EARTH AND ITS RESOURCES
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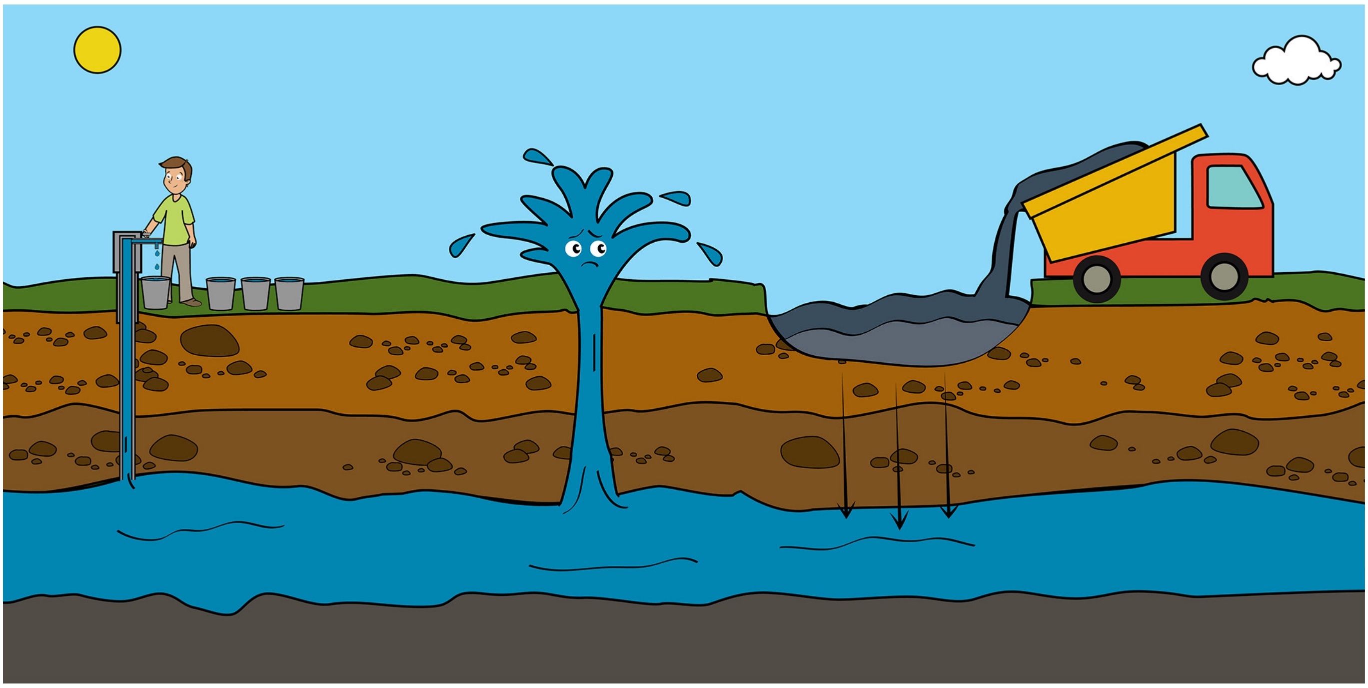

GROUNDWATER: DISCOVERING OUR HIDDEN RESOURCE

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YOUNG REVIEWER:

LAUREL
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Have you ever wondered where the water in your tap comes from? Or why rivers still flow, and lakes can still be full, even when it has not rained for a long time? Or how people can get drinking water from a well in the middle of a dry, hot desert? The answer to these questions may be groundwater! Groundwater is underground, so we very rarely see it, but it is extremely important for billions of people. It gives us water for drinking and for producing food, and it provides habitats for animals. However, groundwater is also facing some big challenges, such as climate change, overuse, and pollution. We all need to do our best to protect groundwater and to spread the word to our families, friends, and governments.

WHAT IS GROUNDWATER?

GROUNDWATER

Water found below the water table in the spaces between rocks and sediments.

If I told you there was such a thing as **groundwater**, you might imagine underground rivers or lakes. Yes, some cave systems do have such things, but more commonly, groundwater is found filling the pore spaces and small cracks in the rocks and sediments beneath the ground surface (Figure 1).

Groundwater is hidden beneath the land surface, so many people do not realize how important groundwater is. In terms of total freshwater volume, groundwater is much more significant than the waterbodies (lakes, rivers, streams) we see on a daily basis. In fact, groundwater represents 99% of the Earth's liquid freshwater (the water not contained in icecaps and glaciers) [1]. Because we have so much groundwater, billions of people rely on it for drinking [2], and groundwater also provides 43% of the water used to grow our food [3].

AQUIFERS

Underground zone of rock or sediment that contains water that can be accessed using a well.

The underground rocks and sediments that contain groundwater are called **aquifers**. The word "aquifer" comes from the Latin language, where "aqui" means "water," and "ferre" means "to carry." Therefore, aquifers carry groundwater. If you dig or drill a well into an aquifer, you can pump groundwater out of the well and use it for drinking, irrigation, or many other uses.

WHERE DOES GROUNDWATER COME FROM AND WHERE DOES IT GO?

RECHARGE

Water added to an aquifer after moving downwards from the land surface. Recharge consists of rainfall, snowfall, or water from leaky rivers or lakes.

Water enters the aquifer (we call this process **recharge**) from snow or rainfall soaking into the soil, or from the water in rivers draining through the riverbeds. As the recharge water moves downward into the ground, it must first move through a zone of unsaturated material, meaning material that is not completely wet (Figure 1). Eventually, the water reaches the aquifer (the saturated zone), where the pores and cracks (usually between rocks, sand or gravels) are filled with water. The boundary between the unsaturated zone and the top of

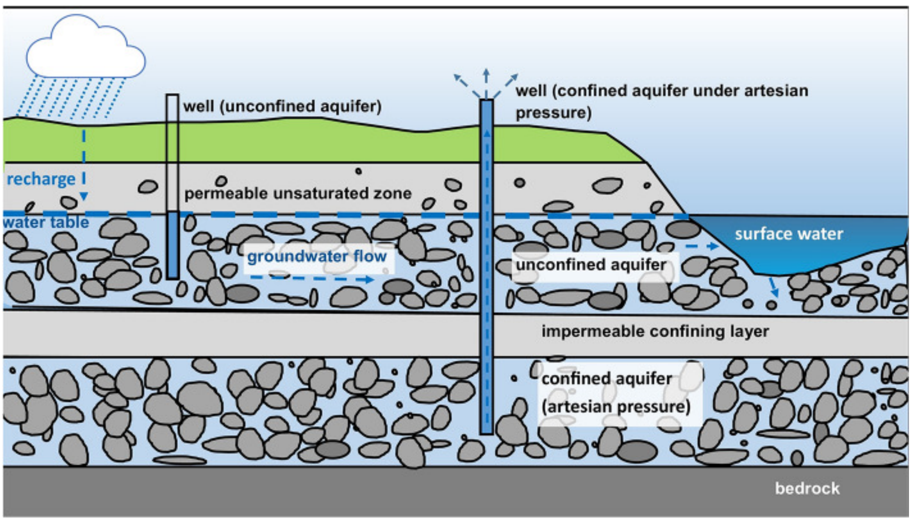

Figure 1

Figure 1

Groundwater is recharged by rainfall and snowfall, and is found in unconfined and confined aquifers, which can be accessed by installing wells. Groundwater can also give and receive water from surface waterbodies.

the aquifer is called the **water table**. The water table can move up and down depending on the season and whether the weather is wetter or drier.

Once the water enters the ground and becomes groundwater, it does not stay there forever. Water can flow back out of the ground into rivers, lakes, or the sea. When groundwater discharges to land, a spring is formed.

ARE THERE DIFFERENT KINDS OF AQUIFERS?

In Figure 1, the top aquifer is called unconfined, because it is not confined (or closed in), meaning the aquifer is open to water entering from the land surface. **Confined aquifers** are closed aquifers, which are underneath an impermeable (water cannot pass through) layer of rock or sediment. Groundwater in confined aquifers is often under pressure, so when a well or spring penetrates the aquifer, pressure is released, enabling water to be forced upwards to the land surface. We call this pressure **artesian pressure**. The word "artesian" refers to the French region of Artois, where wells were drilled into confined aquifers in the tenth century.

HOW DO WE ACCESS GROUNDWATER?

You might be wondering how we access groundwater that may be hundreds of meters deep. Sometimes water can be forced to the surface naturally, as a spring (Figure 2a), or it can discharge into rivers or lakes. However, most of the time, we must bring water to the surface (known as **abstraction**) by digging or drilling wells. A well is a hole or pipe that goes underground until it reaches an aquifer. In unconfined aquifers, a pump is needed to bring the water upwards. In artesian (confined) aquifers, the water will naturally flow to the surface because it is under pressure (Figure 2b).

HOW OLD IS GROUNDWATER?

Confined aquifers often hold water that is older than water in unconfined aquifers. In some confined aquifers, really old groundwater is called **fossil groundwater**. For example, in a confined aquifer in the Great Artesian Basin in Australia (which underlies around 20% of the whole continent of Australia), groundwater can be almost 2 million years old. This means that some people drink fossil groundwater that fell to the Earth (as rain or snow) when mammoths still roamed the Earth!

WATER TABLE

The boundary between the bottom of the unsaturated zone and the top of an unconfined aquifer. The height of the water table can change, depending on recharge rate, abstraction rate, and atmospheric pressure.

CONFINED AQUIFERS

An aquifer with impermeable material above, so that the water is not in contact with the atmosphere. In contrast, an unconfined aquifer is open to the atmosphere.

ARTESIAN PRESSURE

High water pressure in a confined aquifer. Artesian pressure is higher than atmospheric pressure, so when a well is installed, pressure is released, and groundwater is forced upwards above the land surface.

ABSTRACTION

Taking groundwater (usually via pumping). Abstracted water is often used for drinking or irrigation.

FOSSIL GROUNDWATER

Ancient groundwater. Fossil groundwater comes from recharge which fell a long time ago (thousands or even millions of years ago).

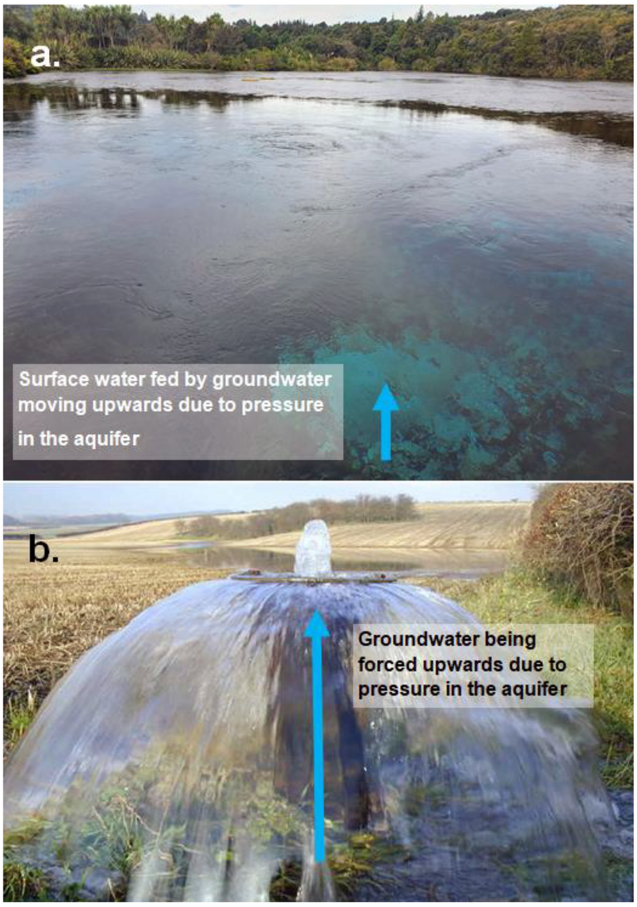

Figure 2

Figure 2

(a) Groundwater feeding a natural spring in New Zealand. **(b)** When springs are not available, we use wells to access groundwater. This example shows groundwater being abstracted from an artesian aquifer. The groundwater is forced upwards and out of the top of the well due to artesian pressure in the confined aquifer. The water from this well is used for growing crops.

WHAT CHALLENGES DOES GROUNDWATER FACE?

Groundwater faces several challenges; including over-abstraction, pollution, and climate change. It is important to be aware of these challenges, so that we can face them:

Challenge 1: Over-Abstraction

We all need water, and, over the past 50 years, global demand for groundwater has dramatically increased [4]. Although groundwater is an enormous resource, in some places it has been abstracted at a faster rate than it has been recharged. This outcome is called over-abstraction, and it can cause aquifers, springs, and wells to become dry. In fact, globally, more than 30% of the world's largest groundwater systems are experiencing a long-term decline in groundwater levels caused by over-abstraction [5]. A lot of the abstracted groundwater ends up in the oceans, and it has even contributed to global sea-level rise [6].

Challenge 2: Pollution

Groundwater can be polluted by human activities like waste disposal, industrial activities, and farming. Common contaminants in groundwater include nitrate, hydrocarbons, metals, and pathogens (bacteria and viruses that can make people sick). At high concentrations, contaminants can make groundwater unsuitable for drinking, they can harm groundwater-dependent ecosystems, and they can make streams and lakes unsuitable for fun activities like swimming.

Unconfined aquifers are especially sensitive to pollution because the water is not protected by an impermeable layer. Confined aquifers are better protected and, because the groundwater is older, it may have been recharged before humans were carrying out polluting activities.

Although humans are responsible for a lot of contamination, some contaminants can occur naturally. Sometimes groundwater is not suitable for drinking. One famous example is in parts of Bangladesh, where millions of people drink groundwater that is contaminated with toxic arsenic that is released naturally from rocks and minerals in the aquifers. In Bangladesh, many people have become ill because of arsenic contamination, so some people remove arsenic from their water using filters, whilst others harvest rainwater on their rooftops for drinking [7].

Challenge 3: Climate Change

Due to climate change, Earth's average temperature is increasing; some areas are becoming drier and other places are becoming wetter. Human behavior will also change in response to climate change. If an area becomes drier and hotter, there will be less recharge to groundwater, leading to lower water tables and less spring flow. Recharge rates already vary between various places due to factors including climate and soil type, so some environments may be more sensitive to climate change than others. Less recharge may also mean farmers have to pump more groundwater to water crops, leading to even lower water tables and less spring flow.

Because of climate change, sea levels are expected to rise in some areas. This can be a problem for groundwater because, in coastal areas, aquifers can be closely connected to the sea. As sea levels rise, saltwater from the sea can mix with the freshwater in the aquifers, causing the groundwater to become too salty to drink. Sea-level rise will also raise groundwater levels in some places, causing increased risks of flooding.

HOW CAN WE TACKLE THESE CHALLENGES?

Protecting groundwater from contamination, overuse, and the effects of climate change is a huge challenge, but one that we can overcome. We should encourage our friends, families, and governments to make changes to the ways we use groundwater, pollute groundwater, and contribute to climate change. Many governments are taking steps to protect groundwater. Some steps include ensuring that abstracted water is not wasted, reducing the use of agricultural fertilizers, improving the management of man-made pollutants, and lowering fossil fuel emissions. However, the process of addressing groundwater problems starts with education and awareness; we can all think about and alter our own activities and lifestyle choices to help limit our effects on groundwater. Groundwater is very precious, and we need to protect it.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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LAUREL, AGE: 10
Hello, I like mechanical engineering and Lego. I like making things and tinkering. I like learning English and science.

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I am a groundwater scientist at Environment Canterbury in Aotearoa/New Zealand. My current work primarily focuses on scientific investigations and ensuring that Canterbury's groundwater quality is protected. I love environmental science, have a Ph.D., in cave geochemistry (University of Waikato), and enjoy exploring the great outdoors. *apearson181@gmail.com

PHILIPPA AITCHISON-EARL
I have been working for over 20 years investigating and reporting on the groundwater resource of Canterbury, New Zealand to fellow scientists, water managers, and the public. Having my own school-age children has inspired me to make the exciting and evolving science of groundwater accessible to all ages.