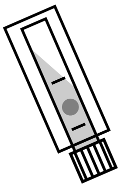
Wear gloves and safety glasses.



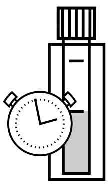
Fill test tube (0106) to 5 mL line with water sample.



Add one nitrate TesTab.
If you're outside quickly slide test tube into protective sleeve*.

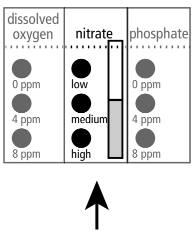


Cap and shake for 2 minutes until tablet has dissolved.



Wait 5 minutes for colour to show.

Remove tube from sleeve.



Compare colour of the sample to nitrate colour chart.

Write result as ppm nitrate on **Data record** sheet.

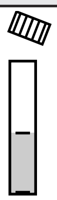
* Nitrate TesTabs are sensitive to UV light. The protective sleeve protects it from UV light. If indoors you don't need to use it.

Biology field test: *E. coli* bacteria

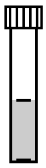
Use your water sample.

Wear gloves and safety glasses.

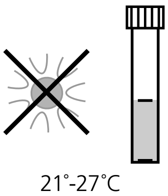
Pour water sample into large test tube with an *E. coli* test in it, until it is filled to the 10 mL line.



Put back cap on test tube.

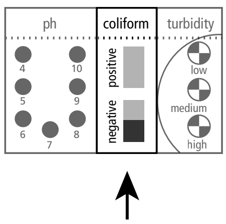


Stand up tube with tablet flat on the bottom.



Store tube upright at room temperature, out of sunlight, for 48 hours.

Do not disturb tube.



Compare tube to picture on coliform colour chart.

Write result as positive or negative on **Data record** sheet.

Appendix J: Data record

Site information:			
Student name:		Date:	
Site sketch:			
TEST	RESULT	TEST	RESULT
pH		turbidity	
nitrate		temperature	
phosphate		salinity	
dissolved oxygen		*E. coli*	
IMPACTS IN AREA			
tourist/recreation	yes / no	weeds	yes / no
farming	yes / no	boats	yes / no
fire	yes / no		
cattle	yes / no		
rubbish	yes / no		

What does the edge of the waterway look like?
Does it look like either of these?

yes / no

yes / no

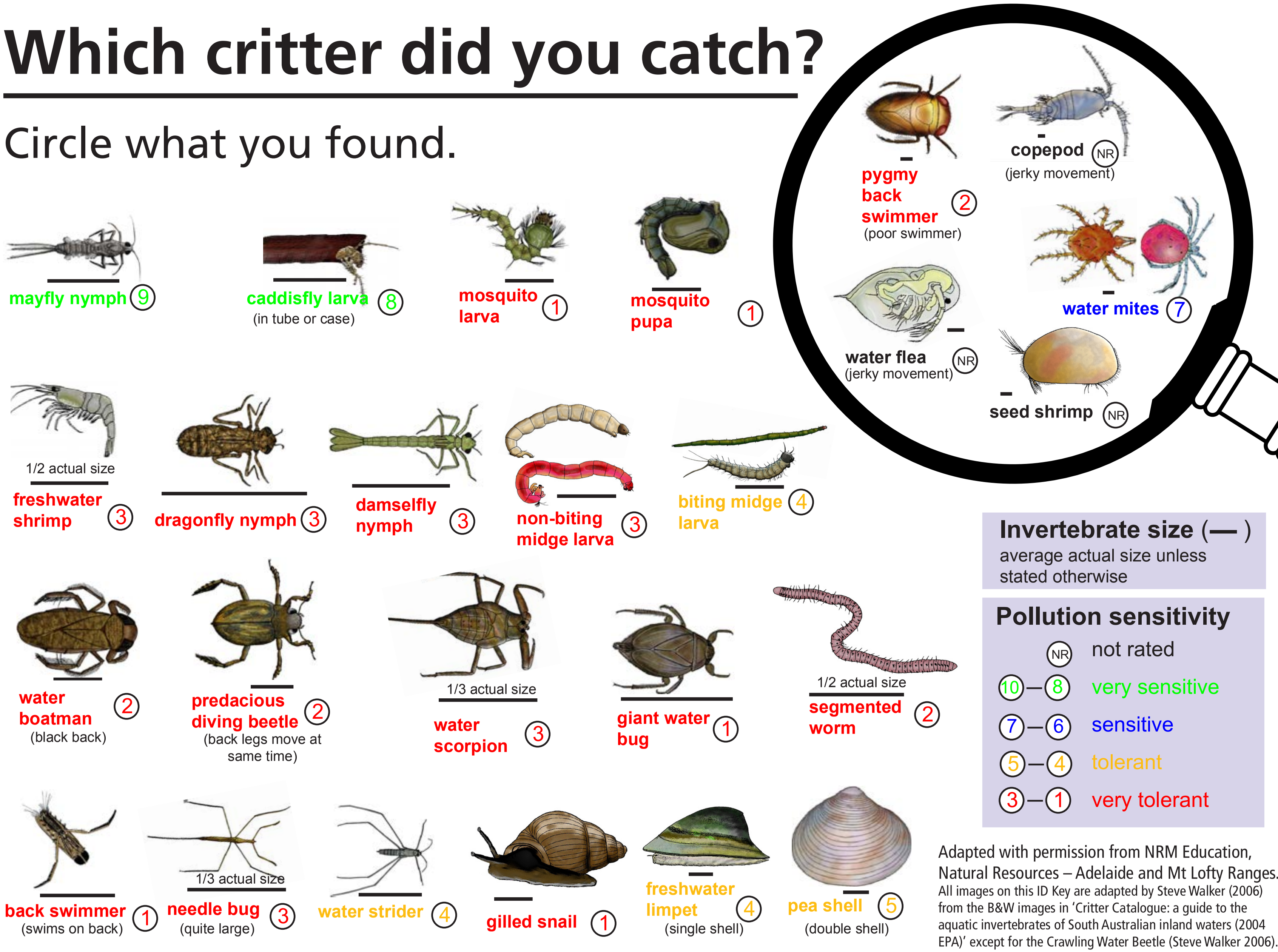
Aquatic macroinvertebrates

	NAME	NUMBER SEEN	YOUR DRAWING

Appendix K: Identification key (simplified)

Which critter did you catch?

Circle what you found.



Adapted with permission from NRM Education, Natural Resources – Adelaide and Mt Lofty Ranges.
All images on this ID Key are adapted by Steve Walker (2006) from the B&W images in 'Critter Catalogue: a guide to the aquatic invertebrates of South Australian inland waters (2004 EPA)' except for the Crawling Water Beetle (Steve Walker 2006).'

Aquatic macroinvertebrate identification key

NRM Education
climate change biodiversity water food air waste transport purchasing

1

Microscopic →
Bigger than microscopic — go to **2**

- green, white or black — **seed shrimp** (NR)
- teardrop shape, jerking movement — **copepod** (NR)
- swims with a jerk using antennae — **water flea** (NR)

2

Shell →
No shell — go to **3**

Single shell

- flattened shell with small hump — **freshwater limpet** (4)
- spiral shell, opening on left — **pouch snail** (1)
- spiral shell, opening on right — **gilled snail** (1)

OR

Double shell

- small, pale delicate shell — **pea shell** (5)
- small, darker shell with ridges — **little basket shell** (4)

3

Legs — go to **4** over page
No legs →

Worm-like

- green to red, twisting — **non-biting midge larva** (3)
- segmented, no suckers, +/- bristles — **segmented worm** (2)
- long, very thin, swims in 'S' shape, can't coil — **biting midge larva** (4)
- suckers, expands and contracts — **leech** (1)
- hair-like, swims in 'S' shape — **round worm** (3)
- slides along bottom — **flatworm** (2)

OR

Tentacles, brushes or tails

- six fleshy lobes at end of body — **cranefly larva** (5)
- breathing tube at rear — **mosquito larva** (1)
- large head, wriggles — **mosquito pupa** (1)
- grub-like with no obvious head — **March fly larva** (3)
- sucker on end of body, waves head — **blackfly larva** (5)
- slender, with tentacles, attached to solid surface — **hydra** (2)
- hangs from surface by ring of hairs — **soldier fly larva** (2)

OR

Mat-like

- simple, multi-cellular colony — **freshwater sponges** (4)

Pollution sensitivity*:

- (NR) not rated
- (10)—(8) very sensitive
- (7)—(6) sensitive
- (5)—(4) tolerant
- (3)—(1) very tolerant

Acknowledgements

This key was designed by Ron Simms and Amy Blaylock, 2002.

Adapted by Steve Walker, 2011.

Assistance was kindly provided by the following staff members of the South Australian Musuem: Dr. Errol Matthews, Dr. Chris Watts and Mr Robert Hamilton-Bruce.

*Sensitivity ratings from SIGNAL2 system in "New sensitivity grades for Australian river macroinvertebrates. Bruce C. Chessman. Marine and Freshwater Research, 2003, 54, 95-103."

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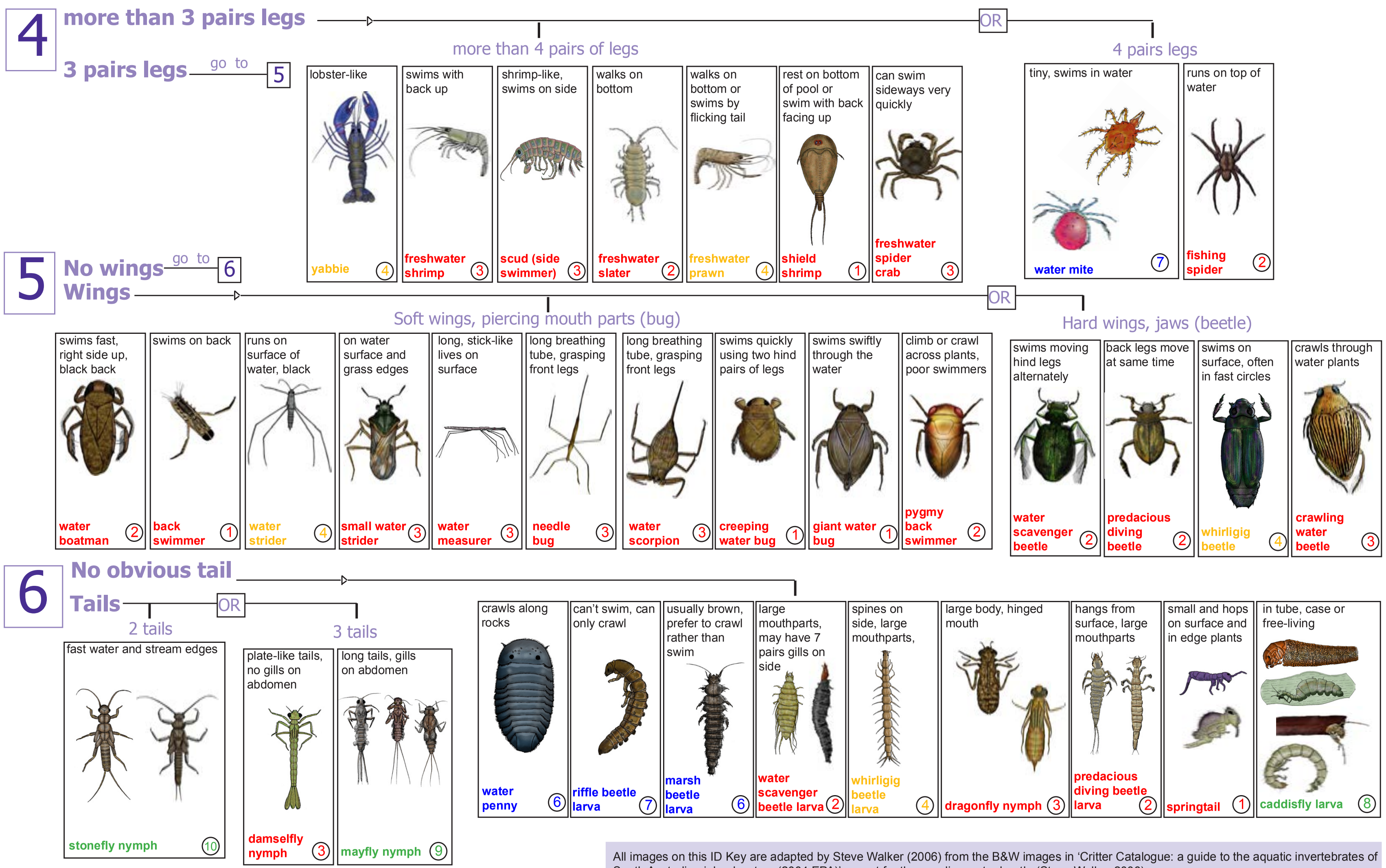

All images on this ID Key are adapted by Steve Walker (2006) from the B&W images in 'Critter Catalogue: a guide to the aquatic invertebrates of South Australian inland waters (2004 EPA)' except for the crawling water beetle (Steve Walker 2006).

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Appendix L: Macroinvertebrate survey (simplified)

Use this record sheet with the identification sheet, *What critter did you catch?*

Date: Site: Time: Number of samples:

SENSITIVITY	COMMON NAME	LOCAL NAME	POLLUTION SENSITIVITY	TICK HERE IF YOU SEE IT	PUT THE SENSITIVITY NUMBER HERE
not rated	water flea		NR		
	copepod		NR		
	seed shrimp		NR		
very sensitive	mayfly nymph		9		
	caddisfly larva		8		
sensitive	water mite		7		
tolerant	pea shell		5		
	water strider		4		
	biting midge larva		4		
	freshwater limpet		4		
very tolerant	freshwater shrimp		3		
	damselfly nymph		3		
	dragonfly nymph		3		
	water scorpion		3		
	non-biting midge larva		3		
	needle bug		3		
	pygmy backswimmer		2		
	predacious diving beetle		2		
	water boatman		2		
	segmented worm		2		
	giant water bug		1		
	gilled snail		1		
	back swimmer		1		
	mosquito larva		1		
	mosquito pupa		1		
			TOTAL:		

Add up the number of different bugs — this is the TAXA RICHNESS.

Add up sensitivity numbers: this is the POLLUTION INDEX.

Appendix L: Macroinvertebrate survey

Use this record sheet with the two-page macroinvertebrate identification sheet.

Date: Site: Time: Number of samples:

SENSITIVITY	COMMON NAME	ORDER	LOCAL NAME	POLLUTION SENSITIVITY	TICK HERE IF YOU SEE IT	PUT THE SENSITIVITY NUMBER HERE
not rated	water flea	Cladocera (suborder)		NR		
	copepod	Copepod (subclass		NR		
	seed shrimp	Ostracoda		NR		
very sensitive	stonefly nymph*	Plecoptera		10		
	mayfly nymph	Ephemeroptera		9		
	caddis fly larva	Trichoptera		8		
	riffle beetle adult	Coleoptera		8		
sensitive	water mite	Acariformes		7		
	riffle beetle larva	Coleoptera		7		
	marsh beetle larva	Coleoptera		6		
	water penny*	Coleoptera		6		
tolerant	black fly larva	Diptera		5		
	crane fly larva	Diptera		5		
	freshwater shrimps/prawns	Decapoda		4		
	biting midge larva	Diptera		4		
	water strider	Hemiptera		4		
	freshwater mussel	Bivalvia		4		
	whirligig beetle adult	Coleoptera		4		
	whirligig beetle larva	Coleoptera		4		
	freshwater yabbie	Decapoda		4		
	freshwater limpet	Hygrophila		4		
	freshwater sponge	Haplosclerida		4		
very tolerant	water measurer	Hemiptera		3		
	damselfly nymph	Odonata		3		
	dragonfly nymph	Odonata		3		
	march fly larva	Diptera		3		
	scud	Amphipoda		3		
	water scorpion	Hemiptera		3		
	non-biting midge larva	Diptera		3		
	freshwater crab	Decapoda		3		
	roundworm	Nematoda (phylum)		3		
	small water strider	Hemiptera		3		
	needle bug	Hemiptera		3		
	crawling water beetle	Coleoptera		3		
	pygmy backswimmer	Hemiptera		2		
	soldier fly larva	Diptera		2		
	fishing spider	Araneae		2		
	freshwater slater	Isopoda		2		
	water scavenger beetle	Coleoptera		2		
	water scavenger larva	Coleoptera		2		
	flatworm	Turbellaria (class)		2		
	predacious diving beetle	Coleoptera		2		
	predacious diving larva	Coleoptera		2		
	water boatman	Hemiptera		2		
	segmented worm	Oligochaeta		2		
	hydra	Hydrozoa		2		
	leech	Hirudinea (class)		1		
	creeping water bug	Hemiptera		1		
	giant water bug	Hemiptera		1		
	shield shrimp	Notostraca		1		
	springtail	Collembola		1		
	freshwater snail	Gastropoda (class)		1		
	back swimmer	Coleoptera		1		
	mosquito larva/pupae	Diptera		1		
	* not seen in Kimberley			TOTALS:		

Add up the number of different bugs: this is the TAXA RICHNESS.

Add up sensitivity numbers: this is the POLLUTION INDEX.

Field report

Name:

Date of field trip:

Site of field trip:

MEASURES	pH	NITRATE	PHOSPHATE	DISSOLVED OXYGEN	*E. coli*	SALINITY	TEMPERATURE	TURBIDITY	TAXA RICHNESS	POLLUTION INDEX
guidelines for safe drinking water	6.8 – 8.5	50 mg/L	5 mg/L	5 – 6 mg/L	negative	500 mg/L	°C	5 NTU	0 – 5: very poor 6 – 10: poor 11 – 15: moderate 15 – 23: good	0 – 40: poor 41 – 51: fair 52 – 69: good 70 – 106: very good 106+: excellent

photo	impacts	riparian (river bank) vegetation % plant cover	overall comment

Appendix N: Interpreting your results

What do your data mean?

Water monitoring measurements tell us about quality of a water supply.

It gives information on plants and animals that might live there, and if water is safe to drink.

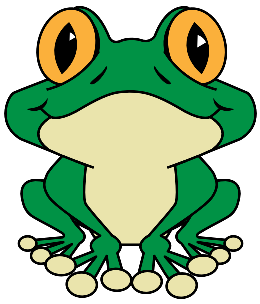
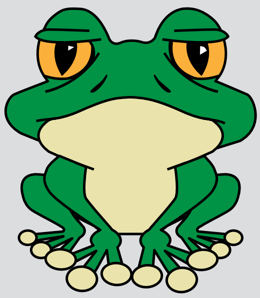
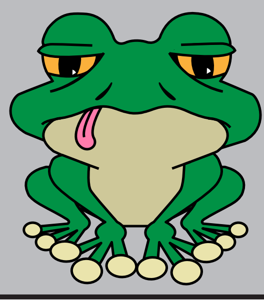
Many plants and animals like special environmental conditions to survive. If these change they may not grow as well. If there are big changes most plants and animals will die.

Use the tables below to interpret your data. Compare each measurement to the best range for plants and animals.

PHYSICAL CHARACTERISTICS

Turbidity

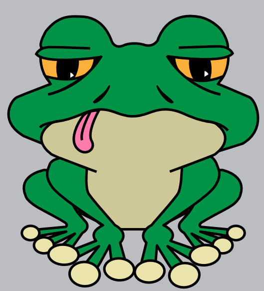
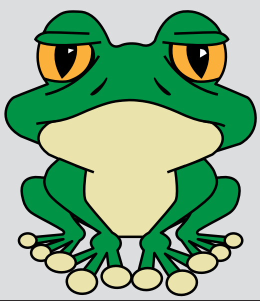
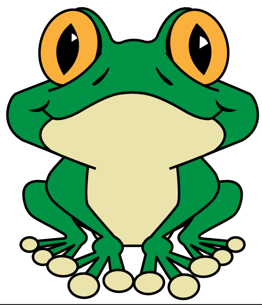
How turbid (cloudy) is your water sample? What does this mean?

Turbidity (NTUs)		
clean	may be polluted	pollution problem
< 25	25 - 30 (moderate) 30 - 45 (high)	> 45
		

CHEMICAL CHARACTERISTICS

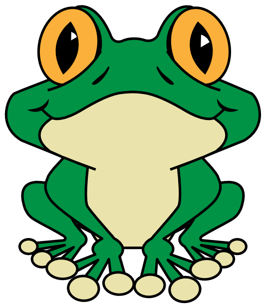
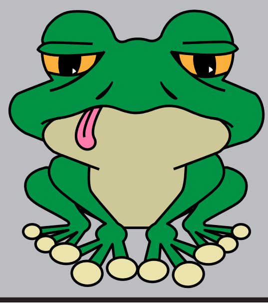
Dissolved oxygen

How much dissolved oxygen is in your water sample? What does this mean?

Dissolved oxygen (ppm)		
too low to support life	stressful for life	supports life
< 3.0	3.0 - 5.0	> 5.0
		

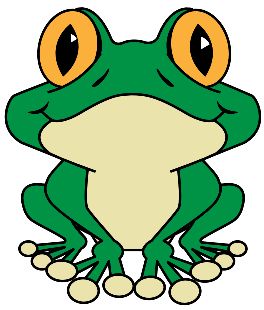
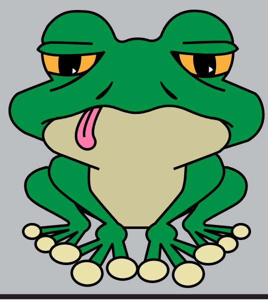
Salinity

What is the salinity of your water sample? What does this mean?

Salinity (ppm)		
fresh	**brackish (slightly salty)**	**salty**
< 500	480 -1500 (moderate) 1500- 6000 (very high)	> 6000
		

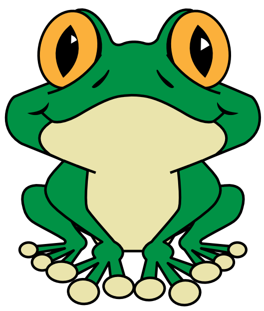
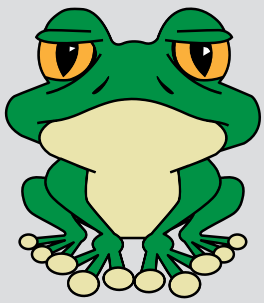
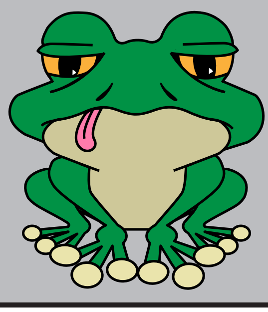
pH

What is the pH of your water sample? What does this mean?

normal	may be polluted	pollution problem
5.0 - 7.0 no limestone 7.0 - 8.5 limestone	8.5 - 9.0 or 4.0 - 5.0	< 4 or > 9
		

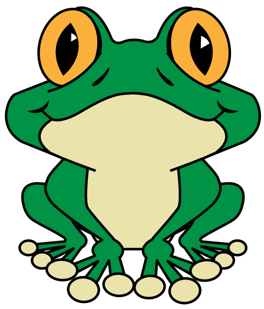
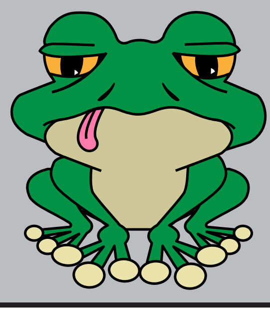
Phosphorus

How much phosphorus is in your water sample? What does this mean?

Phosphorus (mg/L)		
low	**medium**	**high**
< 0.1	0.5	> 1.0
		

Nitrate

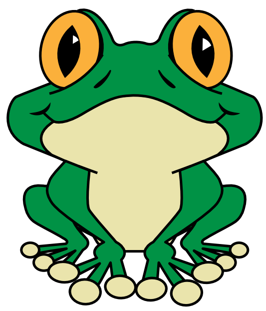
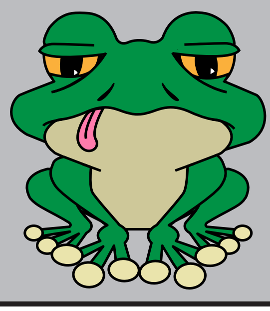
How much nitrate is in your water sample? What does this mean?

Nitrate concentration (mg/L)		
low	**medium**	**high**
< 50 mg/L	50 – 100 mg/L	> 100 mg/L
		

BIOLOGICAL CHARACTERISTICS - PLANTS AND ANIMALS

E. coli

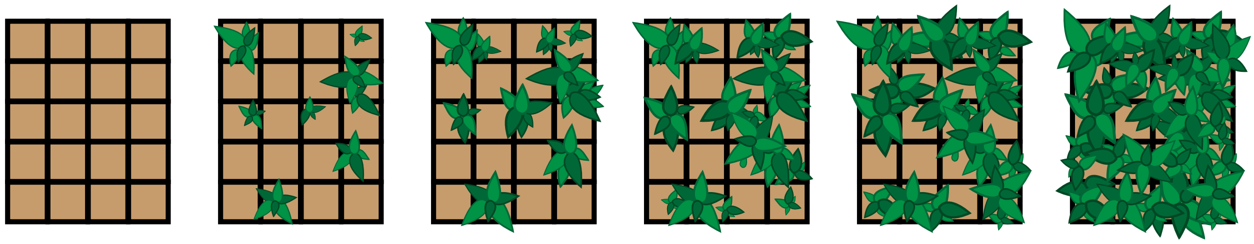
Was *E. coli* present in your water sample? What does this mean?

E. coli negative	*E. coli* positive
	

Vegetation

What percentage vegetation cover did you find at your field site? What does this mean?

0%	20%	40%	60%	80%	100%



poor	fair	good	very good	excellent	

Animals

How many macroinvertebrates did you count at your field site?
What does this mean?

Number of macroinvertebrates	Water quality
0-40	poor
41-51	fair
52-69	good
70-106	very good
106+	excellent

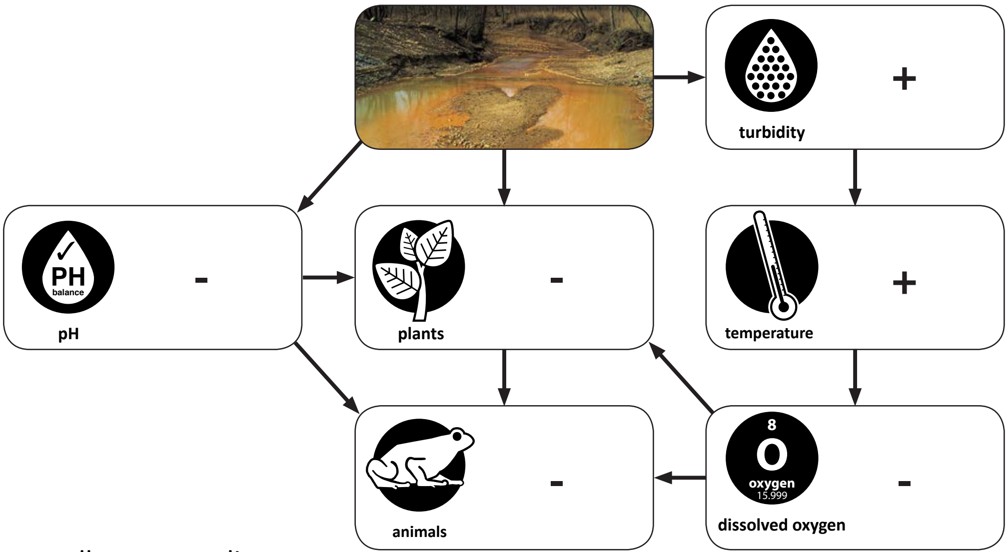
How many different types of macroinvertebrate did you find at your field site?
What does this mean?

Different types of macroinvertebrates	Water quality
0-5	poor
6-10	fair
11-15	good
15-23	very good

Appendix O: Water quality 1

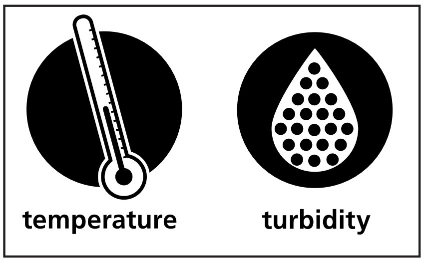
Think about impacts on water quality of the three scenarios in this worksheet.
How might physical, chemical and biological features of water quality change?
Draw a mind map of each scenario showing how water quality features change.
Use '+', '-' and '=' to show which features increase, decrease or stay the same.
Use arrows to show how each change affects others.

Acid chemical spill contaminates lake.

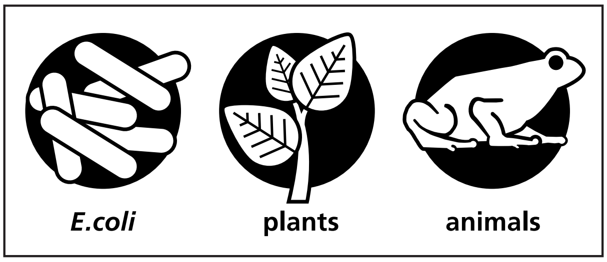


Include any or all water quality features in your mind map.

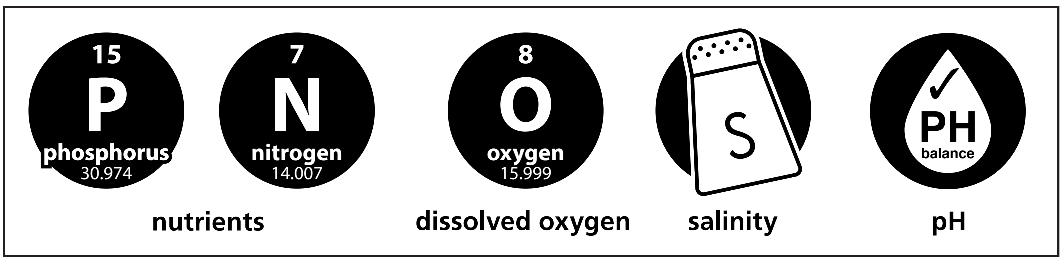
PHYSICAL CHARACTERISTICS



BIOLOGICAL CHARACTERISTICS



CHEMICAL CHARACTERISTICS



Scenario 1

Drought conditions in the Australian interior force large numbers of thirsty feral animals to gather around shrinking waterholes.

Feral animals destroy waterholes

Feral donkeys, pigs, and horses in outback Western Australia have destroyed precious waterholes. Drought in some parts of northern Australia force large herds of animals to gather at low water supplies.

Farmers, land managers and park rangers are dismayed by damage these animals cause local water bodies.

Farmer, Jerry Sturgeon, says, 'Horses and donkeys urinate and defecate in the water, and there are so many of them they destroy banks and trample vegetation.'

Pigs are a problem too, causing damage around waterholes as they dig for food. There is more erosion and muddying of water. Animals die when they are trapped in mud at water holes. The rotting remains contaminate the water supply.

'Feral animals pollute what little water is left. They also use water so there's less for native animals who need the water sources to survive,' ranger Pete Barker said.

Large numbers of animals need to get what water they can from the small sources. This spoils water quality.

'Water here is almost undrinkable, even for livestock. It's muddy, warm, and has lots of nutrients and bacteria,' Jerry Sturgeon said. 'We're really worried. We're waiting for rain.'

Scenario 2

Campers leave litter

Local rangers are dismayed by poor behaviour of tourists around local waterholes.

'They camp too close to the water edges. They leave litter and toilet waste on the banks. These often end up in the water,' said ranger Kelly Bastian.

Some items rangers have discovered in water bodies are fishing tackle, leaking fuel cans, used nappies, and detergent and other chemicals.

All these litter items, and more, have a bad effect on water quality.

Kelly Bastian says, 'Litter can change water's pH, and human waste increases levels of nutrients and bacteria. We don't want to end up where we're forced to close waterholes due to a risk to people's health.'

They might enjoy the great outdoors but some visitors aren't doing the right thing around water bodies.

Rangers and concerned community members are meeting to decide the best way forward. A local community spokesperson, Fran Boldy says, 'We all want to enjoy these places, but poor behaviour of a few could change that for many. We must educate people who visit them.'

Scenario 3

Sewage spill contaminates river

Residents are warned to stay out of the river after thousands of litres of raw sewage leaked into the water.

Warning signs have been put up along a 1-kilometre stretch of the Madder River. A local waste treatment plant discovered raw sewage was leaking directly into the water body. Residents are urged to stay away.

Local Mayor, Sharon Dunstan said, ‘People should not swim in the river. They definitely must not drink water from near the leak.’

Water department staff are monitoring effects of the leak. They’re working with the local council to find the best wat to cope with the problem.

Raw sewage has stopped leaking into the Madder but due to slow currents and poor rains sewage may take longer than usual to clear.

Water department spokesman, Lionel Stern said, ‘We’re monitoring the situation closely. Untreated sewage is a real risk to people because it increases bacteria.’

As well as a risk to human health river polluted rivers can lead to algal blooms due to an increase in nutrients. Only two years ago the Madder had a huge algal bloom that caused many fish to die, and also caused a lot of damage to local plants.

Appendix O: Water quality 2

What might happen to water quality in each of the following situations?

Draw mind maps to show how physical, chemical and biological measurements of water quality might be affected.

Use symbols to show changes in water quality:

+ measurement increases

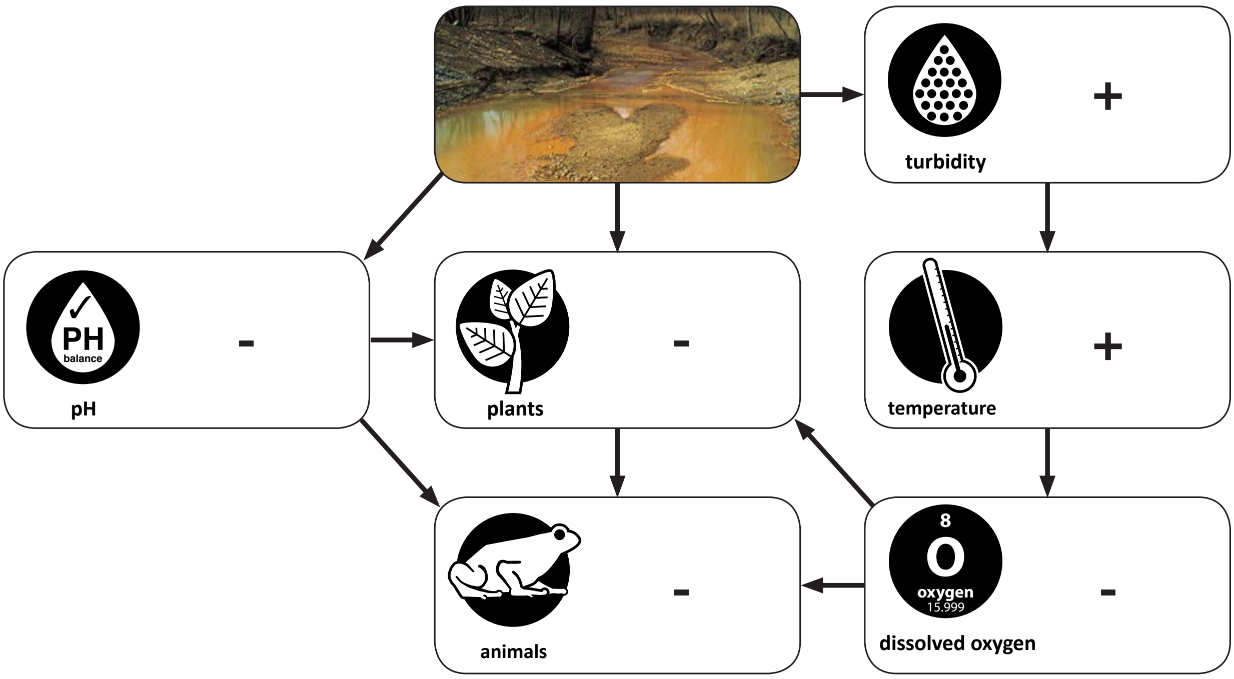
– measurement decreases

= measurement doesn’t change

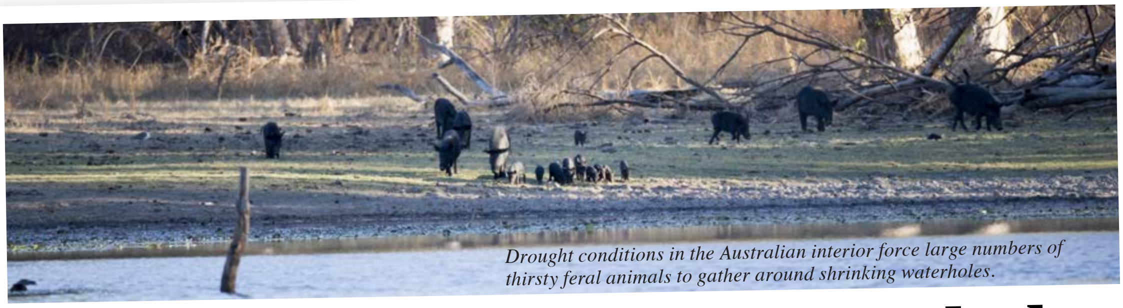
Use arrows (↑ ↓) to show how each change affects others.

To get you started here is a sample mind map.

Acid chemical spill contaminates lake.



Scenario 1



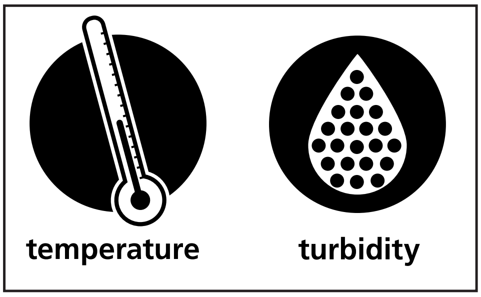
Drought conditions in the Australian interior force large numbers of thirsty feral animals to gather around shrinking waterholes.

Feral animals destroy waterholes

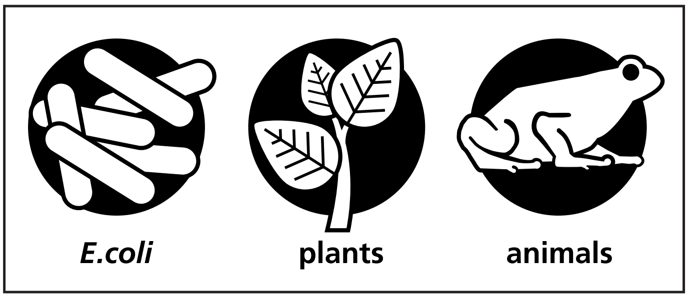
Build a mind map to show how feral animals, such as donkeys, pigs and horses, affect water quality.

Include any of these water quality measurements in your mind map.

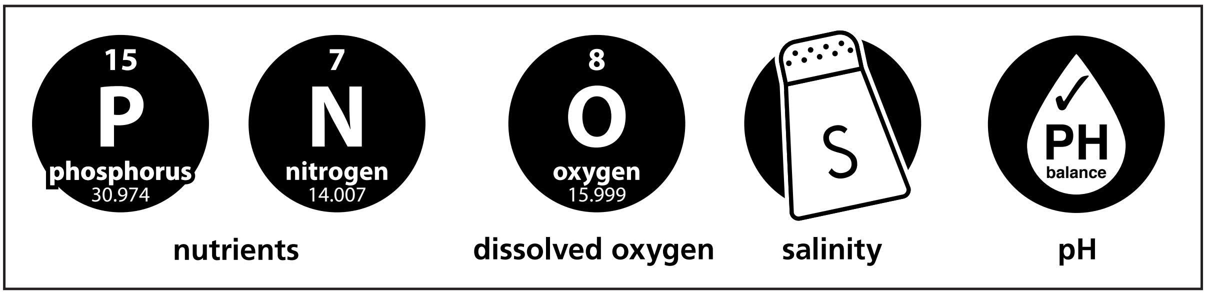
PHYSICAL MEASUREMENTS



BIOLOGICAL MEASUREMENTS



CHEMICAL MEASUREMENTS



Scenario 2

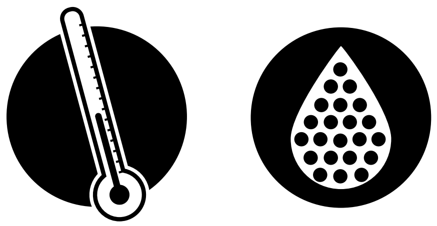
Campers leave litter

They might enjoy the great outdoors but some visitors aren't doing the right thing around water bodies.

Build a mind map to show how leisure activity, such as camping, affects water quality.

Include any these water quality measurements in your mind map.

PHYSICAL MEASUREMENTS



temperature turbidity

BIOLOGICAL CHARACTERISTICS

E. coli plants animals

CHEMICAL CHARACTERISTICS

nutrients dissolved oxygen salinity pH

Scenario 3

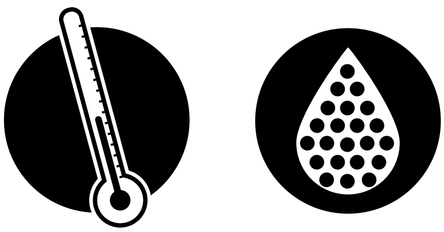
Sewage spill contaminates river

Residents are warned to stay out of the river after thousands of litres of raw sewage leaked into the water.

Build a mind map to show how raw sewage affects water quality.

Include any of these water quality measurements in your mind map.

PHYSICAL MEASUREMENTS



temperature **turbidity**

BIOLOGICAL MEASUREMENTS

E.coli **plants** **animals**

CHEMICAL MEASUREMENTS

nutrients **dissolved oxygen** **salinity** **pH**

Appendix O: Water quality 3

What might happen to water quality in each of the following situations?

Draw mind maps to show changes in physical, chemical and biological measurements.

Use symbols to indicate changes:

\+ measurement increases

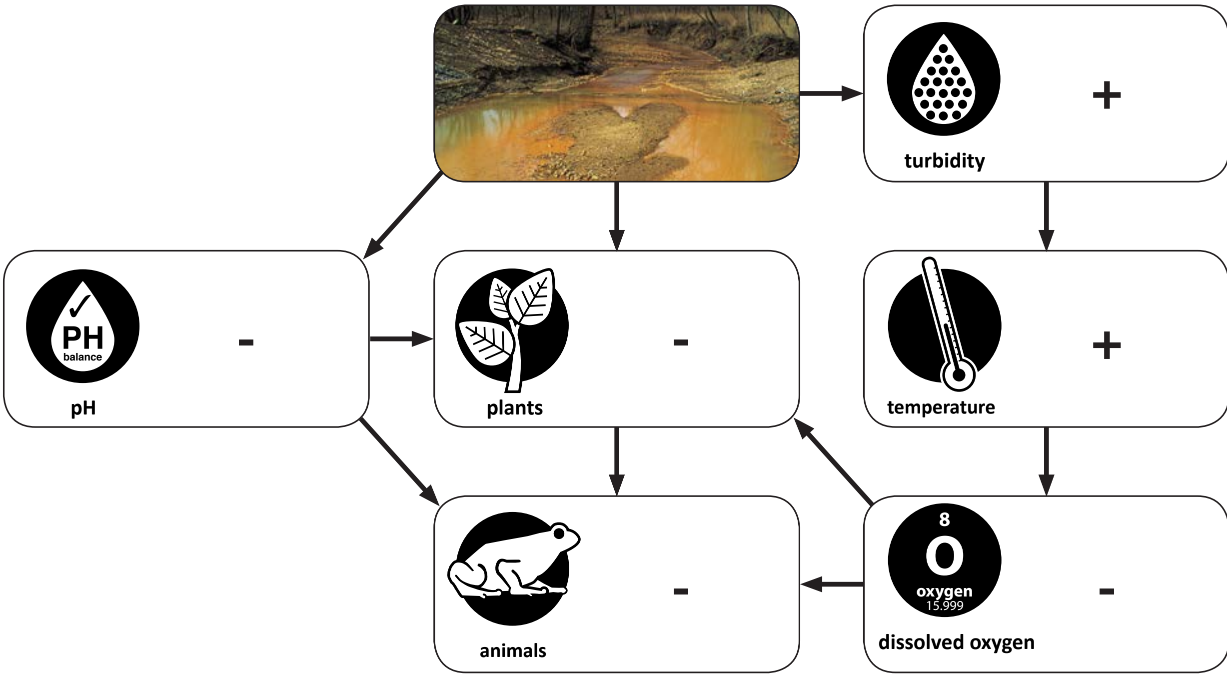
− measurement decreases

= measurement doesn't change

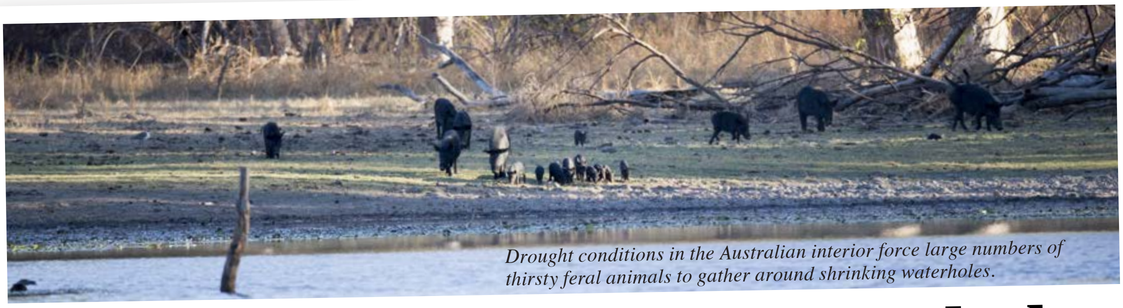
Use arrows (↑ ↓) to show how each change affects others.

To get you started here is a sample mind map.

Acid chemical spill contaminates lake.



Scenario 1



Drought conditions in the Australian interior force large numbers of thirsty feral animals to gather around shrinking waterholes.

Feral animals destroy waterholes

Complete the mind map to show how feral animals, such as donkeys, pigs and horses, affect water quality.

Feral animals damage waterhole.

E. coli

turbidity

nutrients

plants

temperature

animals

dissolved oxygen

Scenario 2

Campers leave litter

They might enjoy the great outdoors but some visitors aren't doing the right thing around water bodies.

Complete the mind map to show how leisure activity, such as camping, affects water quality.

Campers leave litter.

E. coli

nutrients

pH

plants

temperature

animals

dissolved oxygen

Scenario 3

Sewage spill contaminates river

Residents have been warned to stay out of the river after thousands of litres of raw sewage leaked into the water.

Complete the mind map to show how contamination, such as leaking sewage, affects water quality.

Sewage contaminates river.

E. coli

nutrients

15 P phosphorus 30.974

pH

PH balance

plants

turbidity

animals

dissolved oxygen

8 O oxygen 15.999

temperature