Water in the 21st Century

Teacher Booklet

World Water

Just Add Water

Water for Life

Water Farming

Introduction

Dear Educator,

The Inspiring Science & Mathematics Education (iSME) project is a collaboration between Southern Cross University, the University of Wollongong, Charles Darwin University and the Australian Academy of Technology and Engineering (ATSE).

iSME will enhance teaching and learning of the science and maths curriculum in Years 7 to 10 and involves the development of at least five authentic, multidisciplinary classroom modules which use cutting-edge science and engineering contexts and the latest educational theory from the partner universities and other research institutions to excite and engage students.

This module, Water in the 21st Century, is designed using an inquiry-based, student-centred approach to learning where the teacher adopts a facilitator role and the student plans, designs, conducts and evaluates their investigation. The module is divided into four units:

1. World Water
2. Just Add Water
3. Water for Life
4. Water Farming.

Each unit covers a different aspect of understanding water through the associated issues in managing water resources in the twenty-first century.

We trust you will enjoy and look forward to working with you.

Warm regards,

Prof Anja Scheffers, Assoc Prof Geoff Woolcott, Mrs Simone Blom and Mrs Barbara Jensen (Southern Cross University) *in conjuction with* Mr Peter Pentland (Australian Academy of Technology and Engineering).

Professor Anja Scheffers

Research interests / background:

During my studies of Physical Geography and by a series of accidental turns I became fascinated to investigate how coastal environments have changed in the past. I'm particularly interested in processes that shape and modify coastal landscapes over a variety of length and time scales and the coupling and feedback between such processes, their rates, and their relative roles, especially in the contexts of variation in climatic and tectonic influences and in light of changes due to human impact:

- Understanding past and modern marine physical natural hazards such as tsunamis and storms
- The development of long-term records of tsunamis/cyclones from geological and biological proxy evidence as well as historical documentary records
- Exploring linkages between Late Quaternary climate and landscape change focusing on past sea level and response of coastal ecosystems, particularly coral reefs
- Quaternary geochronology based on ESR and U-series dating and multi-proxy study of corals
- Palaeoclimatology
- Geomythology (pairs geological evidence of catastrophic events and reports of such events encoded into the mythological lexicon of ancient societies)

Associate Professor Geoff Woolcott

Research interests / background:

Geoff is a Senior Lecturer in Mathematics Education in the School of Education at Southern Cross University, Australia. He is an experienced scientist educator with over 30 years experience in the education and research sectors. He has successfully undertaken educational and leadership roles in the primary, secondary and tertiary education sector both nationally and internationally and has considerable experience in the development of innovative educational resources, such as competitions and assessments used in Australia and Asia. He maintains an involvement with schools through research-based collaborations across Science, Technology, Engineering and Mathematics (STEM) in both primary and secondary schools. He has a strong background in funded collaborations in both science and education, and research management roles both nationally and internationally. He has combined his research base in systems biology with studies in education to enable a transition to his recent research on scientific approaches to educational theories and practices. His recent publications, with their focus on STEM education and the Learning Sciences, reflect this transition and he is expanding this research profile within such areas as networks and complexity theory in order to develop studies of education that are based in scientific empiricism.

Geoff is interested in: Connectivity in educational theory and practice, STEM education with a focus on mathematics and science, spatial reasoning, gifted education, complex networks, studies of collaboration, impact and innovation, client-centred integrated services and human developmental ecology

https://works.bepress.com/geoff_woolcott/

Mrs Simone Blom BSc, BTeach

Research interests / background:

Simone began her career in education over fifteen years ago. With academic qualifications in science and primary and secondary teaching, she has held a variety of teaching roles during this time, including delivering programs to students from kinder, primary, secondary and tertiary levels. Simone has been employed as a teacher and environmental education consultant in numerous states and territories in Australia. Simone has also had experience as a Head of Science, a school Sustainability Officer and a VCAA assessor. She has worked in collaboration with community groups, and other schools and government departments to create strong, award-winning science-based programs that focus on the environment and increase students' engagement and awareness in science and environmental issues. Since settling in NSW, Simone has been working in the tertiary sector delivering science and technology education workshops to pre-service teachers. Simone is currently completing her research thesis on the influence of parents on children’s engagement with nature and is involved in writing a book chapter on this topic.

Mrs Barbara Jensen

Research interests / background:

Barbara Jensen has had a long and varied experience in environmental education. This includes writing educational resources; delivering programs in the classroom, on the water or in the bush; and working to engage learners of all ages to take action for an environmentally sustainable future. Most recently her focus has been working in the water industry as an education officer for sustainable water supply and whole of water cycle management. This involved programming, developing and running activities and educational resources for water conservation, water quality and healthy catchments.

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Module Framework

This module adopts an inquiry-based approach to guide students through the investigative process in small collaborative teams. It aims to engage students in using maths and science skills in a critical and creative way, developing interest and understanding about very real and current water issues. Each unit contains three Student Scientific Challenges for students to achieve these outcomes.

In this module, the Teacher's role is as a Facilitator with the purpose of supporting students through the student learning pathway of preparation, implementation and extension steps as shown below. To support successful implementation of the module, student work samples are provided at the end of each unit.

PREPARATION

Curriculum links

Read: Unit Summary Table
Review: Big Science Idea and Science Background Information
Understand: Scientific Questions and Scientific Vocabulary
Choose: Student Scientific Challenge/s
Check: The Kit is complete. Some equipment may need to be purchased, prepared or collected, see list in Unit Summery Table.

Background information
Key science knowledge points.

Challenge support information
Answers, results and helpful information.
Samples of students work.

IMPLEMENTATION

The Kit

- Provides the equipment for each Scientific Challenge.
- Check the Unit summary Guide as consumables may be required.

Scientific Challenge

- **Open-ended, student-centred activities.**
- **Small collaborative student teams work with Student Booklet and The Kit.**
- **Student teams are thinking, communicating, designing, problem-solving, questioning and reporting.**
- **Student teams are using inquiry-based investigation skills including identifying variables, making predictions, taking measurements, making observations, recording data, interpreting and analysing information and self-reflection.**
- **Whole class discusses real world relevance.**

Teacher as facilitator

- The coach and questioner.
- Open ended and reflective questions.
- Clear expectations and roles of the students.
- Environment where students feel safe to take risks and share ideas (even if they are not correct).
- Students to share and build on each other's ideas and to use them to elicit more questions and investigations.

EXTENSION

Links within module
Make connections to other units in this module.

Career Case Studies
Watch and discuss video case studies to demonstrate study pathways that lead to careers in the relevant industries.

External Links
Use websites and web tools to build on students' questions, understandings and curiosities.

Extension Investigations
Each unit contains optional investigations that can extend your students' learning.

How to use this module

Risk Management

A general risk assessment and control form is provided to help you prepare and provide safe science lessons; see page 7. Use the form as a guide to write your own risk management strategy, specific for your school requirements.

Teaching the Module

This module contains four units. Each unit has a 'Big Science Idea' and the option of three 'Scientific Challenges'. Choose the Challenges that suit your class time availability and student learning outcomes.

Practical Safety Advice

These activities involve water and a variety of equipment, students need to:

- Have cloths and a mop ready to clean up spills immediately.
- Work on trays or sinks to contain water spills and runoff.
- Only use equipment as it is intended.
- Be supervised when working with electrical equipment.
- Wash hands after working with dirty water samples.

The Scientific Challenges are exploratory investigations or fair tests. These are marked with an icon on the top right of each Challenge page, with scales for a fair test and a magnifying glass for an exploratory investigation. The students are asked to undertake a Scientific Challenge, working in small team of three to design, test, report and reflect on their group's investigation. To assist and guide students through their investigation, a Scientific Challenge Report Planner and Challenge Checklist is provided in the Student Booklet.

As part of an authentic inquiry-based, student approach, the teacher's role is to:

- facilitate discussion,
- supervise safety,
- pose reflective and timely questions,
- stimulate and extend student ideas,
- let students explore and investigate for themselves.

This allows students to:

- take ownership of their learning,
- collaborate in teams to design, test, report and reflect,
- develop curiosity and passion to drive their own interest in science and maths.

Lesson Outline: **Based on the outline below, each unit would take 3 lessons.**

Lesson 1: Questioning and Planning

- The Class explores, discusses and questions the Big Science Idea.
    - Using the Student Booklet, introduce the Big Science Idea and gather questions students have about this concept. Note the Science Glossary and ask them to add words as they work through the unit.
    - Assess Students current level of knowledge and understanding with the stimulus picture and 3 questions, in the Student booklet.
- The Class discuss the types of investigations: exploratory and fair-testing. This will enable them to decide which approach to use.
- The Teams read, discuss and start planning their Challenge.

Lesson 2: Conducting, Processing and Analysing Data

- The Teams conduct their Challenge. This includes the report writing with prediction, methods, observations and results. Space is provided in the Booklet for their report. Students can use the Student Challenge Report Planner (see Student Booklet page 5) to guide them in writing a report for each Challenge.
- Optional Extra Lesson/s: the Teams conduct another Scientific Challenge from the same Unit.

Lesson 3: Evaluating and Communicating

- The Teams work individually and as a group to share, discuss and reflect on the questions and learning that has arisen for them after doing the Challenge.
- The Class undertakes a Reality Check, discussing how this Big Science Idea is relevant to their lives.
- The Class uses the Case Studies to explore career pathways for Science, Technology, Engineering and Maths.

Risk Assessment and Control

This matrix has been written as a guide for you and your students to write your own Risk Management Strategy. Please adapt to suit your classroom, school requirements and local area. The students are reminded to do their own safety check using the clipboard icon for each Scientific Challenge.

ACTIVITY	RISK	LIKELIHOOD	ACTIONS FOR CONTROL
Water spills	Students or Staff slip over and injure themselves.	Medium	Provide bucket, mop and cloths and clean up spills immediately. Display a "Caution Wet Floor" sign.
Scissors	Students or Staff are injured through inappropriate use or accident.	Low	All participants are instructed to use equipment appropriately.
Lifting and carrying water containers	Students fill containers with too much water so that they are too heavy or they lift them incorrectly.	Low	All participants are instructed to use equipment appropriately. The Challenge instructions direct the students to carry a 2 litre maximum.
Using hand held blenders and lamps	Students may trip over cords and electrocution.	Low	All participants are instructed to use the equipment appropriately and switch off and unplug when not in use.
Handling contaminated water sample	Students may become ill if contaminated water is ingested.	Low	Students are instructed to wash hands after use.
Use of scientific equipment	Students may incur injury if equipment is misused, broken or ingested.	Low	All participants are instructed to use equipment appropriately.

Curriculum Links

Science Understanding	Science as Human Endeavour Years 9-10	Science Inquiry Skills Years 9-10
Year 9 *Biological Sciences* Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems. (ACSSU176)	*Use and influence of science* People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities. (ACSHE160 & ACSHE194)	*Questioning and Predicting* Formulate questions or hypotheses that can be investigated scientifically. (ACSIS164 & ACSIS198)
Year 10 *Earth and Space Sciences* Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere. (ACSSU189)	*Use and influence of science* Values and needs of contemporary society can influence the focus of scientific research. (ACSHE228 & ACSHE230)	*Processing and Analysing Data and Information* Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies. (ACSIS169 & ACSIS203)
		Communicating Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations. (ACSIS174 & ACSIS208)

Unit 1: World Water– planetary water and availability

Unit Summary Guide

The Big Science Idea

Students will learn and understand that despite the seeming abundance of water on Earth, fresh water availability is scarce.

Scientific Discussion Questions

- We live on a blue planet but how much is available for us to drink?
- Where can you find fresh water on planet Earth?
- Is all fresh water suitable for drinking?

Scientific Vocabulary

- Hydrosphere – total water on the planet as liquid, gas or solid. It is found on the surface, underground or in the air.
- Water scarcity – only 3% of the world water is fresh and of that only 1% is available for the whole world's use.
- Groundwater – water stored in porous soil, rocks and aquifers.
- Potable water – water which is safe for drinking.
- Green, blue and grey water – see notes below.

Student Scientific Challenge

1. **Water is everywhere, how can we be scarce of drinking water?** Create a simple model to demonstrate where water is found in our world.
2. **Cloud to tap and back! How does fresh water move around our planet?** Build a functioning model of a catchment including land and surface and underground water.
3. **Is there water underground? What does this tell us about the geology and human activities?** What are the quality, location and connection of groundwater sources? Groundwater Monitoring Program: record GPS location, depth and water quality**.**

Real Life Relevance

Whole class discussion questions:

- What are their questions and understanding elicited by this Unit?
- Why is developing understanding about the content in this Unit relevant to their lives?
- How were science and maths integral to their learning?

Scientific concepts:

- Water sustains our life on Earth therefore, we all have a role to play in sustainable water use.
- Ensuring safe, healthy water to our homes has significant financial, social and environmental costs.
- As future scientists and engineers, you can design and plan new ways of using and sourcing water for a sustainable water future.

Challenge Equipment List

Challenge 1:

Flat tray
Large bottles (< 1L capacity)
Small bottles (< 50mL capacity)
Land: Material & foam blocks
Fresh water: Petri dishes
Syringe
Big beaker500ml
Small beaker 25ml
Salt
Teaspoon
Refractometer& pipette
Distilled water for cleaning refractometer
Scales

Challenge 2:

Plastic box
Small pebbles/rocks
Trigger spray bottle
Sponges
Clear plastic sheeting
Weed mat
Foil
Plastic sheets
Scissors

Challenge 3:

Groundwater sample: *this should not include silt or dirt so turbidity is not affecting results.*
Large beakers 500ml
pH meter: *acidity and alkalinity on scale 0-14.*
Electrical conductivity (EC) meter: *transfer of electricity.*
Calcium ion meter: *hardness.*

Background Scientific Information

This unit focuses on water as a core driver of global systems. The role of water in the biosphere – where all life forms on Earth exist – is evident in the hydrosphere. Here, water circulates through the water cycle in its different states, as water vapour, liquid water and ice. However, despite what we may see as an abundance of water on Earth in our oceans, fresh water availability is scarce. Only 3% of the world's water is fresh water. With 2% of that locked up in glaciers, icecaps, atmosphere and soil, this leaves only 1% available for the whole world's use. Much of our freshwater is stored underground in aquifers, which comprises 98% of the world's fresh water. In this context, the world's consumption and production of water is critical.

Water masses at the Earth's surface

reservoir	volume (in millions of cubic kilometres)	percent of total
oceans	1,370.0	97.25
ice caps and glaciers	29.0	2.05
deep groundwater* (750–4,000 metres)	5.3	0.38
shallow groundwater (less than 750 metres)	4.2	0.30
lakes	0.125	0.01
soil moisture	0.065	0.005
atmosphere**	0.013	0.001
rivers	0.0017	0.0001
biosphere	0.0006	0.00004
total	1,408. 7	100

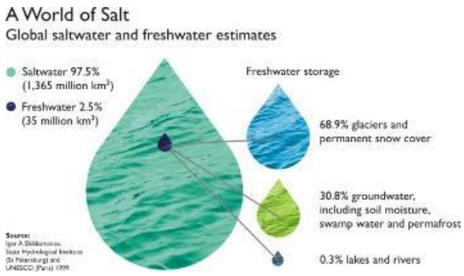
*The total interstitial water in the pores of sediments is on the order of 50×10^6 to 300×10^6 km^3.
**As liquid equivalent of water vapour.

Source: Adapted from Elizabeth Kay Berner and Robert A. Berner, ***The Global Water Cycle: Geochemistry and Environment***, copyright 1987, Table 2.1, p. 13. Reproduced by permission of Prentice Hall, Inc., Englewood Cliffs, N.J.

https://www.britannica.com/science/hydrosph

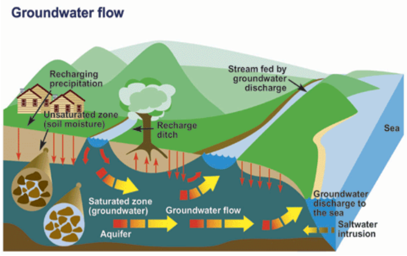
Hydrosphere

- The Earth's hydrosphere includes all the water on the surface, underground or in the air. It can be liquid, gas or solid. The water cycle moves water through the Earth's hydrosphere.
- **Water as a liquid** is located on the surface in the form of oceans, lakes, wetlands and rivers. It is found underground in the soil and aquifers and can be seen in the atmosphere as clouds and fog.
- **Water as a solid** (ice) is in glaciers, ice caps and icebergs. The frozen part of the hydrosphere is called the cryosphere.
- **Water as a gas** is invisible. With heat, water evaporates from a liquid into a gas from the ocean, surface water and other wet surfaces like washing on the clothes line.
- Ocean water and water trapped in the soil make up most of the present-day hydrosphere.
- **The water cycle** is essentially a closed system, therefore the amount of water that we have today has always been present in the Earth system.
- Water sustains life on Earth and the water cycle ties together the land, oceans, and atmosphere into an integrated system.



Water Availability and Scarcity

- The fresh water in our world is found in three main places:
  - **Surface water**: water collecting on the ground or in a creek, river, lake, wetland or artificial water body like a dam.
  - **Groundwater**: water found underground in the cracks and spaces in soil, sand and rock.
  - **Atmospheric water**: water present in the atmosphere either as a solid (snow, hail), liquid (rain, fog, mist) or gas (invisible).
- **Fresh water availability is scarce**. Three percent of the world's water is fresh water but only a fraction of it is accessible on the Earth's surface. Most freshwater is locked up in glaciers and in groundwater. In terms of water, planet Earth and our human body are the same! They are each composed of 70% water.
- **Water availability is closely linked to food security**. Farming/agriculture uses 70% of the world's available fresh water.
- World population growth is predicted to rise to more than 8 billion people by 2050 (from 7.4 billion in 2016).
- Human beings are creating pressure on our water resources through growing populations, climate change, over- consumption (increased demand for water and embedded water driven by a global consumeristic society), poor land management practices (leading to contaminated water) and slow development of alternative water sources (recycled waste water & non-potable water for non-potable activities).

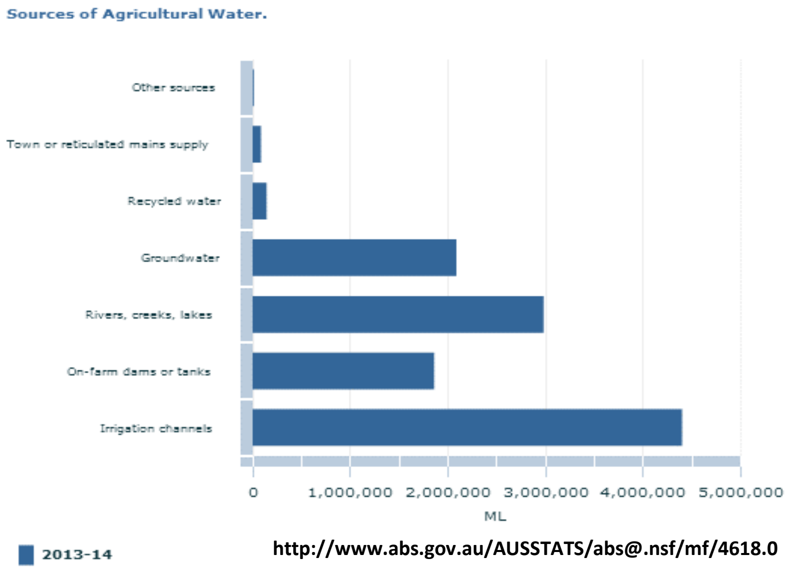


http://www.ec.gc.ca/eau-water

- Natural disasters exacerbate water issues too. Excessive rainfall causes flooding and disruption of drinking water supplies. Areas that rely on groundwater or rainwater are highly vulnerable to droughts.

Groundwater

- **Groundwater is mostly invisible as it is found underground**. Given that it is “out of sight” it can often be “out of mind” and under-recognised and valued for its importance and significance.
- **Groundwater makes up 98% of the world’s fresh water**. Thirty percent of Australia’s water consumption comes from groundwater.



http://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/4618.0

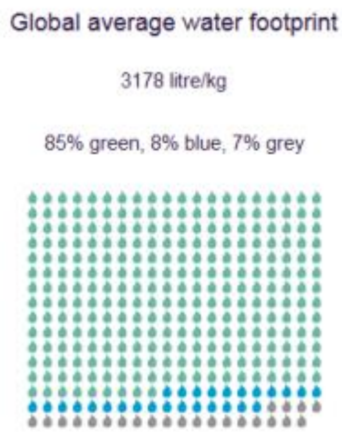
- **Groundwater is stored in porous soils and rocks and in geological reservoirs called aquifers; the study of groundwater is known as hydrogeology**. It flows naturally through springs and seeps but can also be pumped out by bores. As the water infiltrates through soil and rock it leaches minerals into the water. This may affect the colour, taste or salt levels and therefore influence its potential usage.
- **Rain that soaks into the ground drains downwards to the water table**. The water table is the level at which the unsaturated zone above, meets the saturated zone below. The water table is usually below the ground surface but when it is high enough it comes to the surface naturally in springs, lakes and wetlands. In other areas, groundwater may be stored for years in long-term aquifers before coming out again as groundwater discharge.
- **Fossil water forms where aquifers have been cut off for thousands of years**. Fossil water can be extracted but because it is not replenished, it is referred to as groundwater mining (this occurs in many arid parts of Australia e.g. Alice Springs).
- Groundwater is Western Australia’s most important source of water, providing two thirds of its needs.
- **Movement of ground water is crucial for agricultural land**. About 2 billion people worldwide depend on groundwater supplies, which include 273 transboundary aquifer systems.
- **The Great Artesian Basin in central Australia is the largest aquifer of its kind in the world**. It contains enough water to cover the world in half a metre of water. It covers 22% of Australia and contains water that is more than 1 million years old.
- Of the total world energy consumption, about 8% is used to lift, pump and treat groundwater and also, to treat wastewater. This figure is about 40% in developed countries.

Potable Water

- **Potable water is water that is safe enough for drinking and food preparation**. Water can be naturally potable or can be treated in order to be safe for human use.
- Urban regions have water authorities that manage the water source (dams, rivers, groundwater and seawater), treatment and distribution. In rural regions, people will manage their own water supply with rainwater tanks, natural springs, groundwater bores, small dams, creeks or rivers.
- Best practice water supply management is “Integrated water cycle management”. This considers the water cycle as a whole; combining planning for all the elements of water services i.e. drinking water, sewage, waterways, catchments, stormwater and groundwater. It aims to provide more sustainable economic, social and environmental outcomes.
- Different water sources provide different quality water and these can be treated to be potable or used for different purposes e.g. groundwater for gardens, dam water for farming, rainwater for toilet flushing and washing or spring water for drinking.
- Scientists and engineers have developed ways to treat water from most sources, including contaminated or waste water, making them suitable and safe for human consumption. Techniques include: sedimentation, clarification, coagulants and flocculation, disinfection, micro filtration, UV, ozone, biologically activated carbon and desalination.

Green, Blue and Grey and other Water

- Green water refers to precipitation that does not run off or recharge the groundwater but is stored in the soil or temporarily lies on top of the soil or vegetation. Green water eventually evaporates or transpires through plants.
- Blue water refers to fresh surface and groundwater such as the water in freshwater lakes, rivers and aquifers. Blue water availability is the natural run-off (through groundwater and rivers) minus environmental flow requirements. Blue water availability varies seasonally and also from year to year.
- Grey water is the 'polluted' water that is the product of sinks, showers, baths, washing machines and dish washers.
- Other commonly named waters include rainwater (collected on roofs and stored in tanks); blackwater from our toilets high in nutrients and containing faeces, (blackwater that has been cleaned via treatment and captured for reuse is called "recycled" or "reclaimed" water); and stormwater particularly in urban areas that is captured in rain events and washes down the drain to creeks, rivers and eventually the ocean, taking any street litter, soils, oils, detergents, animal faeces or pesticides with it.



The global average water footprint of whole cow milk is about 940 litre/kg. About 50% of this amount is allocated to the fresh unfermented cheese that is derived from the whole milk and the remaining 50% to whey. One kilogram of whole milk gives about 95 gram of cheese, so that the water footprint of cheese is 5060 litre/kg (Mekonnen and Hoekstra, 2010, 2012). http://waterfootprint.org/en/resources/interactive-tools/product-gallery/

Scientific Questions - Answered

We live on a blue planet but how much is available for us to drink?
Fresh water is scarce because of all the water on Earth only 3% is fresh water and of that amount 2% is locked in the icecaps, glaciers, atmosphere and soil. That leaves only 1% available for the worlds use. The amount of global water is finite but the world population is predicted to rise to more than 8 billion people by 2050 (from 7.4 billion in 2016). Humans are creating pressure on our fresh water resources through this growing population, over-consumption, changes in evaporation and rain events due to climate change, and poor land management practices that are contaminating some of the available fresh water supply.

Where can you find fresh water on planet Earth?
Fresh water is found in three main places:
1. Surface water: collects on the ground or in a creek, river, lake, wetland or artificial water body like a dam.
2. Groundwater: found in porous soils, rocks and in geological reservoirs called aquifers.
3. Atmospheric water: present in the atmosphere either as a solid (snow, hail), liquid (rain, fog, mist) or gas (invisible).
There is about 60 times more groundwater than surface water, but as it is out of sight it is mostly out of mind.

Is all fresh water suitable for drinking?
Potable water is water which is safe enough for drinking and food preparation. It can be naturally potable or can be treated in order to be safe for human use, in water treatment plants. Healthy ecosystems provide healthy water. It is naturally filtered through tree roots and sand; disinfected by UV rays and aerated by aquatic plants, wind and waterfalls.

Different water sources provide different quality water and these can be treated to be potable or used for different purposes e.g. groundwater for gardens, dam water for farming, rainwater for toilet flushing and washing or spring water for drinking. Scientists and engineers have developed ways to treat water from most sources including contaminated or waste water, making them suitable and safe for human consumption. Most of these techniques have been mimicked from the water cycles' natural cleaning methods. Water treatment plants include: sedimentation, clarification, coagulants and flocculation, disinfection, micro filtration, UV, ozone, biologically activated carbon and desalination. In urban areas the quality of water supplied by government or water authorities is guided by each country's drinking water guidelines. They address both the health and aesthetic quality aspects of supplying good quality drinking water. In rural areas families manage both their own water supply and quality. This often includes rainwater, groundwater, dams and rivers.

Sample Student Answers

We live on a blue planet but how much is available for us to drink?
"Around 1%." Year 9
"Not enough. We can't drink the ocean as it is." Year 9

Where can you find fresh water on planet Earth?
"In lakes, rivers and deposits under the ground." Year 9
"Rain and in icecaps, glaciers, rivers, soil, atmosphere, mountains and clouds." Year 9

Is all fresh water suitable for drinking?
"No, some water it dirty." Year 9
"Provided it is filtered and clean, yes." Year 9
"Depends whereabouts the water comes from." Year 9

Challenge Support Information

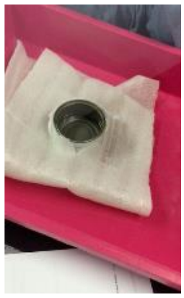
Challenge 1: Water is everywhere, how can we be scarce of drinking water?

Science Background Information
Although there is an abundance of water in our world, 97% is non-potable in its current state found as saltwater in the oceans. Only about 3% of the Earth's water is fresh water, however, most of that is locked up in glaciers, icecaps, atmosphere and soil. Therefore, only about 1% is available on the surface and underground, for the world to use. On the surface, it is found in rivers, lakes, wetlands and dams. Underground, it is found in the cracks and spaces of soil, sand and rock. The water cycle is an integrated system that ties together the water found on land, underground, in the oceans and atmosphere.

Water availability is closely linked to food security, given that farming and agriculture uses approximately 70% of the world's available freshwater. We are creating pressure on our water resources through growing populations, climate change, over-consumption (increased demand for water and embedded water driven by a global consumerist society), poor land management practices (leading to contaminated water) and slow development of alternative water sources (recycled waste water & non-potable water for non-potable activities).

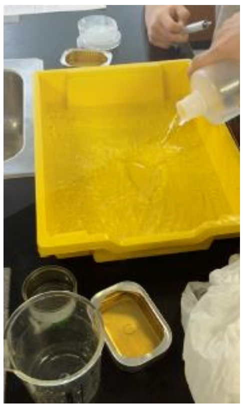
Natural disasters exacerbate water issues too. Excessive rainfall causes flooding and disruption of drinking water supplies. Areas that rely on groundwater or rainwater are highly vulnerable to droughts.

Pre-investigation

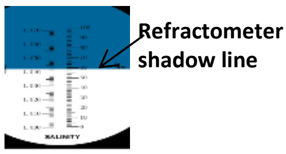



To build the model the students need a variety of different materials to represent the land and the different water bodies eg. rivers, lakes, wetlands and dams. Recycled items such as small tins, cans, plastic bag, material etc can be used. These may be in the Kit or need to be either collected or purchased.
A flat tray works well to represent the ocean.
Prepare the small bottle to represent the freshwater: measure 30ml water into the small bottle. This measurement should remain unknown to the students.
Prepare the large bottle to represent the ocean water: measure 970ml into the large bottle**.** This amount should remain unknown to the students.
Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are measuring the amount of water in the ocean and the freshwater bodies.

During investigation



1. Students are asked to create a simple model to demonstrate where water is found in our world.
Students can use the water in the small bottle to fill the freshwater areas of their model to represent that 3% of the worlds water is fresh. It is important they use only the water in the small bottle to fill the freshwater areas so that their calculations are accurate.
Students can use the water in the large bottle to fill the ocean area of their model to represent the 97% of the worlds water is in the ocean. It is important they use only the water in the large bottle to fill the ocean area of their model so that their calculations are accurate.
2. Students use the water from the large bottle in their oceans to create saltwater with the same concentration as the oceans given that ocean water has a salt concentration of 35g/L. Using scales or teaspoon measures, students can determine the amount of salt needed for their ocean. Salt weighs 6 grams per teaspoon. The whole bottle or "ocean" needs just under 6 teaspoons.
3. Students are then asked to calculate the fresh/salty ratio of water available in our world.
4. Students are asked to use the refractometer to test their their accuracy in creating ocean water with 35g/L.



Measuring the salinity with the refractometer only requires a couple of drops of water. With a pipette put 2 or 3 drops on the prism to cover the entire surface and close the lid. Hold under light and look for the shadow line. An optimal contrast is obtained by holding the instrument underneath and perpendicular to a light source.
Clean the refractometer with distilled water to avoid contamination and wipe with dry cloth.

Post-investigation

Wash, dry and recycle the materials, then return to the Kit for use by the next class.
Ensure the refractometer is carefully rinsed with distilled water and dried with a cloth after use.

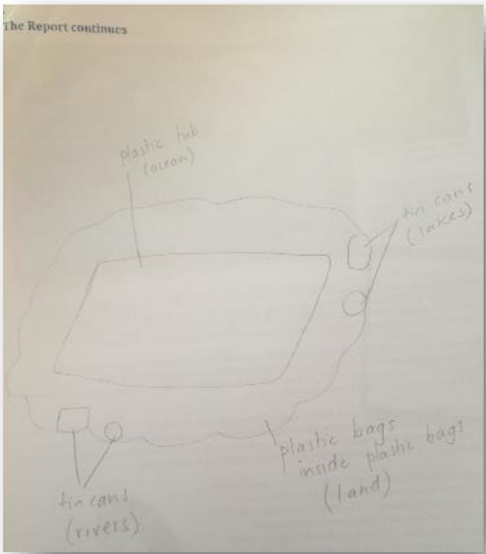
Sample Student Report

Scientific Challenge 1: Water is everywhere; how can we be scarce of drinking water?

Investigation: This Challenge is an exploratory investigation.

Method*:*

1. Collect a variety of the recycled materials available, including small and large containers to represent the freshwater and saltwater areas.
2. Build a model of the Earth with room for water bodies and land.
3. Fill the containers that are on land or underground with fresh water from the small bottle.
4. Fill the container that is the ocean with water from the large bottle.
5. Add 33.95 grams of salt to the ocean.
6. Check if you measured the right amount of salt using the refractometer.
7. Measure the amount of water in the freshwater and saltwater and work out how much fresh water there is compared to salt water.



Observations and results:
This is a diagram of our model.
We found that the fresh water was 30mLs and the ocean was 900mLs. But we spilt some so we talked with another group and found out that it was meant to be 30mLs and 970mLs. That means a 3:97 ratio or 3% freshwater for 97% saltwater. That is not very much water for us to use. Lots of this water is also in ice like in Antarctica and the North Pole. So there is not much for us to drink and clean with.

Evaluation*:*
Be more careful with the water when we were measuring it! Our model was pretty good. But it would have been better if we could show the rivers somehow. And even have something to be the ice and the freshwater we can't actually use.

Reflection:
These are my questions:

- How much water is available for us to drink?
- How does the weather help it to rain?
- What is the best way to keep water?

I didn't know there was such little fresh water on Earth. This makes me want to be more careful with our water and not waste so much.

Challenge 2: Cloud to tap and back! How does fresh water move around our planet?

Science Background Information
Earth's hydrosphere includes all the water on the surface, underground or in the air. It can be liquid, gas or solid and is constantly on the move through the hydrosphere in the water cycle. About sixty times more fresh water than all the earths' surface water storages combined is found underground as groundwater. The fact that groundwater is out of sight does not mean it should ever be out of mind.

Water that soaks into the ground drains downwards to the water table. The water table is the level at which the unsaturated zone above, meets the saturated zone below. It is usually below the ground but also comes to the surface naturally in springs, lakes and wetlands. In other areas, groundwater may be stored for thousands of years in aquifers before coming out again as groundwater discharge or being pumped out by windmills and pumps. The study of groundwater is known as hydrogeology.

Water run-off depends on the ground's surface. In urban areas there are more impermeable surfaces like roads and footpaths. In rural areas more water can infiltrate, depending on the vegetation and soil. Soils are made of particles of different types and sizes, mostly of sand, silt, clay and rock. The space between these particles is called pore space and will determine the amount of water it can hold.

Pre-investigation

To build the model you need a variety of different materials to represent the different layers on or under the ground e.g. aquifers, solid rock, soil, dam, creek, roads or permeable soils. These may be in the Kit or needed to be collected or purchased. Check the Kit and equipment list.
Clear soft and stiff plastic helps the students to see what is happening in their model.
Safety – raining and pumping will create puddles – be prepared for cleaning up spills.
Enough time, plastic boxes and materials would allow for this exploratory investigation to be then conducted as a fair test.

During investigation

Spray bottles can be used for rain and also if you take the top off and out of the bottle, it can then be used as a groundwater pump.
Design options are endless and the first attempt will most likely lead to a new improved design.

Post-investigation
Wash, dry and recycle the materials and rocks, then return to the Kit for use by the next class.

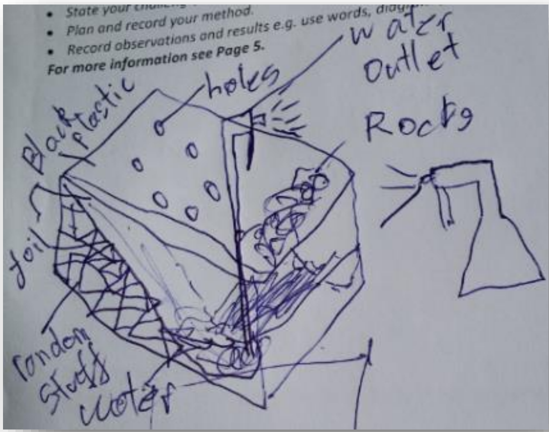
Sample Student Report

Challenge 2: Cloud to tap and back! How does fresh water move around our planet?

Investigation: This Challenge is an exploratory investigation.

Method*:*
- Collect a variety of materials.
- Spray with water to see what happens i.e. runs off, absorbs or soaks in or pools.
- Create different areas in the plastic box, for water to collect, stop or flow.
- Rain (spray) and watch what happens with the water.

- Use the top of the spray bottle like a windmill and putting it in the rocks, pump up water onto the surface above.



Observations*:*
The black weed mat was waterproof at first and then there was some seepage. The water pooled amongst the rocks, the sponge soaked it up and the foil worked well for a flowing creek. Another group used the clear plastic as the sky and almost made it rain.

Results*:*
The spray bottle rained into our model. We created a groundwater aquifer in the rocks and then with the spray bottle top as a windmill, pumped some water out onto the hard ground which then ran down the foil and into the groundwater once again.

Evaluation*:*
It was very hard to draw the 3D diagram but we were happy with our water cycle model. We knew we needed to get water into the ground but at first it was seeping through too slowly so we put some holes in the top ground layer for the water to make it through to the aquifer. The model showed the below and above water movement well but the condensation and precipation part of the water cycle was really not evident. Without a heat source we think it would be hard to replicate this.

Reflection:
Our model got us thinking more about water below and above ground and that connection. So now we have these questions:

- In the real environment, how much is the groundwater connected to the surface water?
- What happens to the groundwater in times of drought or floods?
- Is there water under our school?
- How long does it take for water molecules to pass through the water cycle and back?

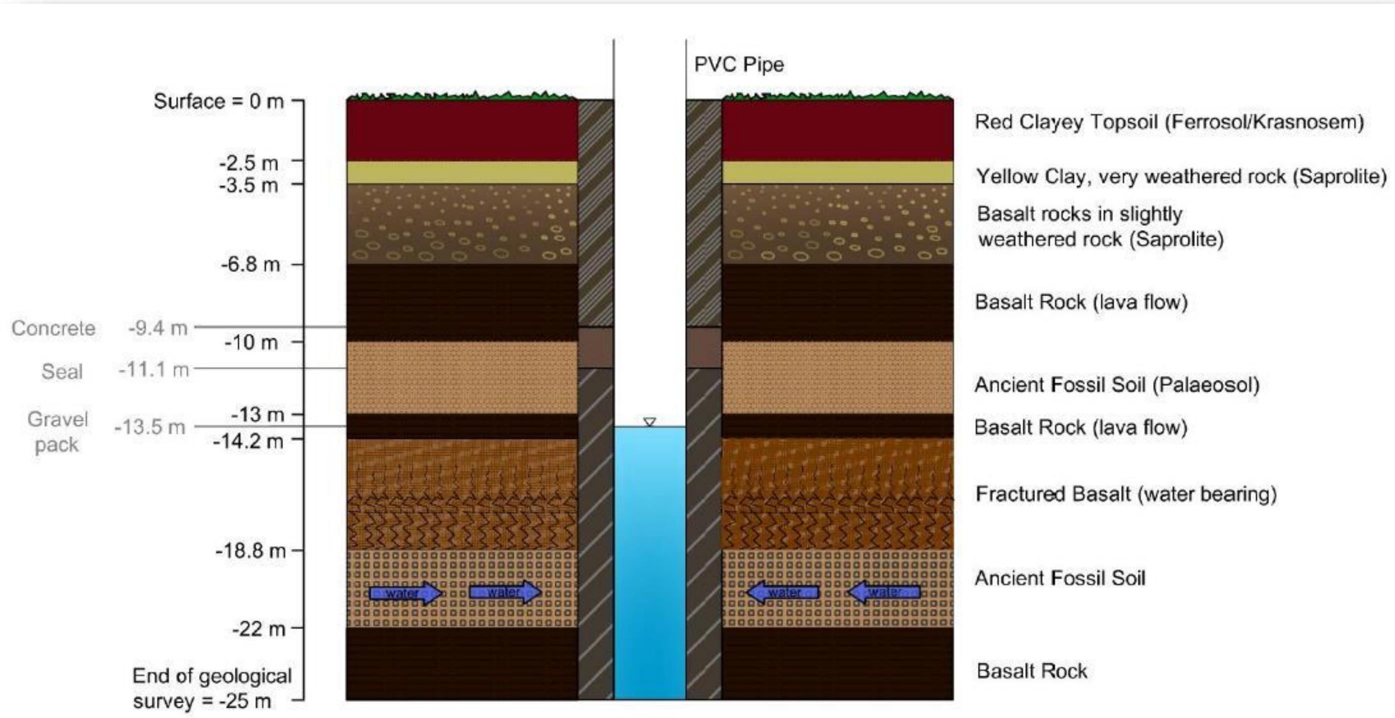
Challenge 3: Is there water underground? What does this tell us about the geology and human activities?

Science Background Information

Rain and river water can soak into the ground, filling the gaps in the rocks and soil and draining down to the water table. The rocks and soils that hold and transmit water are called aquifers. As water infiltrates, natural minerals or contaminants can leach into the water. Depending on the catchment geology and the human activities and land uses, this will affect the water quality e.g. colour, taste, pH or salinity and therefore influence its potential usage. For example the sand beds along the coast of NSW are highly permeable and easily recharged through rainfall. They are also very vulnerable to contamination e.g. fertilisers, pesticides, leaking septic, wastewater, urban runoff, landfill sites and salt water intrusions. *(NSW Groundwater Dependent Ecosystem Policy 2002).*

Although out of sight and therefore so often out of mind, groundwater is connected to surface water as it seeps out (discharges) as springs and into rivers and wetlands. Ecosystems can be dependent on groundwater for providing water to vegetation and sustaining creeks in times of drought. Groundwater can move under vast areas, for example the Great Artesian Basin in central Australia is the largest aquifer of its kind in the world, covering 22% of Australia, passing under state boundaries and containing water that is more than a million years old. Also in Australia aquifers are a source of water for drinking, irrigation, farm animals, bottled water and other uses,(around 30% of Australia's total water consumption) with some places having groundwater as the only available fresh water.

When a bore is sunk, it is done to meet national standards. The contractor will sketch a profile that records the soil and rock types, depth at which the water is found and the concrete seal and gravel pack, as the diagram shows. After testing, the water quality of this groundwater in Northern NSW was fit for all uses including drinking. It is situated in the upper catchment of predominantly native rainforest but also some dairy cattle and macadamia nut farming. An aquifer was found, at about 14 meters, in the ancient fossil soils with weathered water bearing basalt above and the basalt rock lava flow below, acting as an impermeable layer.



A catchment assessment is used to guide the water quality tests required for each groundwater site. Common parameters tested are pH, salinity, hardness, temperature and dissolved oxygen. As the testing is mostly done on site, and this student Challenge is being conducted in the classroom, the latter two parameters will be influenced and changed by collection and transportation, and are therefore not suitable for class work.

The presence of faecal coliform such as E.coli in groundwater may indicate recent contamination, which could contain other bacteria, viruses or disease- causing organisms. E.coli is considered an “indicator”, and testing will be done if there is potential contamination in the catchment, and to confirm if it is a risk to human health. E.coli is the most common bacterium present in the intestinal tract and faeces of mammals, birds and humans. Its presence may be due to wastewater and stormwater contamination, agricultural runoff and waterbird and livestock defecation. Sterilisation techniques and the need for incubation make this test also difficult for this student Challenge.

Groundwater management issues include over-extraction, contamination, salinity, salt-water intrusion and a lack of understanding about the link between surface and groundwater and groundwater dependent ecosystems. An example of groundwater management is the National Water Initiative, signed in the early 2000s by all Australian governments, that promotes a ‘whole of water cycle’ approach to water management. This takes groundwater out of isolation, acknowledging the connections of the hydrosphere.

Water Quality Tests - In this challenge the groundwater is being tested for the following parameters:

1. pH with pH meter. It shows acidity and alkalinity on scale 0-14. pH also controls the ability of water to transport potentially harmful chemicals Result range for pH is:
    - Healthy: 6.5 to 8.5
    - Poor: <6.5 or >8.5
2. Electrical conductivity (EC) with EC meter. It shows the amount of transfer of electricity through water and is a measure of salinity. Low range meters measure in microsiemens per centimetre (µS/cm) and high range meters measure in millisiemens per centimetre (mS/cm). The Australian Drinking Water Guidelines indicate 500mg/L for total dissolved solids. The Australian Water Quality *Guidelines* for Fresh & Marine Waters result range for EC is:
    - Healthy: Less than 300 µS/cm (Less than 0.3 mS/cm)
    - Fair – may affect river health: 300 to 800 µS/cm (0.3 to 0.8 mS/cm)
    - Poor – river health at risk: Greater than 800 µS/cm (Greater than 0.8 mS/cm)
3. Hardness with calcium ion meter. This is not a health concern but can cause build up or scaling and therefore create usage difficulties. The Australian Drinking Water Guidelines indicate that 200mg/L of hardness (as CaCO3) is the aesthetic limit and the result range for hardness is:
    - <60mg/L $CaCO_3$ – soft but possibly corrosive
    - 60-200mg/L $CaCO_3$ – good quality
    - 200-500mg/L $CaCO_3$ – increasing scaling problems
    - >500mg/L $CaCO_3$ – severe scaling

More information

Groundwater Essentials.pdf from National Centre for Groundwater Research and Training (Australia)
http://www.groundwater.com.au

Pre-investigation

Collect groundwater samples:

- Students with groundwater, can be asked to bring in a sample and most likely it will come from a tap at the pump or windmill, rather than using a bailer.
- Sampling method and bottles ideally would be the same for each site.
- Provide students with a sample bottle label to record place, date and time.
- Students need to ensure there is no local contamination when collecting the sample.
- Samples should not include silt or dirt (i.e. turbidity) as this will affecting results.
- Sample volume needed to be collected will depend on the number of students doing this Challenge.
- A photograph that shows the bore site and catchment would be very helpful for the other students in identifying aspects of the catchments and human activities or land uses.
- Ask the students collecting the samples to bring as much information as they can about their bore e.g. depth, age, profile and their usage of the water.

Meter Calibration is always needed before they are used.

Beakers – ensure enough beakers for the number of samples collected and students undertaking this Challenge.

Maps of the local area where the samples are collected would be useful for understanding more about the catchment and geology.

During investigation

Safety – wash hands or use gloves.

Rinse meters in between samples with deionised water to avoid contamination**.**

Post-investigation

Clean meters well before packing away.

Safety – wash hands at the end of the investigation.

Sample Student Report

Challenge 3: Is there water underground? What does this tell us about the geology and human activities?

Investigation: This Challenge is an exploratory investigation.

Method*:*

1. Use the samples bought in by students.
2. Pour 25ml into each beaker.
3. Test each sample for pH and record, then test for the other parameters.
4. Clean meters with deionised water before and after each test.
5. Look at photographs and map of the catchment the sample came from.
6. Analyse our results.

Sample	pH	EC	Hardness	Bore Depth	Catchment
1	8.1	700 µS/cm	500mg/L	16mt	Some trees in a cow paddock.
2	6.9	980 µS/cm	350mg/L	14.5mt	Open paddock with cattle trough.
3	7.7	886 µS/cm	454mg/L	15.5mt	No photo.

Observations*:*

One of the samples looked dirtier than the others. The pH meter took a while to get a stable result. The labels on the sample said they were collected on different days and at different times - Will this make a difference?

Results*:*

Our groundwater testing shows fairly similar results, as shown in the table. The hardness may lead to scaling problems. It is above the 500 µS/cm advised in the drinking water standards but is used by cattle to drink. The pH all fell in the healthy range. The bore depth is very similar.

Evaluation*:*

The three samples came from the same catchment and were used for the same purpose – stock watering. Other human activities that could influence the ground water quality may be paddock fertilsation, septic tanks and farm machinery. However we cannot see any evidence of contamination impacts from our results. We would assume the geology is similar but more thorough research is needed. It was fun testing the water but we are not sure how good our technique was. It would be great to do more tests and find out more background information from the farmers.

Reflection:

Our investigation just got us started in thinking about groundwater testing, quality and use in the local area. Now we have these questions:

- How much is the groundwater used for stock watering in this catchment?
- Is groundwater used for other human activities and is some agency monitoring this?
- What is the geology of the catchment and how is it influencing the groundwater?
- Is it safe for humans to drink this groundwater and what test do we need to do to find out?

Stimulus or Extension Resources

Video and form: Scientific Investigation Fair Testing
The video shows a scientist doing a water investigation using the fair testing method. The form is also available for download.
http://www.watersciencelab.com.au/teacher.html

Information: The Water Cycle
Detailed information on the water cycle.
http://earthobservatory.nasa.gov/Features/Water/page2.php

Information: The Water Cycle
Detailed information on the water cycle.
http://science.nasa.gov/earth-science/oceanography/ocean-earth-system/ocean-water-cycle/

Video: The Water Cycle (1min50secs)
Simple visual explanation of the natural water cycle. (Rous Water, Northern NSW)
http://watersciencelab.com.au/videos.html)

Video: The Water Journey to tap and back (3min31secs)
Simple visual explanation of the urban water cycle (Rous Water, Northern NSW)
http://www.watersciencelab.com.au/videos.html

Video: How the Great Artesian Basin works? (5min35secs)
Clear visual explanation of the Great Artesian Basin and groundwater. (Australian Department of Environment)
https://www.youtube.com/watch?v=oI3QI5SRBFY

Web tool: Groundwater Explorer
Australian Bureau of Meteorology's national groundwater information site for government, industry and the general public to use for decision-making and research, including the Australian web tool to find your local groundwater.
http://www.bom.gov.au/water/groundwater/index.shtml

Lessons, Information & Videos: Precipitation Education
Water in the Hydrosphere, Geosphere, Biosphere, Atmosphere.
http://pmm.nasa.gov/education/lesson-plans/water-earths-hydrosphere

Video: The spontaneous self-assembly of dendrimeric surfactant molecules in water. (1min6secs)
https://www.youtube.com/watch?v=lm-dAvbl330

Video: Animation of fatty acid formation. (1min24secs)
Some scientists have proposed that hydrothermal vents may have been sites where prebiotically important molecules, including fatty acids, were formed.
http://exploringorigins.org/fattyacids.html

Infographic: Water for food
A poster showing some examples of embedded water in food and our future needs (UN water)
http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/water_for_food.pdf

Information and Videos: National Groundwater Research and Training Australia
http://www.groundwater.com.au/pages/what-is-groundwater

Career and Research Case Study

STELR Career Profile Questionnaire

Name **To be completed in the local context**

Job title

Who do you work for?

Where is your job based?

What does your job involve?

Why did you choose to work in this sector?

What is the most rewarding part of your current job?

What has been one of your recent achievements?

What is the most challenging part of your current job?

What do you hope to do in the future?

What are some of the benefits of your job?

What training did you have for this job?

- Upper secondary school
- After secondary school

Why is science (and mathematics) important in your job?

What career advice would you give to school students interested in a similar career?

Unit 2: Just add water – economy and equity

Unit Summary Guide

<table>
<tr>
<td>The Big Science Idea
Students will learn that the real cost of water considers everything involved in water consumption and production. This is often inequitable across the globe, particularly between majority and minority world countries.</td>
<td>Scientific Discussion Questions
• What costs (environmental, economic and social) are there in ensuring you have clean and safe drinking water on tap at your home?
• How is the production of your school shirt dependent on water?
• The world's population is projected to grow from 7.4 billion people in 2016 to 8 billion in 2050, how will we have enough drinking water and will it be shared fairly across all countries?</td>
</tr>
<tr>
<td>Scientific Vocabulary
• Virtual (or embedded) water – water used to produce and process a commodity or service.
• Water footprint – measurement of virtual water along the full production and consumption chain.
• Transboundary water - surface or groundwater that is shared across states or countries.
• Sustainable Development Goals - intergovernmental aspirational goals with targets to end poverty, protect the planet and ensure prosperity for all.</td>
<td>Student Scientific Challenge
4. What is the urban water cycle system; raw water to waste water? Design and build a functioning potable water distribution system, from the water storage dam to the houses.
5. What is the real cost of collecting your daily water? Set up an experiment to physically calculate the cost to you.
6. The water footprint is the clue to solve this investigation! Make paper from recycled paper measuring all the water used throughout the whole of production i.e. blue and grey water footprint.</td>
</tr>
<tr>
<td>Real Life Relevance
Whole class discussion questions:
• What are their questions and understanding elicited by this Unit?
• Why is developing understanding about the content in this Unit relevant to their lives?
• How were science and maths integral to their learning?

Science concepts:
• Water is critical and integral to the production and consumption of our food, goods and services.
• International trade creates a global water footprint.
• Our water footprint is governed by the choices we make and the actions we take. And these choices and actions are not equitable in all nations.
• Whilst access to healthy water is considered a human right it is not equitable in all nations.</td>
<td>Challenge Equipment List
Challenge 4:
Pipes and joiners
Plastic boxes of various sizes (with holes)
Spray bottle

Challenge 5:
Tape measure
Water bottles 2L
Activity tracking device

Challenge 6:
Scrap paper e.g. used newspaper, wrapping paper and office paper.
Blender
Big flat tray
Paper making frame and drying boards
Kitchen strainer
Sponge
Large measuring jug 1L</td>
</tr>
</table>

Background Scientific Information

This unit focuses on not just the economics of water but also the issues of equity surrounding access to water (especially for drinking). Students will learn and understand that water consumption and production across the globe is often inequitable which is particularly evident comparing majority and minority world countries. The concept of virtual water is an important understanding that underpins many social, economic and environmental issues. The Sustainable Development Goals offer an international momentum, agreement and means of addressing many of these issues.

Virtual Water

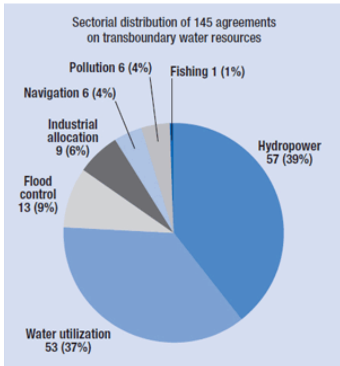
- Virtual (or embedded/embodied water) is the water needed to produce and process a commodity or service. It refers to the volume of water consumed or polluted for producing the product, measured over its full production chain. If a country imports/exports such a product, it imports/exports water in its virtual form.
- In most minority world countries governments are advocating demand management, ways to reduce water consumption and the demand on our water sources. This includes: education; enforcement (water restrictions or building regulations); engineering (leak detection); economics - financial incentives (water pricing) and encouragement (rebates for water efficient taps, toilets etc.) Also governments look for new water sources, seeking options to increase water supply. However they generally don't consider the global dimension of water management (saving water by importing low virtual water products).

Water Footprint

- A water footprint is a measure of the amount of water consumed to produce goods and services along the full supply chain. This measurement includes the virtual water of goods that are produced in one location and consumed elsewhere.
- The water footprint is considered from two perspectives: production and consumption.
- Water footprints encompass the virtual water content of production of goods and services which includes the type of water being used (blue, green, grey).
- Green water footprint – measures the amount of rainwater required (evaporated or used directly) to make a product. It includes the total rainwater evapotranspiration (from paddocks and plantations) plus the water incorporated into the harvested crop or wood.
- Blue water footprint – measures the volume of groundwater and surface water required (evaporated or used directly) to make a product. It also includes water extracted from surface or groundwater in a catchment and returned to another catchment or the sea.
- Grey water footprint – measures the amount of freshwater required to mix and dilute pollutants to maintain water quality (to a Country's acceptable standard) as a result of making a product.

Transboundary Water

- Transboundary water refers to sources of freshwater that are shared among multiple user groups. This may include diverse values and different needs associated with the water use. In this context, water crosses economic, legal and political boundaries.
- Over 90% of the world's population share a river or lake catchment with another country. Throughout the world there are 276 transboundary lake and river catchments that cover about 50% of the Earth's land surface but account for about 60% of the world's flow of freshwater.
- Transboundary water may involve trading and can be a source of cooperation or conflict e.g. Cambodia, Laos, Thailand and Vietnam have cooperated (since 1957) through the Mekong River Commission and a framework for the Nile River Basin, (home to 160 million people and shared among 10 countries), was agreed in 1999 in order to fight poverty and spur economic development in the region by promoting equitable use of and benefits from, common water resources.



http://www.un.org/waterforlifedecade/transboundary_waters.shtml

Source: http://www.un.org/waterforlifedecade/transboundary_waters.shtml

Sustainable Development Goals

- The world's population is projected to grow from 7.4 billion people in 2016 to 9.7 billion in 2050.
- Access to safe water and sanitation is recognised as a *human right.*
- Freshwater is a scarce resource. Its annual availability is limited and demand is growing. Freshwater resources need to be considered in a global context as they are subject to global changes and globalisation (for instance, water footprints as well as transboundary aquifers).
- Water for irrigation and food production use about 70% of global freshwater (including groundwater).
- Global population growth predicts 2-3 billion more people in the next 40 years, plus changing diets, will increase food demand by 70% by 2050.
- At the United Nations Sustainable Development Summit on 25 September 2015, world leaders adopted the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDG). SDG 6: Ensure availability and sustainable management of water and sanitation for all. This includes:
  - 6.1: By 2030 achieve universal and equitable access to safe and affordable drinking water for all,
  - 6.4: By 2030 substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity,
  - See also 6.2 to 6.6 and 6.a and 6.b at *http://www.un.org/sustainabledevelopment/sustainable-development-goals/*

Scientific Questions - Answered

- **What costs (environmental, economic and social) are there in ensuring you have clean and safe drinking water on tap at your home?**

The cost of water varies greatly in different regions and countries depending on lifestyle choices, availability and source. As water is seen as a human right it is often overexploited and undervalued.

Collecting rain from your roof in a tank seems cheap but the real cost includes the raw materials, production, delivery and installation of the tank too. Water treatment plant costs include workforce, infrastructure, chemicals and energy. These will involve a dollar amount but also the social and environmental costs. Yarra Valley Water found that each cubic meter of water conserved delivers $6 through avoided damages to the environment. *Source: http://www.trucost.com.*

Communities without pipe distribution systems have another suite of cost for collecting their water; in wasted time and income, ill-health, lost productivity and degraded ecosystems.

- **How is the production of your school shirt dependent on water?**

Let's assume the school shirt is made of cotton. The production of a shirt therefore depends on growing the cotton plant with water and then using more water in the factory that makes it for washing, dying, cooling, cleaning and managing waste water. With pressure on global water supplies and a focus on environmental sustainability there is a growing recognition that our impacts on freshwater systems can ultimately be linked to our consumption through the concept of a water footprint. A water footprint is a measure of the amount of water consumed to produce goods and services along the full supply chain. Water footprints encompass the virtual water content of production of goods and services which includes the type of water being used e.g. blue, green and grey.

Cotton is mostly grown in drier regions, with big plantations and using irrigation, often from large water storage dams. Its green water footprint measures the amount of rainwater that is stored in the root zone of the soil and evaporated, transpired or incorporated by the cotton plants. Its blue water footprint measures the volume of surface water or groundwater required to irrigate the cotton plants. Its grey water footprint measures the amount of freshwater required to mix and dilute pollutants (factory wastewater) to maintain local water quality as a result of the shirts production. One study states: "For the period 1997–2001 the study shows that the worldwide consumption of cotton products requires 256 Gm^3 of water per year, out of which about 42% is blue water, 39% green water and 19% dilution water." *Source: www.sciencedirect.com*

- **The world's population is projected to grow from 7.4 billion people in 2016 to 8 billion in 2050, how will we have enough drinking water and will it be shared fairly across all countries?**

In 2015 at the United Nations Sustainable Development Summit, the 2030 Agenda for Sustainable Development was adopted. This includes a set of 17 Sustainable Development Goals (SDG). Goal 6 says "Ensure availability and sustainable management of water and sanitation for all". Rivers, aquifers and catchments extend over country boundaries and food and goods are internationally imported and exported so our water supplies are shared and moved around the world. These two factors provide a global focus for water equity planning and management.

In developed countries water management considers the water cycle as a whole; combining planning for all the elements of government water services i.e. drinking water, sewage, waterways, catchments, stormwater and groundwater. This integrated approach aims to provide more sustainable economic, social and environmental outcomes. While new water sources are considered for increasing supply to match increasing demand, governments also have a focus on using existing supplies more efficiently through water sharing, education, financial incentives, new technologies, pricing and regulations.

At a local level sustainable water use includes actions for water conservation and protection. Through our individual behaviours and choices, we can make a difference for water availability and quality in our catchment; today and for the future.

Sample Student Answers

- **What costs (environmental, economic and social) are there in ensuring you have clean and safe drinking water on tap at your home?**

"The cost to ensure that we have safe clean drinking water is most certainly not cheap. Now that we are consuming and using more water we are becoming more limited to our access to water in general. Therefore more processes are taking place to filter non consumable water and this costs a lot". Year 9
"Greenhouse gases, money and workers." Year 9
"Environmental: the emptying of water table and clearing land. Economic: people make large profits from bottled water and sewerage treatment is expensive. Social: recycled water is not socially accepted and people think that bottled water is 'cleaner'." Year 9

- **How is the production of your school shirt dependent on water?**

"The production of our school shirt is water dependent because they need to be cleaned. Year 9
Cotton is grown (dependent on water). It is then shipped overseas, produced over there and shipped back (needing more water)." Year 9
"The dyes and material used to make them; all use water in their creation process." Year 9

- **The world's population is projected to grow from 7.4 billion people in 2016 to 8 billion in 2050. How will we have enough drinking water and will it be shared fairly across all countries?**

"By building more water treatment plants." Year 9
"We have to lower our water consumption." Year 9
"I think the world's drinking water will be recycled water in 2050." Year 9
"I don't think we will have enough water for everyone because many people in developed countries are greedy and use far more water than is necessary. The resources in this world are never used fairly and we are already struggling to support peoples demand for water." Year 9
"Desalination, bore water and getting rid of "third world countries" so everyone is equal." Year 9
"The planet cannot handle that many people; water may become a valuable commodity." Year 9

Challenge Support Information

Challenge 4: What is the urban water cycle system; raw water to waste water?

Science Background Information
In urban regions the main water source will often be a storage dam with a nearby water treatment plant to clean the water. Pipes distribute the potable drinking quality water throughout the region to town storage tanks called reservoirs. More pipes bring this to the homes and business. Consumption is measured with a water meter as it enters each property.

In minority world countries, urban water management considers the water cycle as a whole; combining planning for all the elements of government water services i.e. drinking water, sewage, waterways, catchments, stormwater and groundwater. This integrated approach aims to provide more sustainable economic, social and environmental outcomes. While new water sources are considered for increasing supply to match increasing demand; governments also have a focus on using existing supplies more efficiently through water sharing, education, financial incentives, new technologies, pricing and regulations.

Urban waste management includes sewerage treatment plants with at least three treatment processes and then often finishing dams with reeds and other plants to further clean the water before it is released back into a creek or river or sent to sporting ovals, golf courses and tree plantation for irrigation. In some places it becomes part of the recycled water system and is stored in dams or aquifers, undergoes more treatment and is blended with other potable water. The final water quality will dictate how the water can be used.

Throughout the urban water cycle there are many costs including workforce, infrastructure, chemicals, energy, raw resources and the environmental impacts ensuing from all these activities. As more raw water is needed, new sources are planned and developed e.g. a dam or a desalination plant. Communities often become involved in consultation with the water authorities because of the social, environmental and economic costs.

Pre-investigation

This challenge starts as an exploratory investigation but after the system is built can be then **conducted as a fair test.**

Safety – pipes may leak a little, so be prepared for spills.

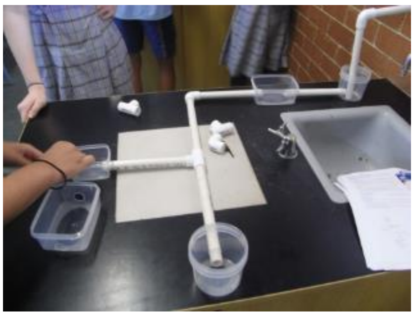
Discussion may arise from students who are not connected to the urban water supply. The equipment provided for this Challenge would work for rural students with families that manage their own water supply e.g. rain water, tanks and dams and a small-scale sewage disposal system (septic system). However if the School is on the urban water supply it would be important for them to investigate that water system.

During investigation

Firstly, students are asked to build the system**.**

Secondly, they can conduct a fair test. Students could measure:

- the angle needed for a constant flow.
- time it takes to reach the house.
- the percentage the dam needs to be full to get enough water pressure to flow.
- the amount that reaches the house etc.



Thirdly the students are asked to:

1. Draw a map of where the wastewater goes, eventually making it back to the water storage dam.

This would be a labelled diagram in their student booklet that maps what they have built and then the steps involved in waste water treatment, piped into the environment and entering the water cycle once more e.g. sewerage treatment plant – cleaned water piped to local creek – flows into a river – river flows into the sea – evaporation from the creek, river and ocean – condensation – precipitation – filling the water storage dam.

2. Then label environmental, social or economic costs involved in this urban water supply system.

Environmental costs include:

- Damming a natural waterway results in changed ecosystems e.g. flow and sediment, changes to aquatic animal movement and water stratification.
- Mining the materials (e.g. alum and sand) used in the treatment plants.
- Transportation (large trucks on roads) of materials to and by-products from the water treatment plants (sludge often used as fill).
- Land clearing needed when installing treatment plants, pipes and other infrastructure.
- Altered flow and changed water quality, from treated wastewater into creeks and rivers.

Social costs include:

- Loss of natural amenity, recreation or access depending on the infrastructure or in other parts of the catchment and waterway.
- Cost of water.

Economic costs include:

- The workforce involved in all aspects of the urban water supply.
- Sourcing raw materials for building and maintaining the infrastructure.
- Chemicals and other raw materials used in the treatment processes.
- Energy needed to run the treatment plants.
- Removal and disposable of by-products from the treatment process.

Post-investigation

A reliable potable water supply for any region is seen as a community asset. Therefore discussion about the advantages and privileges from living in a community with this urban water supply system is important. This would include our individual responsibility for taking action and making choices for water conservation and as a sustainable water user. Challenge 5 investigates the real costs of collecting water in countries without an urban water supply system that will compliment Challenge 4 and help inspire and inform the whole class discussion on global water access and equity.

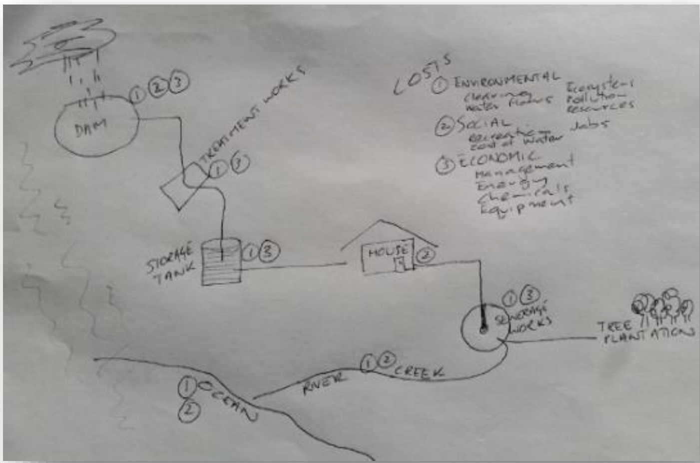
Sample Student Report

Challenge 4: What is the urban water cycle system; raw water to waste water?

Investigation: This Challenge is an exploratory investigation.

Method*:*

1. Choose boxes to suit the different parts of the urban water cycle i.e. dam, treatment plant, reserviour and house, plus pipes.
2. Put our system together.
3. Rain in the dam and observe and monitor results.



Observations*:*
We changed the sizes of the boxes as we went along. One of the joiners made a good water meter for the house. The water movement changed depending on where we put the boxes, using the windowsill worked well to get gravity to move the water better through the system. Connecting it to the tap gave us a 'storm' but also help distribute the water throughout the pipe system. We used a folded sponge to represent the filtering in the treatment plant. There was a bit of water lost in leakage and the water pooled in some boxes.

Results*:*
Although it was not every efficient our house got some water. Drawing the map showed some of the many impacts just from drinking a glass of water or having a shower.

Evaluation*:*
To make a more efficient system we needed a better seal for the pipes, boxes to create more levels and holes in different places in the different box shapes. But then leakage and pipe breakages are a real problem in real life. If we then ran this investigation as a fair test we would discover more about some of the important elements for water supply to homes like gravity, pressure and volume in the storage tank or dam or keep up the supply.

Reflection:
Creating this complex water supply system got us thinkg about these questions:

- How much energy does it take to clean raw water and clean waste water?
- Does our water supply just use gravity or are pumps needed to get the water to the School?
- How much water does the treatment plant clean a day and send to the storage tanks?
- Would it be better if everyone had a rainwater tank and there was no dam?

Challenge 5: What is the real cost of collecting your daily water?

Science Background Information

It is a human right to have access to clean drinking water. However, billions of people worldwide cannot get clean water as simply as turning on a tap, if at all. Many people in these countries live in remote, rural areas and have to travel large distances, spending hours walking to and from the water source each day. Generally, this is done by women and girls who sacrifice their education and employment opportunities. They carry the water to their homes using buckets or jerry cans. Each litre they carry equates to weight, so it is a balance between what they can physically carry and the frequency of their water collection visits.

Often the water collected is contaminated, either faecally or with other water-related diseases. An example of the impact of this is through diarrhoeal diseases, which accounts for more than 2 million deaths each year, mostly children. Unsafe water and poor hygiene practices account for approximately 90 per cent of these cases.

Clean drinking water for all is a possibility; there is enough fresh water on Earth for this to happen. However, given the current economy and infrastructure, this is not the current situation that is experienced by a large number of people worldwide. Through understanding the inequities in access to potable water, there is opportunity to value, appreciate and conserve this precious resource.

Pre-investigation

Local water source: find out the distance to the closest freshwater source to the school e.g. river, lake, pond, as students may require assistance with this. Students could use either the GPS capability of available digital technology or photocopies of maps could also be used to calculate the distance.

Activity tracking device: set up your device as per instructions. This is also a good time to check if the batteries need replacing.

Appropriate space: students will require a large open space to move around in for this task.

Variables: if this task is done as a fair test investigation, more equipment may be required e.g. containers of various shapes (same capacity, see safety note below), containers made from various materials (i.e. plastic, metal, waterproof fabric).

Investigation type: this investigation can be carried out as either an exploratory task or a fair-test investigation. The exploratory task will allow students to calculate the real cost of water. The fair-test investigation will allow students to observe how changing the variables impacts on the real cost of water. The type of investigation could be decided on by either the teacher or by each student group.

Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are carrying the water back from their water source. The maximum carrying capacity per person should be no greater than 2 litres, so it is suggested that the water bottles used are no greater than 2L capacity.

During investigation

Students are asked to participate in a scenario that requires them to collect water as if there is no water tap in their house or school. They consider the distance, time, energy and physical ability needed to go to their closest water source (e.g. river, lake, dam etc) and bring the water back again.

If not chosen by the teacher, students are asked to decide on the type of investigation: exploratory or fair-test.

Students are asked to use the information they have gathered and their team's knowledge of an average afterschool job wage, to calculate the real cost of collecting water. The investigation can be taken further by calculating the number of kilojoules or calories required to collect the water and therefore, the cost of the food required to replenish the lost energy can be added to the calculation.

Post-investigation

Wash, dry and recycle the materials, then return to the Kit for use by the next class.

Sample Student Report

Challenge 5: What is the real cost of collecting your daily water?

Investigation:

This challenge was completed by our group as a fair test investigation.

- **Independent variable:** the way the water is carried.
- **Dependent variable:** the time taken to carry it.
- **Controlled variables:** amount of water, distance carried.

Method*:*

1. Collect the water containers, tape measures and a stop watch or phone.
2. Fill the container with 1 litre of water
3. Measure 66 metres.
4. Time the water carrier carrying the water in the container with the handle.
5. Write down the time in a table
6. Repeat the walk.
7. Repeat the method but instead of using a bottle for the container, use a tray.
8. Calculate the cost of collecting water using the hourly pay rate of $11.06 per hour.

Observations and results*:*

Trials	Bottle	Tray
Trial 1	75 secs	80 secs
Trial 2	69 secs	82 secs
Average	72 secs	81 secs

We found that it was 9 seconds quicker to use the bottle to carry the water than the tray because our results showed that the bottle took 72 seconds to travel 66 metres where the tray took 81 secs. The first trial was the closest, but in the second trial it was clear which method worked best. The tray required more concentration for us to keep it balanced to stop the water from spilling out. This made it awkward to carry. The bottle was easier to carry because it had a lid so that the water did not spill.

To collect 220 litres of water that is enough for one person's daily water use, it would take 220 trips, which would take 4 hours and 24 minutes. This would cost $48.66. This is much more expensive that what we usually pay of $3.60 per 1000 litres!

Evaluation*:*

If we did it again we would repeat the trial more times to make it more accurate. We would also make the same person carry the water because the person carrying the bottle may have been stronger than the person carrrying the tray.

Reflection:

After doing this investigation our questions are:

- What other containers could we use to carry the water more quickly?
- We would like to design a container to carry water.
- What do we pay for when we buy our water?

I did not realise how far people had to travel to get water and how heavy it is! It has made me realise how lucky we are to have access to water so cheaply but also how unfair it is that people don't have the same access to water that we do.

Challenge 6: The water footprint is the clue to solve this investigation!

Science Background Information

People use water for drinking, cooking and washing but even more is used for growing our food and for making our clothing, cars or computers. The water we don't see also forms part of the total water required or water footprint to make a product or provide a service. This is called virtual or embedded water. Virtual water is the amount of water consumed or polluted for producing the product, measured over its full production chain. If a country imports or exports such a product, it imports or exports water in its virtual form.

The production of paper (including toilet paper, tissues, paper towel, cardboard etc.) requires water, whether it is made from wood pulp or recycled paper products. The amount of water to grow the trees to make non-recycled or virgin paper is called the green water footprint. The amount of water used during production is called the blue water footprint. The water that is used and discarded as wastewater, is called grey water.

Paper production is a water-intensive industry. It is estimated the water footprint for a single piece of A4 paper is approximately 8 litres. This amount accounts for paper being recycled after it has been used. If the paper does not get recycled, the footprint of water would be much greater than 8 litres. About 40% of water used in paper production is saved globally through paper recycling. Moreover, recycled paper has a much lower footprint than virgin paper. In grey water alone, recycled paper creates about 50% less waste. *Sources: http://waterfootprint.org/media/downloads/Report46-WaterFootprintPaper_1.pdf; http://www.springer.com/gp/book/9783319117874; http://www.frost.com/prod/servlet/market-insight-print.pag?docid=JEVS-5N2HR7*

The way forward in reducing the water footprint and virtual water in paper is reliant on tighter government regulations on water use, management decisions and improvements in technology that would enable a closed-loop production system where all grey water is treated and reused with none being emitted into the environment, and increased awareness of environmentally sustainable practices are required. The simplest changes are the behaviour changes made by individuals. Using less paper is a great place to start, as is recycling used paper and purchasing recycled paper.

Pre-investigation

Variables: if this task is done as a fair test investigation, more equipment may be required (e.g. various types of paper products). Use waste paper as appropriate, see safety note.

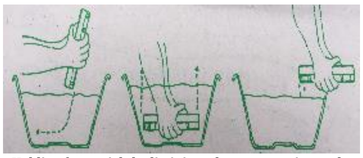
Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are turning their paper into pulp with the hand blender, transferring water to the tubs and measuring the amount of remaining water in the pulp. When sourcing recycled paper ensure that it is from a hygenic source for the students to handle.

During investigation

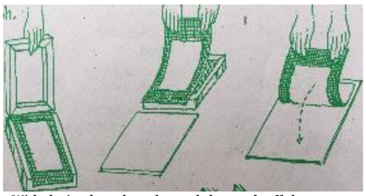
Challenge: Students make recycled paper from used paper following the steps below. They then calculate the water footprint of their student booklet using the data they collect.

***How to make the paper*:**

1. Rip up enough used paper (postage stamp size) to pack full a 250ml beaker.
2. Put it into a tall jug and add 500ml water and blend to a mushy consistency.
3. Pour the pulp into a big flat tray and add 10 litres of water. Mix the pulp and water.
4. Put the 3 parts of the frame together. Start with draining screen, put fine mesh sheet over it and wooden frame on the top to hold it in place.
5. Use the frame to make the paper sheets, one per student – see the pictures (right) or the instructions specific to your device.



Holding frame tightly dip it into the tray, pausing at the bottom. Then take it out but hold on an angle to drip and remove excess water.



With drying board ready, peel the mesh off the screen. Then slowly lower the mesh down onto a drying board. Sponge the mesh and then peel the mesh off leaving the paper behind to dry.

6. Pour the remaining water and pulp through the sieve. Save the remaining pulp and estimate how many more sheets you could have made with that amount of pulp. Do not discard pulp down the drain.

Students measure the amount of water used in the production of the paper (blue water footprint) and the amount of water leftover and the water used in cleaning up this activity (grey water footprint). The green water footprint is not calculated here because this would involve finding out how much water was required to grow the tree/s that were used to make the original paper. We have no way to accurately calculate this during this investigation.

Post-investigation

Wash, dry and recycle the materials, then return to the Kit for use by the next class.

Sample Student Report

Challenge 6: The water footprint is the clue to solve this investigation!

Investigation:

We are going to do this Challenge as a fair test investigation.

- **Independent variable:** the amount of water used.
- **Dependent variable:** the quality of the paper.
- **Controlled variables:** amount of paper, amount of time we soaked and blended for, our method.

Method*:*

1. Collect recycled paper, paper making kit, tubs, strainers, blenders.
2. Follow the instructions given but repeat it 3 times – once using 10L, once using 5L and once using 1L.
3. Once the paper is made, give it a ranking from the best paper to the worst paper.
4. Calculate how much water it would take to produce our 40 page Student Booklet using the 3 different methods.
5. Clean up and put all the resources back.

Observations:

The investigation went well, but we found it difficult to get the sieve into the container when there was less water in it. So we had to kind of pour it over to make the paper; that was a bit tricky, especially when there was only 1 litre of water in the tub. This made the paper a bit lumpy, but we spread it out as much as we could. The paper making frame took a bit of getting used to which is maybe why the paper we made with 10 litres was not very good quality. It was too thin and tore easily.

Results*:*

Name of Judge	**10 litres**	**5 litres**	**1 litre**
Barbara	3	2	1
Geoff	2	1	3
Simone	3	1	2
Result	3	1	2
Student Booklet (40 pgs.)	105 litres	73.15 litres	40 litres

Through our investigation we decided that the paper made with 5 litres of water was actually the best quality. We were not all in agreement though, so we just made an average.

Evaluation:

If we did our investigation again, we would do it better because we know how to use the paper making frame. We would also use some criteria to judge the quality of the paper rather than giving it a ranking. This is so other people could also judge the paper and in our results it is more clear what we are judging the quality of the paper on.

Reflection:

This investigation has made us think about how much water is used in everything, all the objects we use in our everyday life and now we have these questions:

- How much water would it take to make our Student Booklets with non-recycled paper?
- Could we use the grey water to make more recycled paper and reduce the water footprint of our student booklet?
- Do other things we use like pens, pencil cases and computers need water too?

Stimulus or Extension Resources

Information: United Nations – transboundary water
UN information and initiatives for addressing transboundary water.
http://www.un.org/waterforlifedecade/transboundary_waters.shtml

Web tool: USA Water footprint calculator
Easy to use web tool for personal footprint; in gallons and USA example.
http://www.watercalculator.org/complete/

Web tools: Water footprints
Other footprint calculators.
http://www.gracelinks.org/384/water-calculators-around-the-web

Information: Water footprint
Water footprint network - facts & figures, graphs, posters; also in several languages.
http://waterfootprint.org

Web tool: Consumer product gallery
See the blue, green and grey water footprints of coffee, chocolate and other products.
http://waterfootprint.org/en/resources/interactive-tools/product-gallery/

Web tool: national water footprint explorer
See and compare the footprints of different countries and their citizens.
http://production.wfp.fabriquehq.nl/en/resources/interactive-tools/national-water-footprint-explorer/

Video: UNESCO WWAP (6min30sec)
Describes water footprint, including green, blue and grey water and global equity.
http://waterfootprint.org/en/water-footprint/what-is-water-footprint/

Information: United Nations – sustainable development goals
UN SD Goal 6 - facts and figures, targets, stories and links.
http://www.un.org/sustainabledevelopment/water-and-sanitation/

Video: UNICEF water pump rehabilitation project in Sudan (2min)
http://www.thewaterchannel.tv/media-gallery/24-unicef-and-echo-bring-clean-water-to-sudan-s-villa

Information: Report WaterAid: Water at what cost: the state of the world's water (March 2016)
Report and water supply project news.
http://www.wateraid.org/au/news/news/the-high-price-of-water-for-the-poor

Information: Report on the total amount of water required to produce one piece of paper in the Netherlands
http://waterfootprint.org/media/downloads/Report46-WaterFootprintPaper_1.pdf

App: A downloadable interactive Virtual Water application
This App for iPhone provides the virtual water in a range of common products, foods and services
http://virtualwater.eu/

Career and Research Case Study

STELR Career Profile Questionnaire

Name: Nikki Shaw

Job title: Senior Water Engineer

Who do you work for? Arup Singapore. I also consult to World Toilet Organisation (WTO), Engineering Good, World Vision, others from time to time and am a trainer with BushProof.

Where is your job based? Singapore

What does your job involve?
On a day to day basis I carry out design work (calculations, drawings, reports), respond to queries, visit building sites, meet with clients and contractors, manage a small team. It is a mix of technical and managerial work.

Why did you choose to work in this sector?
Really I chose engineering because I wanted to do something useful in the developing world. While I maintain that passion, it turns out it's also quite fun doing useful things in the 'developed' world! Also I like problem solving, and I love spreadsheets ☺.

What is the most rewarding part of your current job?
Having a personal hand in major infrastructure works: seeing my designs forming an essential and real part of fundamental features in the local cityscape (mostly underground train stations and tunnels in recent years); knowing I have worked on infrastructure that is having a very positive impact on the places I live.
At the same time, I am still regularly participating in water and sanitation projects around the region in nearby developing nations which has obvious satisfactions attached. These inevitably have varying levels of success/impact but some have proven immensely rewarding (it turns out – after years in the field – the most satisfying role I can play in developing nations is by training people within those communities in how best to effect water and sanitation improvements).

What has been one of your recent achievements?
I have been responsible for the drainage design for 15 stations and associated tunnels on Singapore's MRT system. While "drainage" doesn't sound very glamorous, when you're building an underground network in a tropical city with frequent torrential downpours, you need to protect your systems from plenty of groundwater, plus potential stormwater flooding which would clearly be devastating!
Speaking of glamorous… In addition, I was technical advisor to WTO as they established their "SaniShop" project in Cambodia and India. This is a programme in which they train local community members to be sanitation promoters, and link them with specially trained and equipped sanitation suppliers who learn to mass-produce affordable toilets: effectively establishing sanitation marketplaces where there were none. It has proven very successful in Cambodia and is expanding in India; it is hugely satisfying to know I have been involved in improving the health and livelihood of countless people.

What is the most challenging part of your current job?
Dealing with authorities who are loathe to deviate from 'what we've done before'. And… working in a very competitive industry, which means seldom having the budget on projects that would give the freedom to really push boundaries in design!

What do you hope to do in the future?
I hope to have a bigger impact in the developing world – perhaps spend less time in the office and more training people in the field.

What are some of the benefits of your job?

The biggest benefit is the people I work with. I swear, engineers are the very best of people: the perfect mix of clever, practical and no-nonsense whilst also being creative and passionate. And full of integrity. Nobody becomes an engineer to become rich; say no more.

This of course contributes to the other benefit: loving what I do. Although there are tedious days, times when things go very wrong, etc, the overall feeling is that I want to do what I do – I am always happy to come to work.

And there's the benefit of being able to work just about anywhere in the world – being in demand, in fact, almost everywhere. I have travelled the world as an Engineer (I have had long-term employment in England, Botswana, Hong Kong and Singapore but in addition I have been on project work – both with Arup and with NGOs or others – in Australia, Bangladesh, Cambodia, China, India, Indonesia, Madagascar, Mongolia, PNG, Philippines, Sri Lanka, Thailand, USA, Vietnam.)

What training did you have for this job?

I went to Pimlico Comprehensive in London, a state school with a very mixed reputation (had police on the doors at various times due to student behaviour but at the same time had some very strong departments [music and art predominantly] and some exceptional teachers: anyone who was self-motivated could excel. The school has since been shut down/demolished.I did 'A' levels in Maths, Physics, English and Art.
After high school, I studied the Engineering Tripos at Trinity College, Cambridge University (Masters degree). I also got a further Masters degree in *Water and Waste Engineering* from WEDC, Loughborough University, through distance learning in later years.

Why is mathematics important in your job?

I use maths on a daily basis as a fundamental part of the design work I do. Less obviously/directly, an overall understanding of maths makes it much easier to estimate what can and can't work when on site and having to make quick and vital decisions.

How do you use digital technologies in your job?

I do most of my work on a computer using spreadsheets, specific software for hydraulics and hydrology, AutoCAD and similar programmes, pdf editing software, Word, Powerpoint etc. Email is my main form of communication although we also have internal and external digital messaging and conference tools. Everything is shared internally on the company Intranet – we are a global firm and tap into expertise all around the world almost daily. (Some projects are done by several offices on different continents.) I avoid using paper as much as I can!

What career advice would you give to school students interested in a similar career?

Basic advice: study maths and physics, as they are requirements. Choose the university that best equips you for the field you want to go into – not necessarily the 'best' overall university, but one that is strong in the engineering field you wish to pursue. Beyond that: have an open, global mind/perspective. Be prepared to push your own boundaries, take risks, be flexible. Always look for opportunities that expand your experiences/expertise. Don't be afraid to ask advice. Do be prepared to make mistakes, own up to them, and help rectify them. Expect to be able to support yourself well but don't expect to get rich ☺. But do expect to have a very fulfilling career.

Unit 3: Water for Life – human biology and ecosystems

Unit Summary Guide

The Big Science Idea

Students will learn and understand the essential role that water plays in our life, from cells, ecosystems to the biosphere.

Scientific Discussion Questions

- Why is water in our body vital for our survival?
- Why is water in ecosystems vital for our survival?
- The biosphere is the parts of earth where life exists: in the ground, on the land, in the water and air. Why is water in the biosphere vital for our survival?

Scientific Vocabulary

- Osmosis - the diffusion of water molecules, from a region of higher concentration to a lower concentration, through a semi- permeable membrane.
- Reverse osmosis - a process that demineralises water by pushing it under pressure through a semi-permeable membrane. (Used in Desalination Water Treatment Plants).
- Ecosystems - interconnected community of living and non-living things
- The biosphere - all the living things on Earth (in the ground, on land, in the air and in water) therefore where all the spheres (geosphere, hydrosphere and atmosphere) interact.

Student Scientific Challenge

7. **Why do cells need water?** Make a simple 3D copy of a single human cell with a zip lock plastic bag as the plasma membrane.
8. **Cell communication: no mobile phone required!** Using a semi- permeable membrane, demonstrate the diffusion of water molecules (osmosis) in cells.
9. **Is this water from a healthy ecosystem?** Identify the macroinvertebrates with a magnifying glass and digital microscope and use the classification chart to help you make your decision

Real Life Relevance

Discussion questions with student:

- What are their questions and understanding elicited by this Unit?
- Why is developing understanding about the content in this Unit relevant to their lives?
- How were science and maths integral to their learning?

Key answer points:

- We are about 70% water and it plays several major functions in our body.
- We rely on healthy ecosystems to filter and replenish our freshwater supplies and therefore have a role to play in improving and maintaining these natural systems.
- Water cannot be seen in one place at one time for one purpose.
- The water cycle links all the spheres in the biosphere.

Challenge Equipment List

Challenge 7:
Laminated picture of human cell
Zip lock bag
Bits to represent cell components: pipe cleaners, interlocking beads, polystyrene balls & other beads

Challenge 8:
Dialysis tubing
Elastic bands to tie off tubing
Small funnel
Large beakers 500ml
Small beakers 25ml
Distilled water
Scissors
Ruler
Salt
Food dye

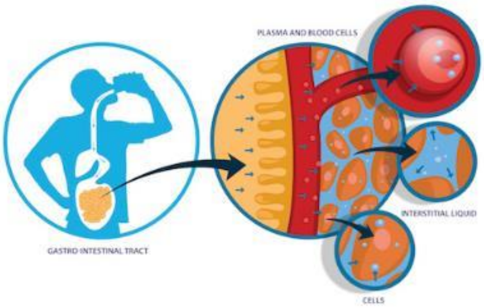
Challenge 9:
Bucket of water with beetles, rocks & reeds from a creek or other waterway. Use a bucket with a lid and the net.
Large low flat tray
Digital Microscope (connected to Lap top)
Wide tipped pipette
Petri dishes
Black rubber rings
Magnifying glasses
Water bug detective guide - ID chart
Field record sheet

Background Scientific Information

This unit focuses on the significance of water to life on Earth and all living organisms. Students will learn and understand the essential role that water plays in life at different scales – from cells to ecosystems to the biosphere.

Water in Cells

- About 70% of our body is water and it serves many essential functions: regulates internal body temperature through sweating and respiration; transports metabolised nutrients and oxygen in the bloodstream; removes bodily wastes; lubricates joints and acts as a shock absorber for the brain and spinal cord.
- About three-quarters of the water in our body is intracellular fluid and the rest is extracellular fluid*,* such as blood plasma, lymph and urine and other bodily fluids.
- Every cell in your body needs oxygen to help it metabolise the nutrients released from food for energy. This cellular respiration oxidises food molecules to carbon dioxide and water.

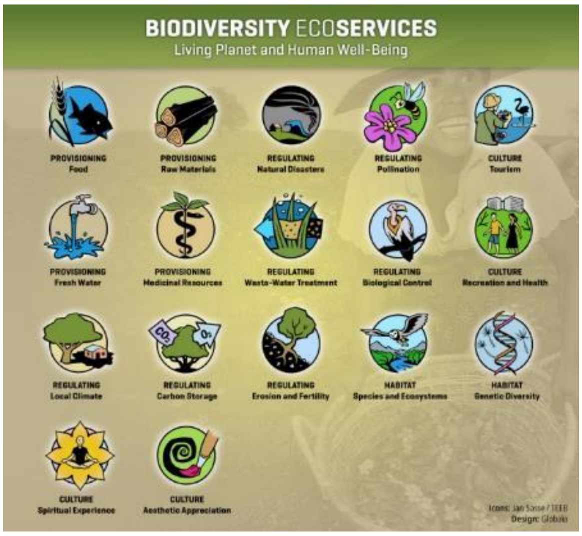


http://www.h4hinitiative.com

- All cells have a membrane that holds the cell together. They let nutrients pass into the cell and waste products pass out.
- Hydrolysis is a chemical process in which a molecule of water is added to a substance, sometimes causing the substance and water molecule to split e.g. large carbohydrates such as starch can be split to form smaller carbohydrates such as glucose.
- Osmosis is the diffusion of water molecules, from a region of higher concentration to a lower concentration, through a semi- permeable membrane. A dilute solution contains a high concentration of water molecules, while a concentrated solution contains a low concentration of water molecules.
- Reverse osmosis is used to convert seawater to drinking water in desalination plants. When pressure is applied to a highly concentrated solute solution (salty water) the solvent (water) will pass through the membrane to the lower concentrated solution, leaving a higher concentration of solute on one side, and only solvent on the other.
- Water is also the major constituent of most foods and this influences their look, taste and structure e.g. 10 to 20% in cereals, 60 to 75% in meat and animal flesh, 80 to 90% in fruits and vegetables. *Source: http://www.azaquar.com/en/doc/water-in-food*

Water in Ecosystems

- Without water there is no life. Water is the single most abundant chemical found in living things. Some organisms live in a dormant state for a long time but come active with water.
- An ecosystem is an interconnected community of living and non-living things. Living organisms are interrelated with soil**,** atmosphere, heat and light from the sun and water.
- Healthy natural ecosystems filter and replenish freshwater, a vital process of the water cycle.
- All freshwater depends on the continued healthy functioning of ecosystems and is an ecosystem service. Water availability and quality for human use, are also ecosystem services.
- A healthy ecosystem has the ability and resilience to maintain its structure and function. This enables it to provide quality ecosystem services for present and future generations.
- The health of many ecosystems is becoming damaged or degraded as the result of stresses associated with human activities e.g. land clearing; the diversion or flow alteration of surface water; increased use (overuse) of surface or groundwater, exotic pests and contamination or pollution.
- Ecosystem stewardship is a key task in environmental sustainability as humans are an integral and interconnected part of healthy ecosystems.

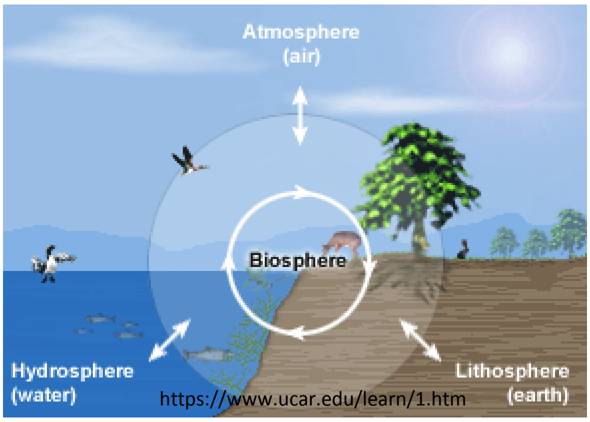


http://www.teebweb.org/resources/ecosystem-services

- In addition to being an important part of human and animal cells, water is also vital for plants. Plant roots absorb water from the soil by osmosis then use it: to carry and distribute minerals and nutrients; as a reactant in photosynthesis; to maintain plant rigidity; to cool leaves and as an aquatic habitat.
- Freshwater contains less than 1 gram per litre (0.01%) of total dissolved salts, seawater is about 35 grams a litre (3.5%) and our blood has 0.9% salt concentration.

Water in the biosphere

- The biosphere is all the living things on Earth and as life exists in the ground, on the land, in the air, and in the water.The biosphere is where all the spheres (geosphere, hydrosphere and atmosphere) interact.
- When it rains, water will either enter the hydrosphere by falling into lakes or wetland or onto the ground and running into creeks (surface water). Water that infiltrates into the soil and rock particles (groundwater) enters the lithosphere. Once this occurs, it is available for the biosphere. Water is released back into the atmosphere through evaporation, transpiration, excretion and respiration and the water cycle continues.



https://www.ucar.edu/learn/1.htm

Scientific Questions - Answered

- **Why is water in our body vital for our survival?**

About 70% of our body is water and it serves many essential functions, it is in our blood, brain, muscles, bones, lungs and cells. The water regulates internal body temperature through sweating and respiration; transports metabolised nutrients and oxygen in the bloodstream; removes bodily wastes; lubricates joints and acts as a shock absorber for brain and spinal cord. We lose water through sweating, excreting and breathing; therefore it is vital we drink regularly to remain hydrated.

- **Why is water in ecosystems vital for our survival?**

An ecosystem is an interconnected community of living and non-living things. All living things need water to survive. Water availability and quality for human use, is considered an ecosystem service as a healthy natural ecosystem replenishes and filters freshwater. Other ecosystem services include: supporting (biodiversity and nutrient cycling); provisioning (pollination, food, hardware and medicine); cultural (sense of place, spiritual and recreational); and regulating (flood, fire, climate and disease control).

The quality of water in many ecosystems is becoming damaged or degraded as the result of stresses associated with human activities e.g. land clearing; the diversion or flow alteration of surface water; increased use (overuse) of surface or groundwater; exotic plants and animal pests and contamination or pollution. Therefore ecosystem stewardship is a key task for us in environmental sustainability, as humans are an integral and interconnected part of healthy ecosystems.

- **The biosphere is the parts of earth where life exists: in the ground, on the land, in the water and air. Why is water in the biosphere vital for our survival?**

The biosphere is where all the spheres (geosphere, hydrosphere and atmosphere) interact. When it rains water will either enter the hydrosphere by falling into lakes or wetland or onto the ground and running into creeks (surface water). Water that infiltrates into porous soil and rocks (groundwater) enters the lithosphere. Once this occurs it is available for the biosphere. Water is released back into the atmosphere through evaporation, transpiration, excretion and respiration, and the water cycle continues.

Sample Student Answers

- **Why is water in our body vital for our survival?**
  "Water is important because it keeps us hydrated and without water we can't do our normal bodily functions like growth, repair, energy production and movement." Year 9
  "Because of how large the role it plays in. Our body consists largely of water." Year 9
  "Water is an all-round regulator." Year 9

- **Why is water in ecosystems vital for our survival?**
  "Without the water cycle we would have major floods and droughts. There would be no plants or food. We would die". Year 9
  "Because water is essential for plants, plants make oyxgen and we breathe in oxygen." Year 9
  "For drinking." Year 9
  " To keep the ecosystems alive and so we can consume more water so we can survive." Year 9

- **The biosphere is the parts of earth where life exists: in the ground, on the land, in the water and air. Why is water in the biosphere vital for our survival?**
  "Everything needs water to sustain them." Year 9

Challenge Support Information

Challenge 7: Why do cells need water?

Science Background Information

About 70% of our body is water and it serves many essential functions: regulates internal body temperature through sweating and respiration; transports metabolised nutrients and oxygen in the bloodstream; removes bodily wastes; lubricates joints and acts as a shock absorber for the brain and spinal cord.

Humans are made of cells and water plays a vital role in the function of the cell. At the cellular level, water is responsible for maintaining cell integrity, carrying nutrients and oxygen into the cell, and waste products out of the cell. Without water, blood would be too thick to flow through blood vessels. About three-quarters of the water in our body is intracellular fluid and the rest is extracellular fluid*,* such as blood plasma, lymph and urine and other bodily fluids. We lose water as waste through our urine, faeces, sweat and even when we breathe out.

Research has demonstrated the impact of lack of water or dehydration on the human body, both at the cellular level and on the entire body. For example, our brains are composed of about 75% water so it makes sense that dehydration can affect our cognitive functions, such as concentration, alertness, choice reaction time and long and short-term memory, and also mood, such as fatigue, confusion and even delirium. This demonstrates how at the cellular level, water is required to send messages via the nerve cells to communicate to the rest of the body how to return to a state of homeostasis. However, as is the nature of science, there is still much that remains unknown about the exact role that water plays in our bodies, especially at the cellular level.

Mitochondria are an organelle that is responsible for cellular respiration. They use oxygen and glucose molecules to make Adenosine Tri-Phosphate (a form of cellular energy also known as ATP) energy for cellular, and therefore, bodily functions. In cases of dehydration, the cell may not have enough fluid to transport oxygen and glucose, which can result in cell death.

Pre-investigation

To build the cell model the students need a variety of different materials to represent the organelles and other cellular components. Craft items such as pipe cleaners and beads, and recycled items such as packaging beans and balls, can be used for this purpose. These may be in the Kit or need to be either collected or purchased. The zip lock bag represents the cell membrane, although it must be emphasised that *the cell membrane is not made of plastic but is a semi-permeable membrane* (lipid/protein bilayer).

Variables: this investigation can be done as a fair test. Ensure there is enough equipment for each student group to have multiple zip lock bags and lots of the same organelles. One example would be changing the number of mitchondrion in the cell and determining the effect this has on the time taken to digest the same number of glucose and oxygen molecules.

Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are filling up their zip lock bags and manouvering the glucose and oxygen molecules to the mitochondrion.

During investigation

Students are asked to create a simple model to demonstrate a 3D model of a single human cell. They can use the cell images as a guide. For students to develop an understanding of the function of water in a cell, they add some small bits to represent the organic molecules or the glucose and oxygen for the mitochondria to digest to produce energy for the cell.

Post-investigation

Wash, dry and recycle the materials, then return to the Kit for use by the next class.

Sample Student Report

Scientific Challenge 7: Why do cells need water?

Investigation:

We will do this Challenge as a fair test investigation.

- **Independent variable:** the amount of water used.
- **Dependent variable:** the time it takes for the molecules to reach the mitochondria.
- **Controlled variables:** same plastic zip-lock bag, same number of organelles and molecules, same person.

Method:

1. Collect 3 x zip-lock bags, the human cell pictures and cell components.
2. Choose what bits and pieces will be used to represent the different organelles.
3. Add the same number of bits and pieces to each of the zip lock bags, using the cell picture as a guide to know how many of each organelle to put in.
4. Label the bags 1, 2 and 3.
5. Add 100mL to bag 1, 200mL to bag 2 and 300mL to bag 3.
6. Add a bit to represent a molecule and time how long it takes to get to the mitochondion. Record the result and repeat this two more times for each bag.

Observations:

We learned that cells need water for distribution of nutrients and minerals. When there was no water in the bag it was difficult to move the bits around. When water was added it was easier to move the parts around. It got easier with more water as the cell held the shape better and didn't flop around. On our last trial with test 3, we added the organic molecule and it was right next to the mitochondria so it very quick! It was clear how the cell uses water to get the molecules to where it needs to go, like the mitochondria.

Results:

Tests	100mL	200mL	300mL
1	20 seconds	15 seconds	10 seconds
2	22 seconds	14 seconds	8 seconds
3	18 seconds	16 seconds	5 seconds
Averages	20 seconds	15 seconds	7.8 seconds

Without water, our cells would not be able to function and each of the organelles would not be able to do what they need to do to keep us alive.

Evaluation:

If we did it again, we would want to find out a way to keep the mitochondria in the same position so that it gives us a fair results about how long it takes for the molecule to reach it.

Reflection:

Our model showed us how important water is for our survival. We didn't realise that cells actually die without it and that is us dying. The questions we have now are:

- What activities cause us to lose water?
- How does water get from our mouths into our cells?
- Is the only way for our cells to get water through drinking it?
- How does drinking alcohol affect our cells?

Challenge 8: Cell communication: no mobile phones required!

Science Background Information

Even though they do not talk like we do, cells are constantly in communication with each other. Cells communicate through the transport of molecules across their cell membrane. This allows them to respond to their environment, to uptake and release molecules that are essential for their function, such as red blood cells obtaining oxygen. Transport across the cell membrane is also important for cellular regulation to maintain homeostasis in the body e.g. greater glucose into muscle cells during activity.

This specialised membrane is composed of a bilayer of lipids (fats) and proteins that allows the movement of compounds both into and out of the cell. This combination of lipids and proteins restricts the movement of most large and or polar molecules, however, water is one of the exceptions. It is a small but polar molecule that can pass through the cell membrane, down a concentration gradient: from a region of high water concentration to a region of low water concentration, across a semi-permeable membrane. Other nutrients can travel across the cell membrane using both active (requires energy) and passive (no energy required) transport.

Unlike plant cells that have a cell wall to prevent over-expansion, animal cells can take in too much water and burst. For example, if the blood contains too much water, the blood cells take in the water in an attempt to maintain the balance in the body. They could take in too much and rupture.

Pre-investigation

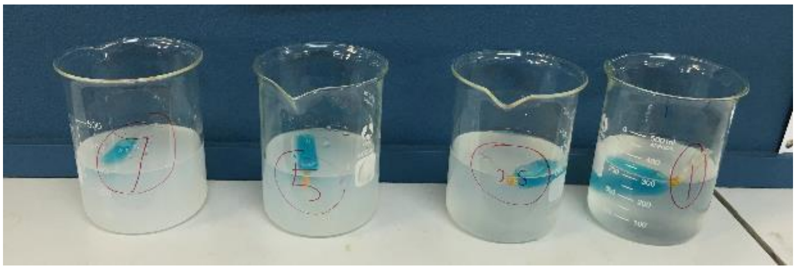
This investigation works well by varying the suggested lesson sequence in the "How to use this module" section. If the investigation is set up during lesson 1 prior to the whole discussion, this allows sufficient time for the distilled water to move out of the dialysis tubing into the saltwater in the beaker therefore creating more visible results. The discussion could start midway through lesson 1 after the investigations are set up and continue into the start of lesson 2 if required.

Variables: this investigation can be done as a fair test. Ensure there is enough equipment for each student group to have enough dialysis tubing, beakers, distilled water and salt for multiple tests with varying concentrations. One example would be changing the concentration of salt in the solution so that students could see the effect of this change on the contents of the dialysis tubing.

The dependent variable: the variable to measure the effect of the change in the independent variable will be determined by the students but ensure appropriate equipment is available e.g. a ruler if the size is used, scales if weight is used, small measuring cylinders if volume is going to be used, stopwatches if time is used.

Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are filling their dialysis tubing.

During investigation



1. Students are asked to use a semi-permeable membrane to demonstrate how water molecules diffuse by osmosis, into and out of cells. **Students prepare** the dialysis tubing as the semi-permeable membrane. Cut a 15cm piece and soak under tap water for 15 seconds. Tie a knot in one end and rub the other end to open it.

2. Students are asked to make enough salt solution to half fill a large beaker. Once prepared, add distilled water with a drop of food colouring to the dialysis tube using a small funnel. Close the top with an elastic band, rinse the outside of the dialysis tubing with tap water. Place it in the beaker with the salt solution. Ensure each test is labelled and set aside in a cool, safe place out of direct sunlight if possible, until the following lesson.

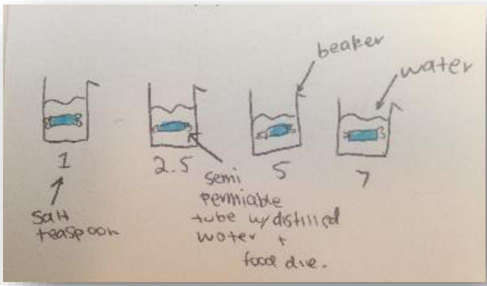
Post-investigation

Ensure students dispose of the dialysis tubing appropriately and wash and dry the other equipment, and return to the Kit for use by the next class.

Sample Student Report

Scientific Challenge 8: Cell communication: no mobile phone required!

Prediction: More water will move out of the semi-permeable membrane that is in the beaker with the highest salt concentration.



Investigation:

We chose a fair test. Our variables are:

- **Independent variable:** the amount of salt in the saltwater in the beaker.
- **Dependent variable:** the amount of water in the dialysis tubing.
- **Controlled variables:** amount of dialysis tubing, amount of water in the beaker and in the tubing, the time we left it for.

Method*:*

1. Collect the equipment – 4 x 500mL beakers, 4 x 15cm strips of dialysis tubing, distilled water, salt, food dye, elastic bands and teaspoon measure.
2. Set up the investigation as shown in the diagram:
    a. Label the beakers A, B, C and D.
    b. Add 1 teaspoon of salt to beaker A and mix with 200mL of water. Repeat this process using 2.5 tsp of salt for beaker B, 5 tsp of salt for beaker C and 7 tsp of salt for beaker D. Keep the amount of water the same, 200mL.
    c. Open the dialysis tubing by rubbing it between your fingers under running water for a few seconds. Tie a knot in one end. Using the funnel and the small beaker, add 20mL of distilled water and 1 drop of food dye. Close the other end of the dialysis tube with an elastic band. Repeat this exactly the same way three more times. Rinse the outside of the dialysis tubing with tap water.
    d. Place the dialysis tubes into the salt solutions at the same time. Leave until the next lesson.
3. Remove each of the dialysis tubes at the same time. Take off the elastic band and measure the amount of coloured distilled water left in the tube. Write down the results.

Observations:

We saw that on the second lesson the salt water in the beakers had changed colour! We thought the tubes might have leaked but then realised that the coloured water had travelled through the dialysis tubing into the saltwater. This is because the tube used is semi-permeable, so the distilled water in the tube could merge out into the salt solution causing the tube to shrivel.

Results:

Amount of salt (g)	Amount of water (mL)
1	19
2.5	17
5	15
7	10

We predicted that more water would move from the dialysis tubing that was in the higher salt concentrations and that is what happened. This is because water always moves from a higher concentration of water to a lower concentration. This is through osmosis and because the salt mixture is less concentrated than the water in the dialysis tubing, the water travels to balance the concentrations.

Evaluation:

If we did our investigation again, we would probably do it twice to increase the validity of our results.

Reflection:

After completing our investigation we have these questions:

- Is water the only liquid that can travel through the cell membrane?
- Is this what happens in our cells when we eat salty food?
- If we go swimming in the ocean, does water move out of our skin cells into the ocean?
- What is the concentration of salt in our bodies?

Challenge 9: Is this water from a healthy ecosystem?

Science Background Information
Freshwater macroinvertebrates are animals that spend all or part of their lives in water. They provide a food source for other animals such as fish, frogs, platypus and birds and include snails, beetles, lava and worms. They have no backbone and are large enough to be seen without a microscope. To assist with environmental monitoring macroinvertebrates have been rated according to their sensitivity to pollution (as shown on the chart in the Kit). Identification and counting of the macroinvertebrates will provide a quick assessment of the site at that particular time.

The Challenge asks about ecosystem health. Ideally this would also involve assessment of the catchment around the waterway. This would include: surrounding vegetation type (native v weeds); surrounding vegetation cover (shade); rocks, logs and water plants (habitat); access by animals or people (bank erosion or contaminants); human made structures e.g. causeways or drains (water flow influence or contaminants e.g. dirt, chemicals or rubbish); and other factors. In place of this you could take photographs of the site, to show the Students.

How to use the Field Record Sheet for the data collection survey
A system has been developed, using aquatic macroinvertebrates, called the Stream Pollution Index (SPI) to score the 'health' of fresh water in rivers or other waterways. 'Pollution' can mean high levels of salinity, turbidity, nutrients (nitrogen or phosphorus) or a decrease in oxygen. A healthy ecosystem would be one where there is a number and diversity of animals, with many from the sensitivity category. If you have enough animals (at least 50) and time, the SPI calculation can be included in the Challenge. This will provide a rating of poor, fair, good or excellent.

Macroinvertebrate field guides links:
www.environment.nsw.gov.au/resources/waterwatch/SnrFieldmanual/20090497SeniorFieldManualSection10.pdf
www.melbournewater.com.au/getinvolved/protecttheenvironment/Documents/Waterbug%20Guide_Online.pdf
http://www.mdfrc.org.au/bugguide/resources/howtouse.htm

Pre-investigation

Collect a sample from your local creek, river, dam, lake or other fresh waterway. Use the dip net to scoop out the beetles and some rocks or organic matter. Sweep the net in a figure of 8 and then transfer the life and organic bits to the bucket of water. Dip the net in different parts of the waterway (e.g. along the edge, in the reeds, under rocks and roots and on the surface) to give you a sample of the aquatic ecosystem. Aim to collect about 50 macroinvertebrates from about 10 meters of the creek.
VERY IMPORTANT: Ensure you look after the macroinvertebrates and return them to the same location.
Set up the digital microscope by installing appropriate software and connecting it to a Labtop and/or Interactive White Board.

During investigation
Pipettes are for carefully moving individual macroinvertebrates from the tray into the petri-dish.
Black o-ring is used to restrict the movement of the macroinvertebrate in the petri-dish for ease of viewing.
Water bug detective guide is used to identify and classify the macroinvertebrates, refer to the information above.
Field record sheet is for recording the survey of the macroinvertebrates identified and calculating the Stream Pollution Index.

Post-investigation
Wash and dry in the sun, the bucket and dip net. This is to ensure next time it is used, (maybe at a different site), you do not introduce any fungi, algae or other microscopic life from one site to another.

Sample Student Report

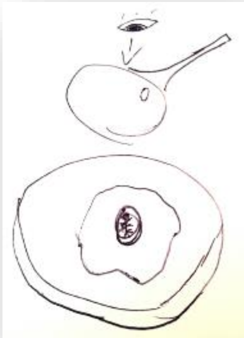
Challenge 9: Is this water from a healthy ecosystem?

Investigation: This Challenge is an exploratory investigation.

Method:

1. Carefully observe bugs using the magnifying glass and digital microscope.
2. Look on the chart to identify them and find out whether they are sensitive or tolerant to polluted water.
3. Use the Field Record Sheet to record and count the types and number of macroinvertebrates we identified.
4. Work out the Stream Pollution Index to get a guide of how healthy or polluted the water is.
5. Decide if this means a healthy or unhealthy ecosystem.

Observations:



Looking at the photograph from the creek site we can see a lawn picnic area, a cow paddock and some trees and bushes along the creek edge. The creek seemed to be flowing fast in some places and slow in others.
In our tray there were small rocks, leaves, some reeds, fine silt and a little bit of mud. These give us a bit more information about what the creek environment is like.
The bugs were using the rocks and leaves in the tray to hide and the freshwater shrimp kept trying to jump out of the petri dish.
It was hard to identify the difference between the water boatman and back swimmer until we looked under the digital microscope to see which way up they were swimming.

Results:

In short it is fair! To start the water appeared too dirty for life but with a closer investigation and as the water settled, it revealed more species living in the water.
We got some very sensitive and sensitive macroinvertebrates but only two types. Then we identified 8 species in the tolerant and very tolerant range.
By sharing results with all the groups doing this Challenge, in total we got 147 bugs from 10 different species.
Our results show the water quality is only fair which means that the creek ecosystem is only fair too and must be affected by pollution. This could be from homes, streets, farms or industries.

Bug type			A	B	C	D
Sensitivity rating	**Taxa richness (bug types)**	**Tick if present**	**Sensitivity rating**	**Number of bugs**	**Weight factor**	**Column A X Column C**
Very sensitive	Stonefly nymph	✓	10	3	2	20
Sensitive	Water mite	✓	6	20	4	24
Tolerant	Whirligig beetle & larva	✓	4	11	4	16
	Freshwater yabby/crayfish	✓	4	2	1	4
	Damselfly nymph	✓	3	5	2	6
	Freshwater shrimp	✓	3	30	5	15
Very tolerant	Water boatman	✓	2	16	4	8
	Freshwater worm	✓	2	15	4	8
	Mosquito larva & pupa	✓	1	12	4	4
	Freshwater snail	✓	1	33	5	5
	TOTALS	10		147	35	110

Calculate the stream pollution index (SPI).*

Step 1: Calculate the SPI = $\frac{\text{total of column D}}{\text{total of column C}} = \frac{110}{35} = 3.2$

Evaluation:

At first it was hard to identify the macroinvertebrates. Then we started looking for features like the number of tails or legs and this helped a lot. The digital microscope helped with identification but it was also interesting to see them close up.
To improve our investigation we could have an excursion to the creek and do an assessment of the environment. This would help us find out more about what the ecosystem is like and what the people living in that area are doing that could affect the water quality in the creek.

Reflection:

Getting a 'fair' results means there must be some pollution getting into the creek, so we have these questions:

- Why was the water quality only fair?
- What human activities are going on in the creek ecosystem?
- How else could we test the water to find out more about its health?
- Do the local people know their creek ecosystem is only fair?
- What could the people living in the catchment do to improve the health of this ecosystem?

Extension Investigations

Water moves through time and space in the biosphere in many ways! Demonstrate one or more processes of the water cycle: capillary action with paper water lilies or set up an outdoor experiment to show transpiration and condensation. Examples:
http://www.abc.net.au/science/surfingscientist/magic.flower.htm
http://www.nuffieldfoundation.org/practical-biology/transpiration-plants
http://www.mhhe.com/biosci/genbio/virtual_labs/BL_10/BL_10.html

Are you really eating or drinking? Determine how much water is in a fruit or vegetable: oranges, apples, carrots, tomatoes and lettuce are all about 85% to 95% water content. Example:
http://www.miniscience.com/projects/WaterinOrange/

Stimulus or Extension Resources

Information: Hydration for health Initiative: Water and hydration: Physiological basis in Adults
Article reviews for scientific evidence on hydration physiology. Includes graphs and images.
http://www.h4hinitiative.com/fr/book/print/68

Information: Institute of Science in Society
Detailed article on the importance of cell water.
http://www.i-sis.org.uk/TIOCW.php

Video: How the cell works (3mins10secs)
Simple description of cell components and their function.
https://www.youtube.com/watch?v=RW7NunH5Oto

Animated slideshow and Video (1min34secs): Diffusion and osmosis
http://www.wiley.com/legacy/college/boyer/0470003790/animations/membrane_transport/membrane_transport.htm
http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Photographs: Cell Image Library
http://www.cellimagelibrary.org

Videos: Live Cell Video collection
http://www.microscopyu.com/moviegallery/livecellimaging/index.html

Web tool: Centre of the cell
3D model of a cell and all its components.
https://www.centreofthecell.org/learn-play/games/explore-a-cell/

Information: Genetics Home Reference
Human cell description.
https://ghr.nlm.nih.gov/primer/basics/cell

Information: UN Human Decade for Water
http://www.un.org/waterforlifedecade/

Information: Ecosystem services
http://www.teebweb.org/resources/ecosystem-services/#.UkLdURaWeRg

Water monitoring guide: Water Watch Field Manuals
http://www.environment.nsw.gov.au/waterwatch/20090497SnrFieldmanual.htm

Information: Research reports and articles
Three articles on hydration and health: http://www.h4hinitiative.com/hydration-and-health

Dehydration and cognitive function:

- Reference: Wilson, M. M. G., & Morley, J. E. (2003). Impaired cognitive function and mental performance in mild dehydration. *European Journal Clinical Nutrition, 57*(S2), 24-29.
  Access: http://www.nature.com/ejcn/journal/v57/n2s/full/1601898a.html?rel=1
- Masento, N.A, Golightly, M., Field, D.T., Butler, L.T., and van Reekum, C.M. (2014). Effects of hydration status on cognitive performance and mood . *British Journal of Nutrition*, 111, 1841-1852. doi:10.1017/S0007114513004455.
  Access:http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9236055&fileId=S0007114513004455

Cellular dehydration:

- Reference: Haussinger, D. (1996). The role of cellular hydration in the regulation of cell function. *Biochemical Journal*, 313 (3), 697 – 710.
  Access: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1216967/pdf/8611144.pdf

Information: Water for health
http://kidshealth.org/en/teens/drink-water.html?ref=search
https://www.betterhealth.vic.gov.au/health/healthyliving/water-a-vital-nutrient

Career and Research Case Study

STELR Career Profile Questionnaire

Name **To be completed in the local context**

Job title

Who do you work for?

Where is your job based?

What does your job involve?

Why did you choose to work in this sector?

What is the most rewarding part of your current job?

What has been one of your recent achievements?

What is the most challenging part of your current job?

What do you hope to do in the future?

What are some of the benefits of your job?

What training did you have for this job?

- Upper secondary school
- After secondary school

Why is science (and mathematics) important in your job?

What career advice would you give to school students interested in a similar career?

Unit 4: Water Farming – water quality and water recovery

Unit Summary Guide

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The Big Science Idea

Students will learn and understand that water can be collected, harvested or recovered. Human behaviour and lifestyle choices will impact water quality and availability.

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Scientific Questions

- Where does your school tap water come from? Has it been clean and treated?
- How would you reply if someone said to you, "*Why should I bother saving water?*"
- The water authority in your local area is proposing to use recycled wastewater. What is your opinion about recycled water? Write an argument to justify a vote <u>for</u> or <u>against</u>!

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Scientific Vocabulary

- Water harvesting and recovery, recycling and reuse – water sources are many and varied. Water can be treated to a potable level, however end use dictates the level of treatment.
- Water quality issues – water quality is affected by inorganic and organic matter caused by human activities and land management practices e.g. oils, soil, detergents, pesticides, herbicides, fertilisers, rubbish, human waste and animal faeces.
- Water treatment –Techniques to clean water include micro filtration as well as sedimentation, clarification, coagulants and flocculation, disinfection, UV, ozone, biologically activated carbon and desalination.
- Water fingerprinting – Techniques to identify water using isotope signatures, bacterial indicators or geochemistry.

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Student Scientific Challenge

10. **Invisible water – how can you harvest water from out of the air?** Build a simple model that turns water as a gas into liquid water.
11. **What if you were out at sea and ran out of fresh drinking water?** Make fresh water from salty water with a plastic bottle and tin can.
12. **Dirty water, would you drink that?** Design and build your own water filter and compare your filters effectiveness to that of the microfilters.

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Real Life Relevance

Discussion questions with student:

- What are their questions and understanding elicited by this Unit?
- Why is developing understanding about the content in this Unit relevant to their lives?
- How were science and maths integral to their learning?

Key answer points:

- Our everyday choices and actions impact water availability and quality, therefore we all have a role to play in sustainable water use.
- Increasing population means more demand for water which is leading water authorities to look for new sources e.g. recycled wastewater, stormwater harvesting and desalination.
- Poor land management practices result in contaminated waterways. This impacts ecosystem health and fresh water availability. Dirty water requires more treatment to make it potable, which in turn has environmental/social/economic impacts.

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Challenge Equipment List

Challenge 10:
Pipes and joiners
Retort stand and clamps
Spray bottle
Shade cloth
Plastic sheeting
Weed mat
Tape and Scissors

Challenge 11:
Plastic bottles - empty
Cans - empty
Scissors
Small beaker 25ml
Refractometer/Pipette & Distilled water for cleaning
Hot water & Heat lamp for non-sunny day
Teaspoon/Scales/Salt

Challenge 12:
Dirty water
Large Beakers 500ml
Katadyn microfilter
SteriPEN - UV microfilter
Turbidity meter and cleaning cloth
Conical flask and powder funnel
Filter making materials e.g. coffee filter papers, charcoal, rocks, wiping cloths, sand & cotton wool.

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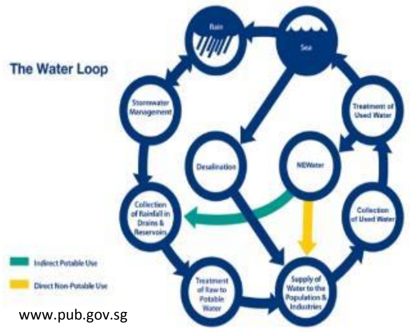
Background Scientific Information

This unit focuses on scientific approaches and technologies (simple and complex) that enable people to harvest and farm water. In particular, water-harvesting approaches are considered depending on the context of the availability and intended water use. Students will learn and understand how their own behaviour impacts water supply and quality.

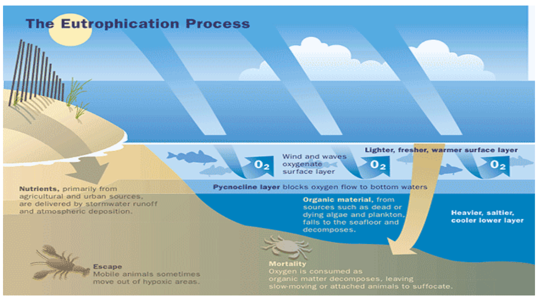
Water harvesting, recycling, reuse, recovery



www.pub.gov.sg

- **Water scarcity and variability** (seasonally or population increases) often leads to innovation in water management.
- **Water can be harvested, farmed, recycled, reused and recovered.** Case studies are a valuable means to investigate innovative approaches to 'water farming' where solutions match the context of the problems (e.g. Singapore '4 National Taps' – the local catchment water, imported water, highly-purified reclaimed water known as NEWater and desalinated water. Alice Springs aquifer mining - treated waste water stored in an aquifer for non-potable reuse).
- **Historic perspectives of water harvesting** e.g. The Mayans from the Yucatan Peninsula of Mexico: archaeologists have uncovered evidence of water management that goes back to at least 800 BC. Because the peninsula is composed mostly of limestone and other soluble rocks, there is almost no surface water. The few lakes and marshes that survive are swampy and not potable water. The only reliable water sources were rain and groundwater. They used a system of caves to reach the water table and cisterns and reservoirs to keep the water flowing.
- **Simple water harvesting techniques** such as the example from Chile (high-altitude area in the Atacama Desert), which has the driest desert in the world, where some weather stations have never recorded rainfall! They catch the fog with giant mesh nets. It drips into pipes that both hold up the nets and act as gutters. The gutters feed the water into a series of pipes and tanks distribute the water to farms.
- **Rainwater is harvested** with roofs, gutters and stored in tanks. Mostly it is potable quality and used throughout the house. In new homes where tank water is required to supplement the town water supply, they have tanks and use this water in the laundry, toilet flushing and outdoors. Factors that influence the water quality are poor maintenance of roof and gutters, atmospheric pollution, animal droppings and roofing material and paints.
- **Stormwater is harvested** in urban areas, collected from stormwater drains and temporarily stored then treated (recycled). It is often used to water public gardens, sports fields, golf courses or parks. It mostly requires less treatment. Australian communities are more prepared to accept stormwater than wastewater, as shown by acceptance of its use in Victoria in the 2000 drought. *Source http://www.atse.org.au*
- **Recycled or reclaimed water** is derived from various wastewater sources and has many uses. It can be treated to a level considered fit-for-purpose from watering public parks to potable drinking water. You can identify recycled water by purple pipes, taps and meters.
- **Water recovery** e.g. On the International Space Station, the Environmental Control and Life Support System recovers and recycles water from everywhere: urine, hand washing, oral hygiene, and other sources. "Yesterday's coffee turns into tomorrow's coffee." NASA Astronaut *Source: http://mars.nasa.gov/*

Water Quality

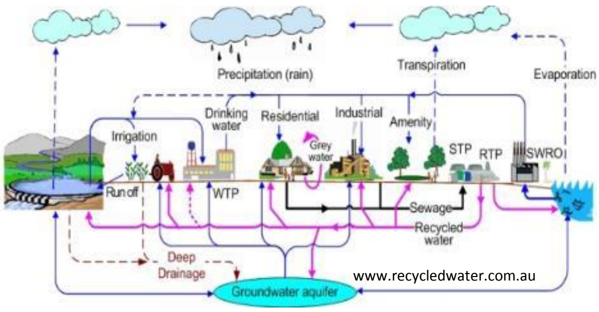


http://www.wri.org/our-work/project/eutrophication-and-hypoxia/about-eutrophication

- **Water is a solvent** that means that water-soluble wastes pollute water easily. As water flows down through the catchment it easily picks up substances, these then wash down drains and into creeks, rivers and the ocean.
- **Healthy water is produced by healthy catchments**. Water quality in our waterways is directly related to land management practices and human activities e.g. riparian vegetation filters water, stabilises soil, reduces erosion, slows water flow, all leading to improved water quality and ecosystem health.
- **Indicators of water quality** can be biological (e.g. macroinvertebrates), chemical (e.g. pH) and physical (e.g. turbidity).

- **Water quality issues** include inorganic and organic matter e.g. oils, soil, detergents, pesticides, herbicides, fertilisers, rubbish, human waste and animal faeces. This can affect turbidity, temperature, light, acidity, total dissolved salts, dissolved oxygen and nutrient levels.
- **Water pollution** can be point source (discharged from a discernible point) or non-point source contaminants.
- **Eutrophication** is the result of high-nutrient loads (mainly phosphorus and nitrogen) and is a major water quality issue. Nutrient sources include urban stormwater runoff, agricultural runoff, domestic sewage, industrial effluents and atmospheric inputs from fossil fuel burning and bush fires. It leads to stratification, hypoxia and algae blooms which in turn lead to fish kills, human illness, ecosystem imbalance, increase of invasive species and biodiversity loss.
- **Pathogenic water pollution** is faecal contaminations including bacteria, viruses, protozoa and parasitic worms.
- **Worldwide clean water figures** state that 783 million people do not have access to clean water and almost 2.5 billion do not have access to adequate sanitation. Globally, one third of all schools lack access to safe water and adequate sanitation. *World Health Organization and UNICEF Joint Monitoring Programme (JMP). (2015) Progress on Drinking Water and Sanitation, 2015 Update and MDG Assessment.*
- **Every 90 seconds a child dies from a water-related disease**. *http://water.org/water-crisis/water-sanitation-facts/*

Water treatment



- **Techniques to clean water** include micro filtration as well as sedimentation, clarification, coagulants and flocculation, disinfection, ultra violet or chlorine disinfection, ozone, biologically activated carbon and desalination. The quality of the source and its catchment will dictate the level and type of the treatment process.
- **At water treatment plants** raw water is treated to a potable level, this includes processes to make it healthy and safe for drinking (i.e. remove microbiological pathogens like giardia); aesthetics (i.e. no colour or smell) and to prevent problems occurring in the distribution system (i.e. prevent pipe build up or corrosion).
- **Large water treatment plants** service large communities. Small or personal filtration systems are available for hiking and outdoors with limited access to clean water; boats at sea for desalination; and household tap filters for rainwater or removal of certain compounds.
- NASA's Johnson Space Centre developed a filtration device to purify wastewater for reuse aboard the International Space Station but it also has application on Earth (e.g. to make potable water from a contaminated water supply). The technology uses acoustics rather than pressure to drive water through small-diameter carbon nanotubes which requires less power than conventional filtration systems; does not depend on gravity for water to flow through the system and can be used for a single filter or a large bank of integrated filters.

Water Fingerprinting

- **Forensic geoscience** is used to determine the source of sediment in watercourses, referred to as water fingerprinting. Soil samples are collected and identified from natural properties such as geochemistry, radionuclides, magnetics and colour.
- **Molecular fingerprinting** identifies and tracks bacterial indictors (*E. coli*). This has been used to evaluate the effectiveness of treatment processes and to access source points of contamination.
- **Chemical isotope signatures** (like carbon or nitrogen) have been used to trace oil spills through the coastal and offshore food web to determine the magnitude of its impact.
- **Chemical clues** can also be used to trace the source of water that entered the ground, the geological material through which the water passed, and the time it took to do so.
- **Temperature is used as an environmental tracer** to measure the exchange of water between groundwater and surface water. Underground the temperature is more stable, while above ground there are changes throughout the day. Therefore it can be used to monitor the water exchange above and below ground.

Scientific Questions - Answered

- **Where does your school tap water come from? Has it been clean and treated?**

This will vary greatly depending on your location. If you are unsure about your water supply contact the School Principal or your local government authority.

- **How would you reply if someone said to you, "*Why should I bother saving water?*"**

Arguments may include: saves money; we share it with plants, animals and ecosystems which in turn provide us with other important functions and services; reduces environmental impacts; it's a valuable resource and should not be wasted; we can't live without it so it is our responsibility to look after it; we share it with others and their need is equal to our need; it is 70% of our body and we would die without a daily intake; it is used to make all our food and goods and . . .

- **The water authority in your local area is proposing to use recycled wastewater. What is your opinion about recycled water? Write an argument to justify a vote <u>for</u> or <u>against</u>!**

This question is about recycling wastewater from sewerage treatment plants. Some countries have no choice and are drinking recycled wastewater e.g. Singapore and Namibia. The treatment plants use a variety of methods to treat it to potable water quality. This often involves many steps e.g. micro filters, reverse osmosis, oxidation and UV light. It is also mixed with a natural supply, treated again, stored in aquifers and dams and blended with other water.

The above techniques are planned reuse with scientific studies, risk management and new technologies. But incidental reuse happens already in two ways. The water cycle recycles the water we currently drink; your cup of tea could contain water molecules from the time of dinosaurs. As these molecules move through time and space they are naturally clean by plants, sand, oxygen and sunlight. As well many people (within countries and across boundaries) share the water from a river and its catchment, using it both for drinking and then for removal of their stormwater and treated wastewater. The river flows on, which means towns downstream draw their water from that same source.

The concerns about drinking recycle wastewater are really about community acceptance. Overcoming the "yuck factor" is about trusting the processes are removing all the latest chemicals and contaminants including "micro pollutants". If we are over consuming, over exploiting, wasting and moving into a new drier climate, do we really have a choice?

Sample Student Answers

- **Where does your school tap water come from? Has it been clean and treated?**

"The river and yes it has been cleaned." Year 9
"The dam and it is filtered." Year 9
"Comes from the sky. Yes and has been treated in a water plant." Year 9

- **How would you reply if someone said to you, "*Why should I bother saving water?*"**

"Because you don't know when you will get another lot of rain. And you need water for a lot of things." Year 9
"I would say that if you don't save water it is bad for the environment." Year 9
"Because there are people around the world that have no clean water and can't get it whenever they want." Year 9
"It's a valuable resource." Year 9 "There is only a limited amount, use it wisely!" Year 9
"Because there are people in the world that don't have clean water and you are just wasting it." Year 9
"You should bother with saving water because there is always someone that is in need of it and wasting it says that you don't care about sustaining our environment." Year 9

- **The water authority in your local area is proposing to use recycled wastewater. What is your opinion about recycled water? Write an argument to justify a vote <u>for</u> or <u>against</u>!**

For: "I believe it would be a good idea because it would be cleaned anyway so does not matter." Year 9
For: "It is still water and we need it to survive." Year 9
Against: "Yuck, I'd rather drink rainwater." Year 9

Challenge Support Information

Challenge 10: Invisible water – how can you harvest water from the air?

Science Background Information

There are many sources and ways of harvesting fresh drinking water. Water harvesting is literally the collection and storage of water for human use; just like the harvesting of a crop of fruit or vegetables. Water is harvested from rainwater, groundwater, floodwater, stormwater, seawater and even from the air, as fog. The most common source of water harvesting is rainwater. It is harvested with roofs, stored in tanks and is mostly of a potable quality. Further information about groundwater harvesting can be found in the Science Background Information for Challenge 3.

Floodwater in some majority world countries is stored in the soil of the floodplain, which has limited potential for use once this water has subsided outside of the rainy or wet season. Wetlands and swamps once stored the stormwater but we now drain these regions to use them for farming and housing. This means losing the ecosystems (both above and below ground) and the vital function they provide. Another option for storage is through using below ground tanks or cisterns. This practice dates back several thousand years and the benefits include reduced water loss through evaporation, less pollution potential and reduced loss of agricultural land compared to using the soil matrix.

Technological advances in the early 21st century have seen water come literally out of the air. Collaborative work by scientists, engineers and researchers from Chile have done exactly that. Chile is a highly elevated, very dry mountain region where there is no rain but regular fog. Instead of harvesting rainwater, they catch the fog with giant mesh nets. It drips into pipes that both hold up the nets and act as gutters. The gutters feed into a series of pipes and tanks distribute the water to farms.

There are a number of conditions that impact the possibility and success of fog water harvesting. Primarily these include: the frequency of fog occurrence, the fog water content and the design of the fog water collection system. As the devices rely on the interaction between wind flow and topography, secondary considerations are those specific to choosing a site for the fog catchers. These include Global Wind Patterns, topography, relief in the surrounding areas, altitude, orientation of the topographic features, distance from the coastline, space for collectors and crest line and upwind locations. (http://www.oas.org/dsd/publications/unit/oea59e/begin.htm#Contents)

Pre-investigation

To build the models, students may need a variety of different materials for water collection, if they choose this as their independent variable. Materials such as netting, shade cloth, plastic, baking paper, aluminium foil and fabrics could be used. These may be in the Kit or need to be either collected or purchased.

A flat tray can be used underneath the models to reduce water spills and leaks.

Prepare pipes by cutting some of them in half lengthways. A variety of lengths will enable students to use this as their independent variable.

Safety: have cloths and mop and bucket ready to clean up spills. These will most likely occur when students are testing their devices using the spray bottles.

During investigation

Students are asked to create a functioning model of this scenario to harvest water from the air through the process of a fair test investigation. **Allow** students time and resources to design and build their models. They can use the example from Chile as a guide and the water mist from the spray bottles to represent the fog.

Post-investigation

Wash, dry and recycle the materials, then return to the Kit for use by the next class.

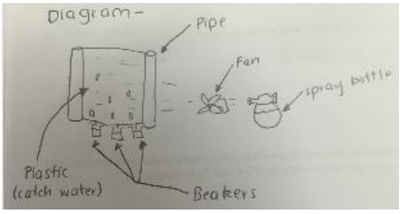
Sample Student Report

Challenge 10: Invisible water – how can you harvest water from the air?

Prediction: We will collect a generous amount of water with our water collecting device.

Investigation:
We did a fair test.
- **Independent variable:** the type of material used to catch the water mist.
- **Dependent variable:** the amount of water caught.
- **Controlled variables:** amount of material, amount of piping used, amount of water sprayed on the water collecting device, the amount of time we let it collect for.

Method:
1. We collected our equipment.
2. We connected the pipes.
3. Then we put sticky tape on the plastic sheet to attach it to the side pipes.
4. Placed the construction on top of a container.
5. Sprayed the device with water and collected it in three beakers at the bottom.
6. We measured how much water we caught.
7. We did the experiment again using shade cloth and then baking paper.

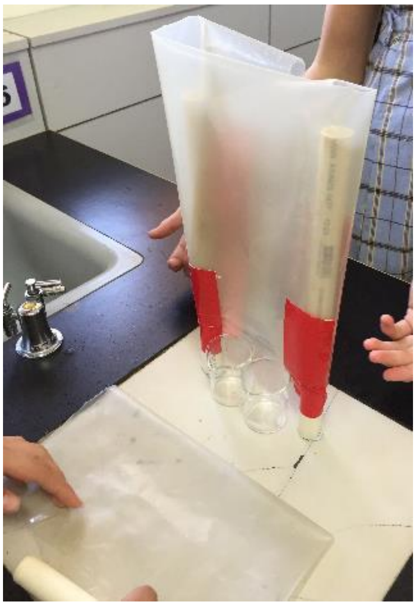


Observations:
We realised that the pipes on the sides were not actually doing anything except for holding the material in place. We also lost of a lot of water in between the beakers at the bottom. The plastic caught the most water. The shade cloth caught the least because lots of the water just passed through to the other side. The baking paper was okay for a while, but then it got a bit soggy. It was difficult to keep the material flat and tight so we ended up holding it in place.

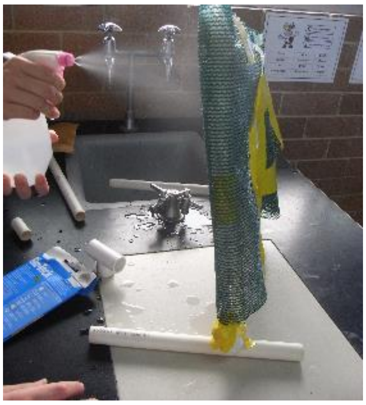
Results:

Material	Amount of water
Plastic	15mL
Shade cloth	4mL
Baking paper	6mL

Evaluation:
If we did our investigation again we would use a half-pipe down the bottom of the material to catch more water in. We would make a stand to hold the device in place. The fan did not really work so we would not use that (note: this has been omitted from the equipment list since this trial). We would measure the distance we sprayed the water from to the material to make sure this was the same each time.



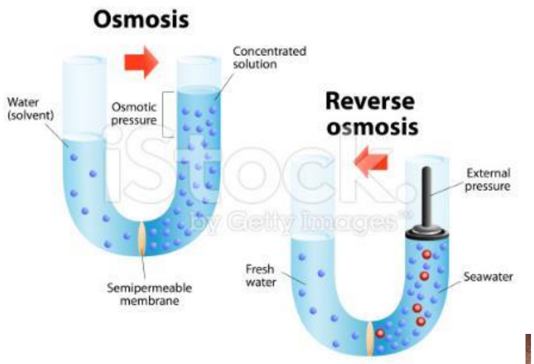
Reflection:
From making our model and doing this activity, we have some questions:
- If the shade cloth collected the least water, why do they use this material for the fog collectors in Chile?
- Is there anywhere that we could collect fog in our area?
- We used water mist, but in Chile they collect fog. What is the difference?
- Do the fog collectors in Chile need a change in temperature, like condensation on the car window in the morning?



Challenge 11: What if you were out at sea and ran out of fresh drinking water?

Science Background Information

Water can be harvested, farmed, recycled, reused and recovered. One case studies of 'water farming' is Singapore. A drink of water there can come from one of the '4 National Taps' i.e. drains and channels in the local catchment; imported water from Malaysia; highly-purified reclaimed water known as NEWater and desalinated water.

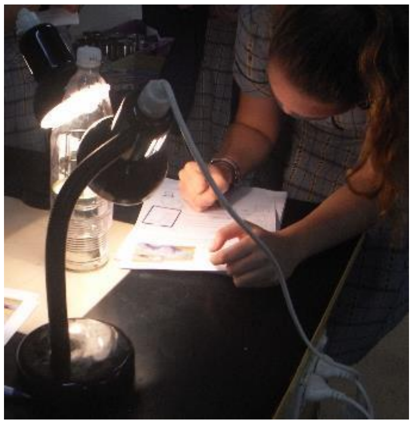


A healthy ecosystem filters and replenishes fresh water. However, it can also be recycled or reclaimed water from a variety of wastewater sources. The quality of the source and its catchment will dictate the level and type of the treatment process.

At water treatment plants raw water is treated to a potable level, this includes processes to make it healthy and safe for drinking (i.e. remove microbiological pathogens like giardia); aesthetics (i.e. no colour or smell) and to prevent problems occurring in the distribution system (i.e. prevent pipe build up or corrosion).

Large water treatment plants service large communities. While small or personal filtration systems are available for: hiking and outdoors with limited access to clean water; boats at sea for desalination; and household tap filters for rainwater or removal of certain compounds.

A desalination plant separates seawater into fresh water (20% to 70%) and a concentrated or brine solution. It requires energy to operate and can use several different technologies. Desalination plants can provide water supplies for large cities (e.g. Australia) and for irrigation (e.g. Spain, United Arab Emirates). One of the processes for desalination is reverse osmosis which requires energy to move the salty water, through the membrane.



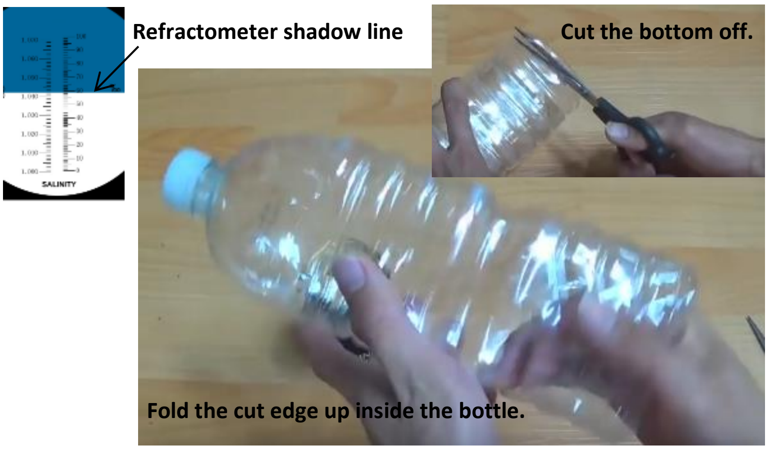
Pre-investigation

- **Collect** empty plastic drink bottles (1.5 litre size is best) and empty tin cans (400mL size or smaller). At least 4 per team for this Challenge.
- **Weather** will dictate your energy source i.e. sunny day or heat lamps. Or both if you like.
- **Variables** can be many and varied, so students need to plan carefully to control the fair test eg size of bottle, size of can, intensity of sun or heat lamp, temperature of water put in the cans, other weather influences, length of time, salt concentration and the amount of water in the cans.
- **Calculating salinity** - A baked bean sized can holds 400mL water; the ocean is 35 grams salt per litre of water and a teaspoon of salt is just under 6 grams, therefore you would need just under 2.5 teaspoons of salt to match sea water. However students may choose to use other concentrations and scales can be used too.

During investigation

To make the collection bottle cut the bottom off the plastic bottle and turn the bottom edge up about 2cm inside the bottle.

Fit the plastic bottle over the tin carefully and remove it carefully, as you can contaminate your result.



Time is needed to achieve a results, from 20 minutes depending on the energy source.

Safety, check how hot the heat lamp is getting**.**

Measuring the salinity with the refractometer means you only need a couple of drops of water produced by this gadget. With a pipette put 2 or 3 drops on the prism to cover the entire surface and close the lid. Hold under light and look for the shadow line. An optimal contrast is obtained by holding the instrument underneath and perpendicular to a light source.

Clean the refractometer with distilled water to avoid contamination and wipe with dry cloth.

Post-investigation

Clean the refractometer with distilled water and dry cloth before packing it away.

Wash well all bottles and cans that you are keeping**.**

Sample Student Report

Challenge 11: What if you were out at sea and ran out of fresh drinking water?

Prediction: If the salt water in the can and bottle is exposed to heat it will begin to evaporate, collecting fresh water in the gadget.

Variables:
Change the heat source, measure the salinity and control the time and salt concentration in the tin.

Method:
1. Conduct a fair test.
2. Dissolve 1.5 tspn of salt into 250ml of water and put in the can x 2.
3. Cut and fold two bottles and fit over two cans of salty solution.
4. Put one gadget outside in the sun and the other inside with lamps.
5. Leave for 20 minutes, then measure salinity of the condensing water from each bottle.

Observations:
Fogged up quicker in sun than with lamps. Then droplets formed inside the plastic and some ran down and were caught in the folded bottle edge. Only made a tiny amount but that was enough for testing.

Results:

Environment	*Salinity*
Salty water	26 to start ppt
Outside (sun) - fresh	1 ppt
Inside (lamp) – fresh	6 ppt

Evaluation:

We sucessfully distilled fresh water from salty water. But it was a little bit hard getting the bottle off the can so contamination would be possible. If we repeated this investigation we would think carefully about the can and bottle size and the level of water in the can. Also did we controll all the variables e.g. weather influences?

Reflection:

After this investigation our questions are:

- Why was there still some salt in the fresh water and would it be safe to drink at this salinity level?
- How do desalination plants on boats work and how much energy is needed?
- How does the refractometer measure the parts per thousand?

Challenge 12: Dirty water, would you drink that?

Science Background Information

Water is a solvent which means that water-soluble wastes pollute water easily. As water flows down through the catchment it easily picks up substances, these then wash down drains and into creeks, rivers and the ocean. Water contaminants include inorganic and organic matter e.g. oils, soils, detergents, pesticides, herbicides, fertilisers, rubbish, human waste and animal faeces. This can affect turbidity, temperature, light, acidity, total dissolved salts, dissolved oxygen and nutrient levels. Therefore water quality in our waterways is directly related to land management practices and human activities.

Turbidity is a measure of the cloudiness of the water due to the silt, dirt and other particles in the water. It is one of the physical water quality monitoring tests and is measured in NTUs = Nephelometric Turbidity Units. It is measured directly with a meter or indirectly with a secchi disc or tube. Turbidity is caused by erosion from animals or people, stirring up by bottom feeders like carp, waste discharge, algae growth and urban runoff. For drinking water it is essential to remove the turbidity to effectively clean it. With the particles you will also remove most of the pathogens, heavy metals or toxic organic compounds. For the aquatic ecosystem turbidity: increases temperature; reduces oxygen in the water; decreases photosynthetic activity of plants and algae, which lowers the oxygen concentration even more; fills in shallow lakes; and clogs animal's gills, eggs or larvae. For waterways the turbidity ranges are: HEALTHY = <10 NTU, FAIR = 10 to 25 NTU and POOR = 25>. The Australian Drinking Water Guildlines requires potable water to have < 5 NTU.

In most water treatment plants coagulants and flocculation will gather together the silt and other particles and the turbidity will be filtered out through a sand bed. Depending on the water source other chemicals will be added to help combine the particles and balance pH, which aids this process. In a healthy catchment riparian vegetation filters water, stabilises soil, reduces erosion and slows water flow; natural turbidity management.

Pre-investigation

Collect or make dirty water. This can be done by adding silt or dirt to water.
Safety – wash hands after handling dirty water. Turbidity does not give you any information about pathogens or other compounds attached to the dirt particles, that could be unhealthy.
Collect filter making materials. These can include coffee filter papers, charcoal, rocks, wiping cloths, sand, gravel and cotton wool. Other materials can be collected and used. A combination of natural and artificial is intended.
Variables can be many and varied so students need to plan carefully to control the fair test e.g. filter materials, layers and quantities; amount and speed of pouring in dirty water; amount of filtered sample collected and dirty water sample (is the bottle shaken each time?).
To build the filter the Kit includes a powder funnel and large conical flask. You can also use an empty plastic drink bottle cut in half, as shown in the photographs.

During investigation

Katadyn Microfilter will remove sediments and bacteria, protozoa, cysts, algae, spores. Inside is a pleated cartridge made with 0.2 micron glass fibre and activated carbon granules. It uses a hand operated pump.
SteriPen filter uses UV light to destroy bacteria, viruses, and protozoa but does not remove sediments. It uses battery power.
Turbidity readings need to be taken immediately as the fine particles will settle and the reading change with time. Also the small specimen bottles can be affected by fingerprints, so must be cleaned each time before they are put in the meter.

Post-investigation

Safety – wash hands after handling cleaning up.
Filter materials can be recycle if possible by drying them out.

Sample Student Report

Challenge 12: Dirty water, would you drink that?

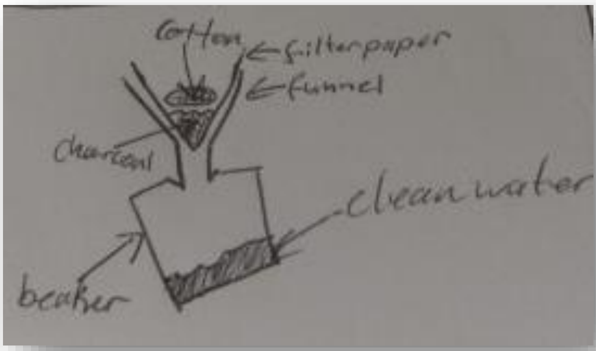
Prediction:
If I build a filter, using some of the materials available, that cleans the dirty water it will be good enough to drink.

Investigation:
Fair test. Change the materials in the filter, measure the turbidity and controll the dirty water source, amount of water filtered and the speed it was poured through the filter.

Method:
1. Conduct a fair test.
2. Build filter with cotton wool, filter paper and charcoal inside.
3. Pour 200ml dirty water in as slowly as possible.
4. Test the turbidity of this filtered water.
5. Build a second filter with coffee paper, 6 pieces of charcoal and cotton wool to cover the charcoal, pour through the same amount of water at the same speed and test this turbidity.
6. Test the turbidity of the dirty water.
7. Use the microfilter pump and then test the turbidity of that filtered water.
8. Compare all the results.

Results:
Yes we would drink the water from the Katadyn filter but not from our filter because it still looks a bit dirty and the guidelines say <5NTU is safe to drink. Our water could be used outdoor e.g. for washing the dog or car and gardening.

Dirty water turbidity	72.4NTU
Filter 1 turbidity	104.2NTU
Filter 2 turbidity	19NTU
Katadyn micro filter turbidity	2.8NTU



Observations:
A filter which isn't constructed properly will increase the turbidity, this happened with our first time and it was important to pour slowly or you could flood the filter. We found that the Katadyn filter worked much better than our filter. By changing the filter layers we got very different results.

Reflection:
After this investigation our questions are:
- What is inside the Katadyn filter that cleans it so well?
- Why does charcoal work when it is black and made from burnt wood?
- What other tests do we need to do to make sure it is really clean enough to drink?

Extension Investigations

Which water is which? Identify unknown water samples by testing for pH, electrical conductivity (salinity) and turbidity.
- Collect a variety of water samples e.g. sea, dam, river, tank, bore and town water supply. Mark these A, B, C etc.
- Use the testing equipment in the Kit to identify the unknown samples.
- Characteristics to help identify: Rainwater has lower pH (6) and no salinity; seawater will be the most salty by far; tap water will have neutral pH (7), turbidity <5 and low salinity; river & dam water will vary from site to site but will have turbidity around 10> NTU.

Stimulus or Extension Resources

Information: Water harvesting with fog catching nets in Chile
Daily news story with photographs.
http://www.nydailynews.com/news/world/world-driest-desert-chile-harvests-water-fog-article-1.1304082

Information: Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean
Chapters 1.3 and 5.2 are specific to fog water harvesting
http://www.oas.org/dsd/publications/unit/oea59e/begin.htm

Video and information: National Geographic Education
Background, questions and vocabulary.
http://education.nationalgeographic.org/media/technology-rainwater-survival-maya/

Video and Information: Recycled Water in Australia
Facts and stories about recycled water.
http://www.recycledwater.com.au/

Case study: Alice Springs "Aquifer mining"
http://www.environment.gov.au/water/australian-government-water-leadership/nwi/case-study9-mining-aquifers

Case study: Singapore "4 National Taps"
http://www.pub.gov.sg/water/Pages/default.aspx

Information: SA Environmental Protection Authority
Monitoring data, human activities, programs and initiatives.
http://www.epa.sa.gov.au/environmental_info/water_quality/threats/human_activities

Information: World Resources Institute
Eutrophication impacts, sources, drivers and solutions.
http://www.wri.org/our-work/project/eutrophication-and-hypoxia/about-eutrophication

Web tool: SEQ Water – Water Island Interactive
An online game to consider quality and scarcity e.g. building dams, water treatment, desalination and water recycling.
http://www.seqwater.com.au/education/water-island-game

Information: Filtering Water with Acoustics Nanotube Technology
https://www.nasa.gov/centers/johnson/techtransfer/technology/MSC-24180-1_Water-Filtering-Device_prt.htm

Information: National Centre for Excellence in Desalination
News, articles and teacher resources.
http://desalination.edu.au/education/education-program/teacher-resources

Information: Recycled water in Australia
http://www.recycledwater.com.au

Information: National Centre for Groundwater
http://www.groundwater.com.au

Information: Groundwater Essentials
Australian Government pdf with diagrams and key points.
http://www.nwc.gov.au/__data/assets/pdf_file/0020/21827/Groundwater_essentials.pdf

Career and Research Case Study

STELR Career Profile Questionnaire

Name **To be completed in the local context**

Job title

Who do you work for?

Where is your job based?

What does your job involve?

Why did you choose to work in this sector?

What is the most rewarding part of your current job?

What has been one of your recent achievements?

What is the most challenging part of your current job?

What do you hope to do in the future?

What are some of the benefits of your job?

What training did you have for this job?

- Upper secondary school
- After secondary school

Why is science (and mathematics) important in your job?

What career advice would you give to school students interested in a similar career?