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THE SOUTH AFRICAN WATER COMPENDIUM

WATER RESEARCH COMMISSION

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Preface

Water is fundamental to our survival. It is a unique and irreplaceable resource. Water security is the foundation of shared prosperity. Clean water is essential for drinking and food production, which are the basis for a healthy, productive life. It is a key input for economic production and growth. Water is also vital for healthy ecosystems.

Yet, the reality in water scarce South Africa is that every day there are communities dealing with water issues, whether it is a shortage of water, or whether it is water that is not of a suitable quality. Climate change, population growth and urbanisation are some of the compounding challenges that are placing additional strain on South Africa's water resources. Those of us fortunate to have access to regular, good quality water gushing through our taps often give little thought about our water resource and how challenging it is to make water available to us.

The South African government cannot achieve a water secure nation without the active participation of its citizens. Communities have valuable insights into local water challenges and provide valuable input to decision-making processes. As residents of South Africa we can play a crucial role in water security by understanding South Africa's precarious water situation, actively participating in water conservation practices, engaging in decision-making processes related to water management and monitoring water quality within our communities. By raising awareness about water issues, citizens can also influence broader community behaviour towards water conservation. Active citizen participation fosters a sense of responsibility and ownership for water resources, leading to more sustainable practices.

This booklet is aimed at raising awareness regarding South Africa's water resources, promoting active participation in water conservation and citizen science efforts, and empowering local communities to engage positively with decision-makers regarding policies and actions to promote water sustainability and responsible water management. It is only by working together that we can achieve a water secure South Africa.

Chapter 1

THE BLUE PLANET – WATER AT A GLANCE

Water is simultaneously the most precious resource on Earth and the most undervalued one – along with the rivers, lakes, wetlands and aquifers that store and supply it. Water lies at the essence of all life on the planet. An essential resource for human survival, water is also at the core of all human development, including agriculture, industry, power generation and social advancement.

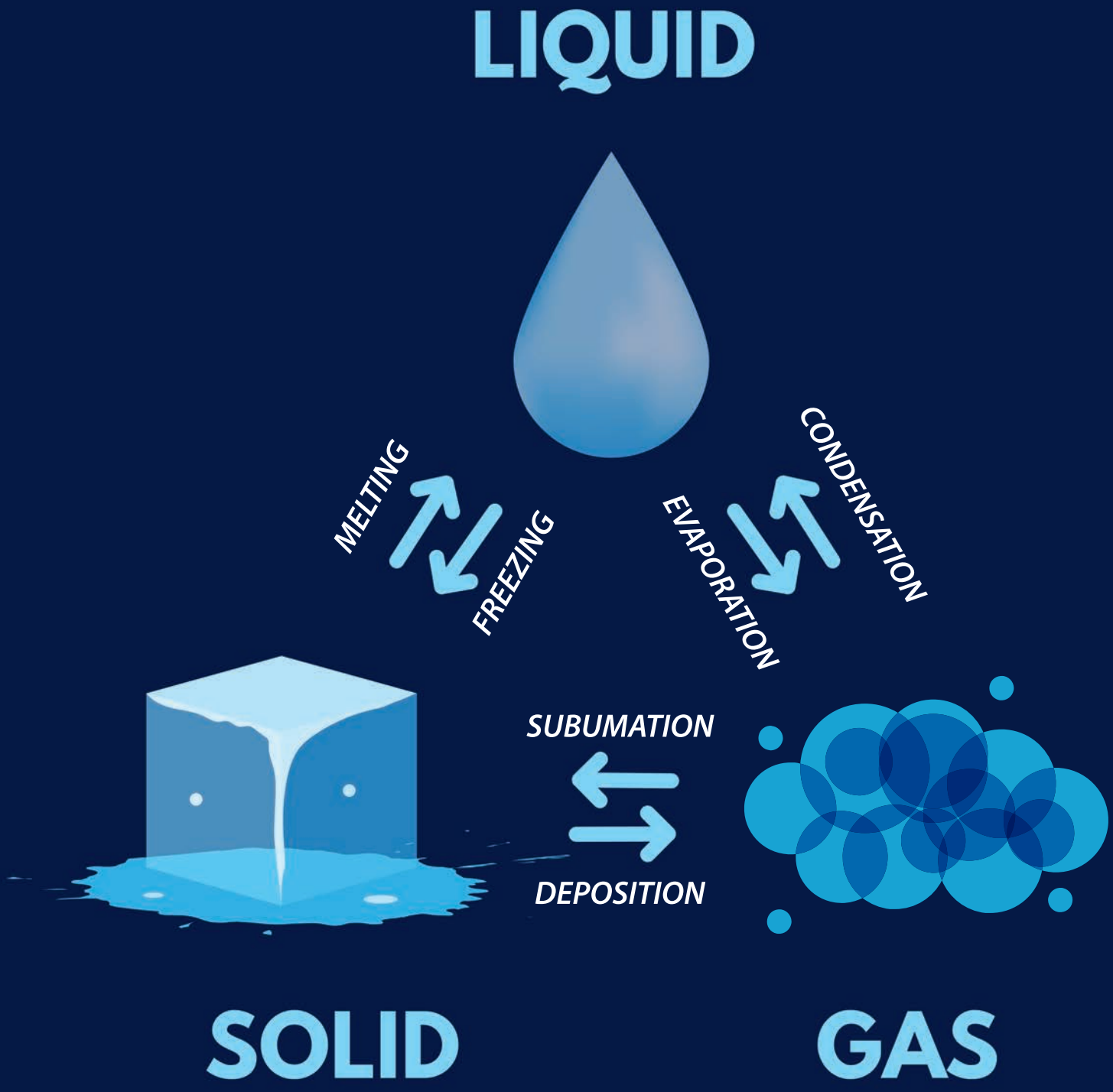
Clean water is vital for the survival of both humans and the natural world. Yet freshwater ecosystems are also the most threatened systems across the globe. Nowhere is the world's biodiversity crisis more acute than in freshwater ecosystems. In contrast to its importance, the volume of water available and suitable to human use is very little. Despite the massive role water plays in our world, it is a surprisingly finite resource. Less than 1% of the world's surface water is covered by freshwater and accessible (as a liquid). Globally, challenges of water availability and quality are causing increasing pressure on people and nature.

WHAT IS WATER?

No one is quite sure how Earth got its water. Scientists believe that either Earth was 'born' with the molecular precursors of water already present or that water-laden space rocks like asteroids and comets brought water here after the planet's formation. Scientists do agree, however, that water is a very interesting substance. For example, water is one of the most versatile materials known, being the only substance that occurs naturally on our planet as **a gas** (water vapour and steam), **a liquid** (liquid water), and **a solid** (ice). It is constantly changing and interacting with its surroundings.

Ice is a type of solid water. Most of Earth's freshwater is ice, locked in glaciers, ice sheets, and ice caps. As ice melts, it turns to liquid. The ocean, lakes, rivers, and underground aquifers hold liquid water. Water vapour is an invisible gas and is not evenly distributed across the Earth's atmosphere.[1] Most water on Earth is saltwater in oceans, and freshwater is locked up in polar ice. Water vapour contributes to air, clouds, fog, mist, and rain. Freshwater is found in rivers, lakes, groundwater, dams, and wetlands.[2]

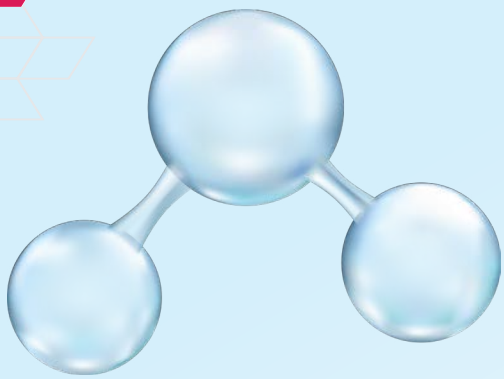
[1] National Geographic. 2023. Hydrologic cycle https://education.nationalgeographic.org/resource/hydrologic-cycle/.
[2] National Geographic. 2023. Aquifers. https://education.nationalgeographic.org/resource/aquifers./



The different states of water

Earth's water is always in motion. It moves below ground, across the surface, and in the atmosphere above. All water on Earth is linked in a vast, natural cycle. We call this the hydrological or **water cycle**.

The term hydrological cycle describes how water is exchanged (cycled) through Earth's land, ocean, and atmosphere. In the process, water as a substance undergoes various transformations, such as melting, evaporation, condensation, and circulation; water never remains static. The water cycle has a direct impact on weather conditions, thereby affecting the climate of a region. (Climate refers to the long-term weather patterns of a particular region, which are influenced by various factors, including humidity and temperature.



THE AMAZING WATER MOLECULE

Water has many remarkable properties. The hydrogen bonds that attract water molecules to each other play a significant role in many of these properties and give water its unique characteristics.[3]

Water is made up of two smaller hydrogen atoms and one larger oxygen atom, and its chemical symbol is H_2O. A lot of energy is needed to break H-bonds when water is heated. Water can transform into different phases due to the weak bonds it forms with other atoms. Individual water molecules may move through the water cycle in a few days or could be in storage as ice or groundwater for many decades or even hundreds of years.

THE DIFFERENT STATES OF WATER

Water is the only substance that occurs naturally on our planet as a gas (water vapour), a liquid, and a solid (ice). Water expands when it freezes, which is unusual for liquids. The liquid phase is one of the most common states of water, and it's also the one we're most familiar with. Water is the only compound that is lighter as a solid than as a liquid.

EXTRAORDINARY PROPERTIES

Water has unique characteristics, such as being odourless and tasteless in its pure form. Pure water has a neutral pH of 7, meaning it is neither acidic nor basic. When water is cooled to about 0°C, it freezes; when heated to about 100°C, it boils.

Water's unusually high latent heat of vaporisation (the amount of energy required to convert water into steam), as well as its high latent heat of fusion (the amount of energy required to melt ice), for example, contributes to the ocean's ability to moderate global temperatures and maintain the moderate ambient temperatures on our planet. Water is also transparent at visible wavelengths, which is why plants can grow under water.[4]

A UNIVERSAL SOLVENT

Water is an excellent solvent, with its charged ions capable of breaking apart and dissolving substances such as salts. Minerals that are dissolved in water help nourish living things, but harmful substances such as decaying animal and vegetable matter, as well as poisonous chemicals, may also dissolve in water. This is why drinking water sources must be tested and treated before we can safely drink it.

[3] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition***. https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/Vanishing%20waters_web_part1.pdf.
[4] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***

WATER SHAPES OUR PLANET

Water is a powerful natural force, constantly changing and interacting with its surroundings. Falling and running water erodes rocks and changes landscapes. Rivers and streams move topsoil around. Glaciers scrape across the landscape, carving valleys in the process. In addition, tides and storms constantly affect our coastlines.

HIGH SURFACE TENSION

Water has a high surface tension, meaning water tends to clump together in drops rather than spread out in a thin film. This is why water drops are, in fact, drops. The molecules on the water surface cling together, small volumes pulling together into drops and larger volumes forming a surface tension 'skin', which is strong enough to support small objects like insects. This surface tension is responsible for capillary action, which allows water (and its dissolved substances) to move through the roots of plants.

WATER AND THE HUMAN BODY

Water is the most abundant molecule in the human body. Each living human cell consists of more than two-thirds water, which acts as a solvent and facilitates the transportation of crucial materials like oxygen into cells. Water also supports all our body's processes and helps in exporting waste products like ammonia and carbon dioxide (CO_2).

Source: Splash - A water source for curious kids[5] ; Vanishing Waters[6] ; American Museum of Natural History ; Groundwater: the myths[7], the truths and the basics[8]

[5] Water Research Commission (WRC). 2018. ***Splash - A water source for curious kids.*** https://www.wrc.org.za/wp-content/uploads/mdocs/Splash%20book_Web.pdf
[6] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***
[7] American Museum of Natural History. 2023. What is water? https://www.amnh.org/explore/ology/water/what-is-water,
[8] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics***. https://www.wrc.org.za/wp-content/uploads/mdocs/Groundwater%20book_web.pdf.

Why water is really, really weird (and wonderful).[9]

FROM CLOUDS TO CURRENTS (THE WATER CYCLE)

The hydrological or water cycle describes how water is exchanged (cycled) through Earth's oceans, land, and atmosphere. This is a never-ending cycle whereby water moves in its three forms (liquid, solid or gas) through the atmosphere, soil, plants, rivers, oceans and rocks.[10] This cycle has no start or end; water can exist in different states throughout the various stages.

The sun's energy and gravity power this ongoing cycle. Heat from the sun plays a crucial role in creating a continuous circulation pattern from sea to air to land, allowing water to alternate between its various states of liquid, vapour, and ice. This process generates renewable freshwater resources that are essential for life on Earth. A country's access to freshwater resources is largely determined by its geographic location, which can impact its water supply through rainfall over its territory, upstream rivers, or shared aquifers with neighbouring countries. Despite the variability of rainfall from year to year, it is important to remember that the supply of renewable freshwater is ultimately limited.[11]

The water cycle consists of three major processes: evaporation, condensation, and precipitation. Water from different sources evaporates into the air. This process changes liquid water into water vapour, an invisible gas. **Evaporation** is faster when it is hot and slower when it is cold, so plants need more water in the summer.[12] Evaporation is vital for regional weather systems. Without this process, clouds cannot form, and rain cannot fall.

Transpiration is another important part of the water cycle. Water evaporates from surface water sources like lakes and dams or through the process of transpiration in plants. Water is absorbed through the roots of plants and moves up through the plant to the leaves. The movement of water up the plant is due to capillary action.[13] Capillary action occurs because water is sticky, thanks to the forces of cohesion (water molecules like to stay close together) and adhesion (water molecules are attracted and stick to other substances).[14] Plants return water to the atmosphere as water vapour through tiny pores (stomata) in their leaves. Water vapour,

[9] BBC Ideas. 2019. Why water is really, really weird. https://www.youtube.com/watch?v=mPpKhxtFf1Q

[10] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***

[11] World Bank. 2023. The Atlas of Sustainable Development Goals 2023. https://datatopics.worldbank.org/sdgatlas/goal-6-clean-water-and-sanitation?lang=en.

[12] National Geographic. 2023. Evaporation. https://education.nationalgeographic.org/resource/evaporation/.

[13] City of Cape Town. 2018. Water services and the Cape Town urban water cycle. https://resource.capetown.gov.za/documentcentre/Documents/Graphics%20and%20educational%20material/Water%20Services%20and%20Urban%20Water%20Cycle.pdf

[14] USGS. 2024. Capillary action. https://www.usgs.gov/special-topics/water-science-school/science/capillary-action-and-water

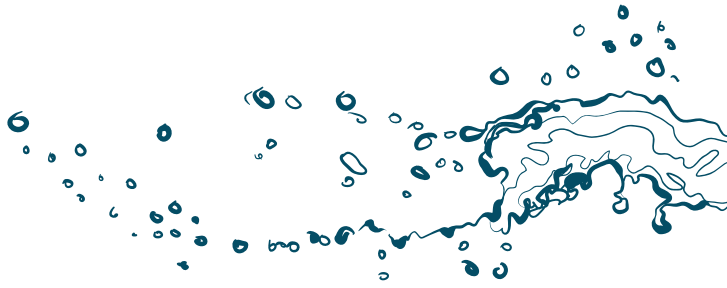
droplets of water suspended in the air, builds up in the planet's atmosphere.[15] This process is called **condensation**. As the water vapour rises, it condenses to form clouds that release water back into the water cycle. Condensation is the process where water vapour (water in a gas form) changes to liquid water. This is the process that allows clouds to form. When the sun heats moist air near the ground or the surface of the sea, the layer of air closest to the sea surface is warmed by the sea's heat over the oceans. As the air ascends and cools, the water vapour condenses, leading to the formation of clouds.[16]

As clouds become saturated, it falls from the clouds as **precipitation**. This term refers to any type of water that forms in the atmosphere and then drops onto the planet's surface, for example, when it snows, rains or hails. This precipitation falls on Earth and either infiltrates the soil, flows across the land (surface water) and collects in wetlands and rivers. Surface runoff eventually travels to a river or another surface water body and evaporates into the atmosphere. Nearly 40% of all precipitation flows across the land to seas and oceans.

Some of the water also seeps deeper into the ground into layers of rocks or soil underground that hold the water (these are called aquifers). This process is called **infiltration**. It reaches the water table and becomes groundwater. Water in the saturated groundwater system moves slowly and may eventually discharge into streams, lakes, and oceans. Some of the infiltrated water will be transpired by plants and returned to the atmosphere.

The water cycle plays a crucial role in regulating the temperature of a particular region. It involves the exchange of heat, which causes temperatures to fluctuate. When water evaporates, it absorbs energy from the environment, which results in cooling of the local area. On the other hand, when water condenses, it releases energy, which warms up the environment.[17]

There is global variability in the water cycle. Water moves from place to place through this cycle, which is changing as climate changes. Climate change is likely causing parts of the water cycle to speed up as warming global temperatures increase the rate of evaporation worldwide. With the rise in global temperatures, the rate of evaporation is increasing, which is causing more precipitation on average. We can already see the adverse effects of this phenomenon, such as floods and droughts, and it's predicted that it will worsen in the coming century if we don't take action to address climate change.[18]



[15] City of Cape Town. 2018. Water services and the Cape Town urban water cycle.
[16] USGS. 2024. Capillary action.
[17] National Geographic. 2023. Hydrologic cycle.
[18] UCAR. 2023. The water cycle. https://scied.ucar.edu/learning-zone/how-weather-works/water-cycle.

The Water Cycle

The water cycle is the way that water moves from the Earth's surface to the air and back again. It involves four main processes:

Precipitation: This is when the water droplets in the clouds get big enough and heavy enough to fall back to the ground as rain, snow, hail, or sleet.

Condensation: This is when water vapor in the air cools down and turns back into tiny droplets, forming clouds.

Transpiration: This is when plants release water vapor into the air through tiny openings in their leaves, called stomata.

Evaporation: This is when the sun heats up water in rivers, lakes, and oceans, turning it into water vapor.

In the water cycle, water is constantly moving and changing form. The water cycle helps to provide fresh water for plants and animals to drink, and it helps to regulate the Earth's temperature by distributing heat energy.

EVER WONDERED HOW RAIN IS FORMED?

WHAT IS A CLOUD AND HOW DOES IT FORM?

A cloud is an aggregate of tiny water droplets, ice crystals, or a mixture of both, with its base above the Earth's surface in the atmosphere. It is made up of small droplets of water or particles of ice that are suspended in the air. These droplets are tiny, with a diameter of only about a hundredth of a millimetre. Despite their small size, they can remain in liquid form even at temperatures as low as -30°C. At higher elevations and colder temperatures, clouds are made up of ice crystals that can be up to one-tenth of a millimetre in length.[19]

The clouds overhead contain water vapour and cloud droplets, which are tiny drops of condensed water. These droplets are too small to fall as precipitation but large enough to form visible clouds. Water is continually evaporating and condensing in the sky. Clouds are formed when air contains as much water vapour (gas) as it can hold. This is called the saturation point. Saturation in clouds is reached through evaporation and condensation. When saturation occurs, moisture becomes visible water droplets in the form of fog and clouds.[20,21,22,23]

Clouds are formed mainly due to the vertical motion of air, as in convection, forced ascent over high ground, or the large-scale vertical motion associated with depressions and fronts.[24] For precipitation to happen, tiny droplets may grow as a result of additional condensation of water vapour when the particles collide. If enough collisions occur to produce a droplet with a fall velocity exceeding the cloud updraft speed, it will fall out of the cloud as precipitation.[25] Clouds contain thousands of tiny water droplets that are so small that they float in the air. However, as they bump into each other, they join together to form bigger droplets. Eventually, the droplets become too big and heavy to stay suspended in the air and fall as rain.[26]

Clouds are confined to the troposphere (the lowest level of the Earth's atmosphere) except for certain rare types and the occasional occurrence of cirrus in the lower stratosphere.

How are clouds created?

- As air is heated by the ground rises in thermal currents into cold air;
- As air is forced upward by a topographic feature such as a mountain (called an orographic cloud);
- As two fronts meet and the warmer front is forced to rise;
- As turbulent air currents move across the Earth's surface; and
- As cold air meets the ocean surface.[27]

[19] Weather.gov. 2023. Clouds – how do they form? https://www.weather.gov/source/zhu/ZHU_Training_Page/clouds/cloud_development/clouds.htm.
[20] https://www.weather.gov/source/zhu/ZHU_Training_Page/clouds/cloud_development/clouds.htm.
[21] USGC. 2019. The little cloud that could... But why?. https://www.usgs.gov/special-topics/water-science-school/science/precipitation-and-water-cycle.
[22] USCG. 2019. Condensation and the water cycle. https://www.usgs.gov/special-topic/water-science-school/science/condensation-and-water-cycle.
[23] USGC. 2019. Precipitation and the water cycle. https://www.usgs.gov/special-topics/water-science-school/science/precipitation-and-water-cycle.
[24] Metoffice. 2023. Clouds. National Meteorological Library and Archive. Fact sheet 1 — An introduction to clouds. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/library-and-archive/library/publications/factsheets/factsheet_1-clouds.pdf.
[25] USGC. 2019. Precipitation and the water cycle.
[26] City of Cape Town. 2018. Water services and the Cape Town urban water cycle.
[27] WRC. 2018. ***Splash - A water source for curious kids.***

CLOUD TYPES AND GROUPS

Cloud types include cloud genera as high (cirro-, cirrus), middle (alto-), multi-level (nimbo-, cumulo-, cumulus), and low (strato-, stratus) clouds. These groupings are determined by the altitude level or levels in the troposphere at which each of the various cloud types is normally found. Some clouds are grouped not by their height, but by their unique characteristics, such as those that form over mountains (lenticular clouds) or beneath existing clouds (mammatus clouds).

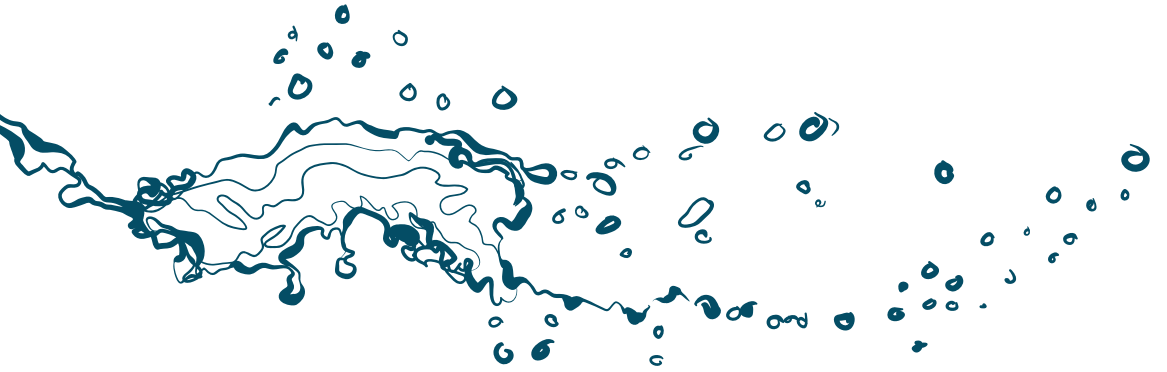
What's in a (cloud's) name? Most of the names for clouds come from Latin and are usually a combination of the following prefixes and suffixes:

- Stratus/strato cloud: flat/layered and smooth cloud
- Cumulus/cumulo cloud: heaped up/puffy cloud, like cauliflower
- Cirrus/cirro cloud: high up/wispy cloud
- Alto cloud: medium level cloud
- Nimbus/nimbo cloud: rain-bearing cloud

Where these names are combined, we can often build up an idea of that cloud's character. For example, if we combine ***nimbus*** and ***stratus***, we get 'nimbostratus' – a flat and layered cloud with the potential for rain.[28] Low, white, lumpy cumulus clouds reflect sunlight away from the Earth, while thin, wispy, high-altitude clouds transmit light and trap heat, warming the Earth.

Most clouds can be divided into three groups (high clouds/ middle clouds/ low clouds) based on the part of the Earth's atmosphere (altitude) at which they form:[29]

- **Low clouds:** Cumulus, Cumulonimbus, Stratus, and Stratocumulus. Low clouds form from near the surface to about 2 km and are generally composed of water droplets.
- **Medium clouds:** Altocumulus, Altostratus and Nimbostratus. Medium clouds form from 2 to 7 km in the atmosphere in temperate latitudes; may be composed of water droplets or ice crystals depending on the temperature profile at that altitude range.
- **High clouds:** Cirrus, Cirrocumulus and Cirrostratus



[28] Met Office. 2024. Cloud names and classifications. https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/cloud-names-classifications.
[29] Met Office. 2024. Cloud names and classifications.

TYPES OF CLOUDS AND HOW TO RECOGNISE THEM

Clouds are constantly changing and appear in an infinite variety of forms. While some clouds might look like fluffy tufts of cotton wool or marshmallows, they are really suspended masses of water or ice crystals floating above us. Clouds are classified according to their height above and appearance (texture) from the ground. They differ significantly in size, shape, and colour. Experts split clouds into three main types — stratus, cumulus and cirrus.

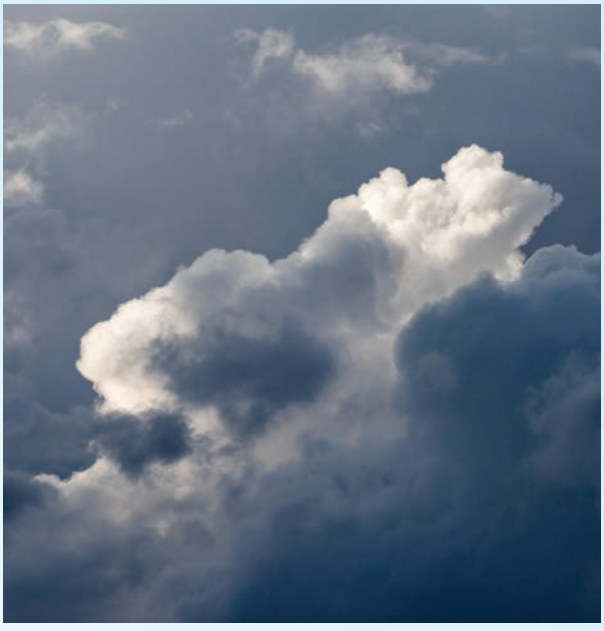
Stratus clouds are horizontal and stratified or layered. They usually occur close to the Earth's surface. These clouds form at the edge of a warm front, where warm, moist air is forced up over cold air. Impenetrable grey sheets, stratus clouds create the rainy-day look typical of Cape winters. Altostratus forms in the middle of the cloud-forming layer of the atmosphere (2 000 metres to 6 000 metres) and may contain ice and water. The presence of stratus clouds usually means a chilly, overcast day. If precipitation falls from stratus clouds, it is usually in the form of drizzle or light snow.[30]

Cumulus clouds are large and lumpy. These clouds can stretch vertically into the atmosphere up to 12 000 metres high. Strong updrafts of warm and moist air create these clouds. Most heavy precipitation falls from these clouds. The weather they bring depends on their height and size.

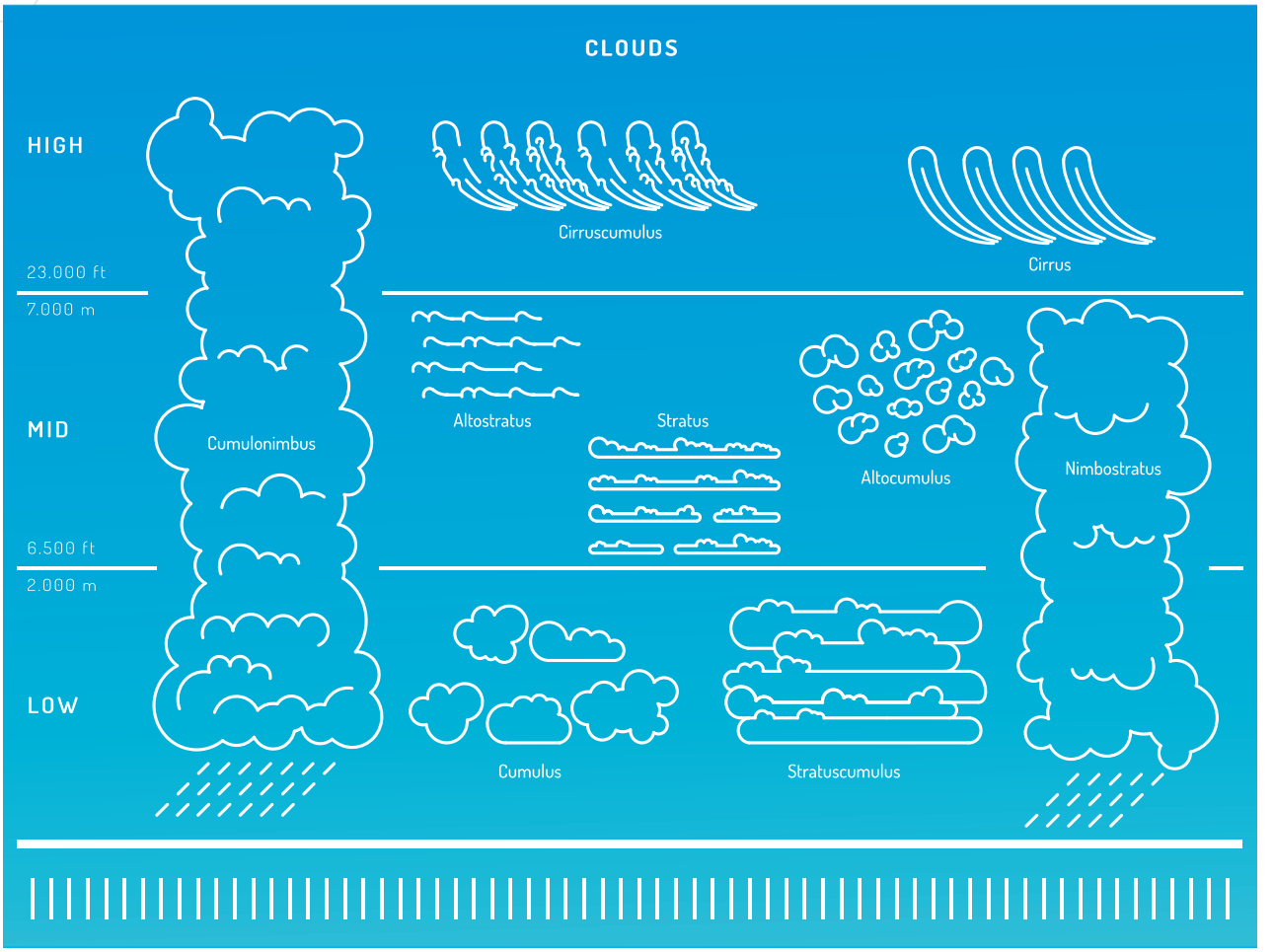
Cirrus clouds are wispy, curly, or stringy in shape. They are found high in the Earth's atmosphere — typically higher than 6 000 metres — and usually consist of ice crystals. The shape of these clouds often indicates the direction the wind is blowing high in the atmosphere.

The higher the base of a cloud, the drier the atmosphere and the fairer the weather will be. Heavy snow or rain could be on the way when clouds occur close to the ground.

Source: National Geographic[31] , Splash - A water source for curious kids[32] , Met Office[33] , and the National Center for Atmospheric Research[34]



[30] WRC. 2018. ***Splash - A water source for curious kids.***
[31] National Geographic. 2023. Clouds. https://education.nationalgeographic.org/resource/cloud/.
[32] WRC. 2018. ***Splash - A water source for curious kids.***
[33] Metoffice. 2023. Cloud names and classifications.
[34] UCAR. 2023. Clouds. https://scied.ucar.edu/learning-zone/clouds/cloud-types.



There are many different types of clouds, each with a unique shape and location in the sky.

HOW TO CLASSIFY CLOUDS

Cloud types are further divided into 27 classifications — from the wispy to the ominous. They are named according to their height and form. Many of these classifications represent the same basic cloud type (or combinations of clouds) but in various stages of development, opacity, or sky cover.[35]

Cumulus clouds are cauliflower-shaped. They begin to form in the lower level of the sky and may tower up to 16 kilometres high. This type of cloud is formed when warm air rises carrying water vapour with it by evaporation.[36]

Cirrus clouds typically form high in the sky (above 6 000 metres) when strong winds sweep ice crystals into shapes that remind of wisps of fleece. These clouds are thin because they are made of ice crystals instead of water droplets. A blue sky and a few cirrus clouds high in the sky usually means it is going to be a nice day.

Clouds usually appear white because the tiny water droplets inside them are tightly packed, reflecting most of the sunlight that hits them. White fluffy clouds mean no rain, but when they form into dark or grey clouds, it is probably going to rain. Clouds darken because the water vapour is clumping together into raindrops, which in turn leaves larger spaces between drops of water. This causes less light to be reflected, making the rain cloud appear black or grey.[37]

HOW MUCH WATER DOES EARTH HAVE?

Overall, very little of the water on our planet is available (and suitable) for human use. Understanding how much (or how little) we have is key to managing water resources efficiently. How much water do we have? In simplest terms, water makes up about 70% of the Earth's surface, while the other 30% comprises continents and islands. The oceans hold most of the planet's water — over 97% of Earth's water is salty and unfit for human use. Less than 3% is fresh — this is the water we drink, water plants with, and use to keep our urban hubs going.[38]

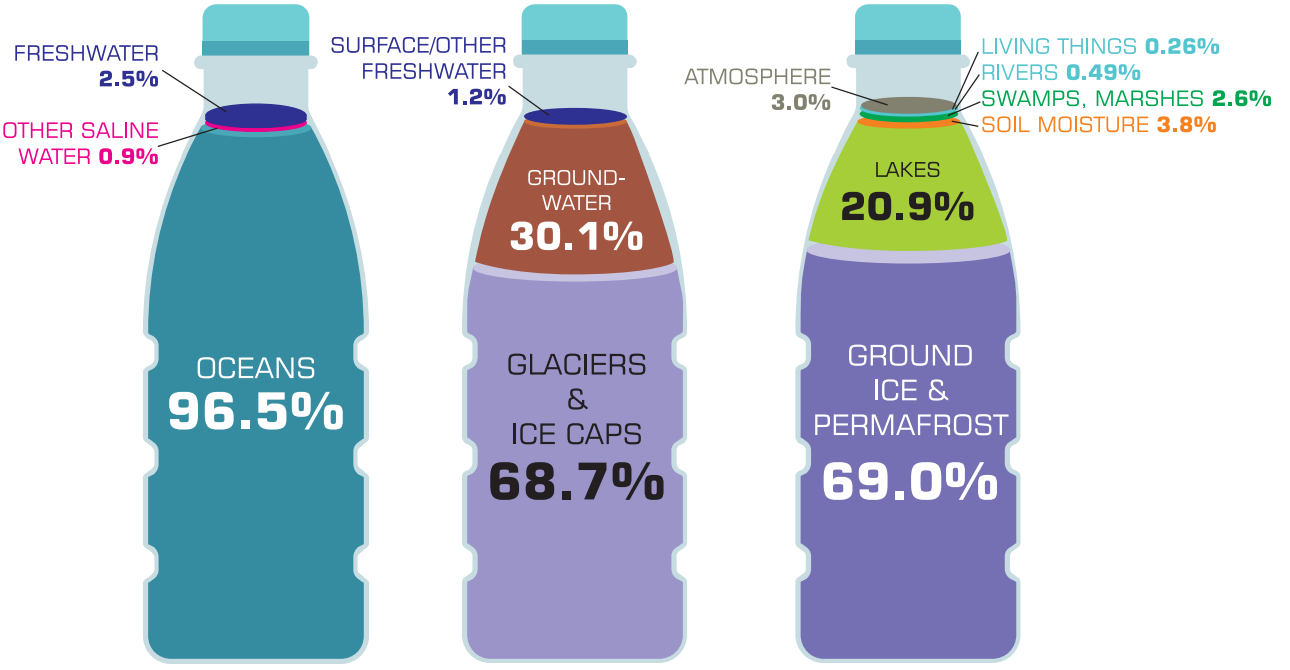
The total amount of water on Earth is enormous – some 1.42 billion cubic kilometres. Despite this mind-boggling amount of water, surprisingly little of it is directly available as freshwater. The proportion of water that is both fresh and liquid is just under 1% of the total. Out of this meagre portion, approximately one-third is surface water, while the rest is hidden away as groundwater.

About two-thirds of the available freshwater on the planet is locked in glaciers and ice caps at the poles. The remaining fraction of freshwater includes not only water in rivers and dams, but atmospheric water and soil moisture, and the water in living organisms.[39] Interestingly, only 0.03% of all water on Earth is present in the atmosphere as water vapour. This vapour plays a crucial role in the water cycle and the planetary climate, as it is responsible for precipitation in the form of rain, mist, and snow.[40,41,42]

[35] UCAR. 2023. Cloud types. https://scied.ucar.edu/learning-zone/clouds/cloud-types. https://scied.ucar.edu/learning-zone/clouds/cloud-types.
[36] WRC. 2018. ***Splash - A water source for curious kids.***
[37] UCAR. 2023. Cloud types.
[38] National Geographic. 2023. Water distribution on earth. https://education.nationalgeographic.org/resource/all-about-the-ocean/
[39] GEOSS. 2020. Understanding groundwater in South Africa. https://geoss.co.za/understanding-groundwater-in-south-africa/
[40] WRC. 2018. ***Splash - A water source for curious kids.***
[41] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***
[42] National Geographic. 2023. Water distribution on earth.

Apart from being present in different forms, water is also not distributed equally across the planet. In other words, some countries have access to more water resources than others. For example, countries along the Equator generally have more water, because here warm, moist air rises, causing higher levels of rain.

WHERE IS EARTH'S WATER?



The distribution of water on Earth.

WHERE DO WE FIND WATER?

There are different sources of water available on our planet, including the ocean, in glaciers, and in aquifers as groundwater.

- **Salty seas (the global ocean)**

The ocean plays a vital role in regulating the planet's climate and weather patterns. When the sun's heat reaches the ocean's surface, it causes evaporation, which adds moisture to the air. The planet has one global ocean, though oceanographers and the countries of the world have traditionally divided it into distinct regions: the Pacific, Atlantic, Indian, Southern and Arctic oceans. When viewed from space, the ocean's vast expanse gives Earth its distinctive blue appearance. Thousands of marine organisms call the ocean home, including the blue whale, the world's largest animal. Despite its significance, we've only explored 20% of the ocean, leaving much to be discovered.[43]

- **Cold storage (glaciers, snow and ice)**

Glaciers are mainly found near the poles. Most of the world's glaciers are in Antarctica, a continent that has been at least partially covered by an ice sheet for the past 40 million years.[44] Water can stay trapped as ice for tens of thousands of years or longer. Most glaciers are typically located in areas that receive high levels of snowfall during winter months while experiencing low temperatures throughout the summer. These conditions ensure that the snow that accumulates in the winter is not lost during the summer. Examples of such regions are Alaska, Patagonia, and the Himalayas.

Relic ice bodies formed during the most recent ice age on the planet still exist in several tropical mountains, including in countries like Mexico and Papua New Guinea, as well as in Kenya, Tanzania and Uganda. In Africa, glaciers are still present in the Rwenzori Mountains (Uganda/Democratic Republic of Congo (DRC), Mount Kenya (Kenya), and Kilimanjaro (Tanzania). These represent the highest mountain summits in Africa, where cold air conditions are present.

Other glaciers have melted completely or are predicted to do so, given the current rate of climate change. Glacial retreat is a process where glaciers melt at a faster rate than they can accumulate ice through precipitation. This process has far-reaching consequences, particularly related to the availability of freshwater on Earth. On average, glaciers worldwide have been losing mass since at least the 1970s, which in turn has contributed to observed changes in sea level. It is worth noting that a longer measurement record from a smaller number of glaciers suggests that they have been shrinking since the 1950s.

The rate at which glaciers are losing mass appears to have accelerated over roughly the last decade.[45] The current rate of glacial retreat underscores the need for immediate action to address the underlying causes of this phenomenon, namely to reduce greenhouse gas emissions into the Earth's atmosphere that fuels the current rate of climate change. Read more about this in Chapter 2.

[43] Worldatlas. 2020. How many oceans are there in the world? https://www.worldatlas.com/articles/how-many-oceans-are-there-in-the-world.html
[44] EPA. 2023. Climate change indicators: Glaciers. https://www.epa.gov/climate-indicators/climate-change-indicators-glaciers
[45] National Snow and Ice Data Center. 2023. Glaciers. https://nsidc.org/learn/parts-cryosphere/glaciers/glacier-quick-facts

What is a glacier?

A glacier is a large mass of snow and ice that has accumulated over many years and is present year-round. Glaciers and ice caps store about 68.7% of the world's freshwater. They are crucial in maintaining the water balance on our planet. If all land ice melted, the sea level would rise about 70 metres worldwide.[46]

An aerial view of icebergs in the Arctic.

[46] National Snow and Ice Data Center. 2023. Glaciers.

Ice sheets are massive bodies of ice that cover hundreds of thousands of square kilometres on Greenland and Antarctica. The ice sheet on Greenland reaches more than 1,6 kilometres (km) thick on average in the interior. Antarctica's ice is nearly 4,8 km thick in some places. Together, these ice sheets hold more than two-thirds of the world's freshwater. Ice sheets accumulate snowfall — just like small glaciers but at a larger scale. Over time, this snow becomes compacted into layers of ice, and the weight of this ice causes it to flow downhill and outward toward the ocean. Ice sheets tend to naturally fluctuate with seasonal changes in temperature, precipitation, and other factors. When an ice sheet is in equilibrium, new snow accumulation is exactly balanced by melting at the surface, runoff, and calving (ice breaking off to form icebergs) at the ocean.[47]

It is worth noting that some of this ice has been in place for more than 1 million years. As the climate gets warmer due to climate change, it has a significant impact on ice sheets in many regions. The most noticeable effect that has been observed so far is the loss of ice due to the warmer air and ocean waters. Warmer ocean waters have a significant impact on the polar ice caps. They cause the edge and base of the ice sheet to melt, accelerating the process of calving. Warmer ocean waters also weaken the floating ice shelves that form in key places along the coast, especially in Antarctica. Ice sheets are considered important indicators not only because of their sensitivity to changes in climate but also for their role in global sea level rise.[48] Since 1992, Greenland and Antarctica have both lost ice overall, each losing more than 100 billion metric tons of ice annually on average.

Melting of the Greenland and Antarctic ice sheets accounted for about one-third of observed global sea level rise between 2006 and 2015. The impact of rising oceans due to global heating is a major concern, as numerous major cities around the world are situated on coastlines and are becoming increasingly vulnerable to flooding and storm surges.

Reports suggest that the West Antarctic ice sheet may have already passed the point of no return, which could eventually result in metres of sea level rise.[49]

- **Starting fresh (surface water, inland)**

Surface water refers to any body of water that can be found on the Earth's surface, such as freshwater in rivers, streams, and lakes. A body of surface water can persist all year long or for only part of the year. As noted above, most of the world's freshwater is not easily accessible to us humans. Read more about our freshwater resources in Chapter 2 and 3.

- **Groundwater – the hidden treasure beneath our feet**

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks. Groundwater is present beneath the surface almost everywhere, including under hills, mountains, plains, and deserts. This water can lie close to the land surface in wetlands or hundreds of metres below the surface.

[47] EPA. 2023. Climate change indicators: Ice sheets. https://www.epa.gov/climate-indicators/climate-change-indicators-ice-sheets
[48] EPA. 2023. Climate change indicators: Ice sheets.
[49] Carrington, D. 2023. Ice sheets can collapse at 600 metres a day, far faster than feared, study finds. In ***The Guardian*** (online edition). Published on 5 April 2023. https://www.theguardian.com/environment/2023/apr/05/ice-sheets-collapse-far-faster-than-feared-study-climate-crisis

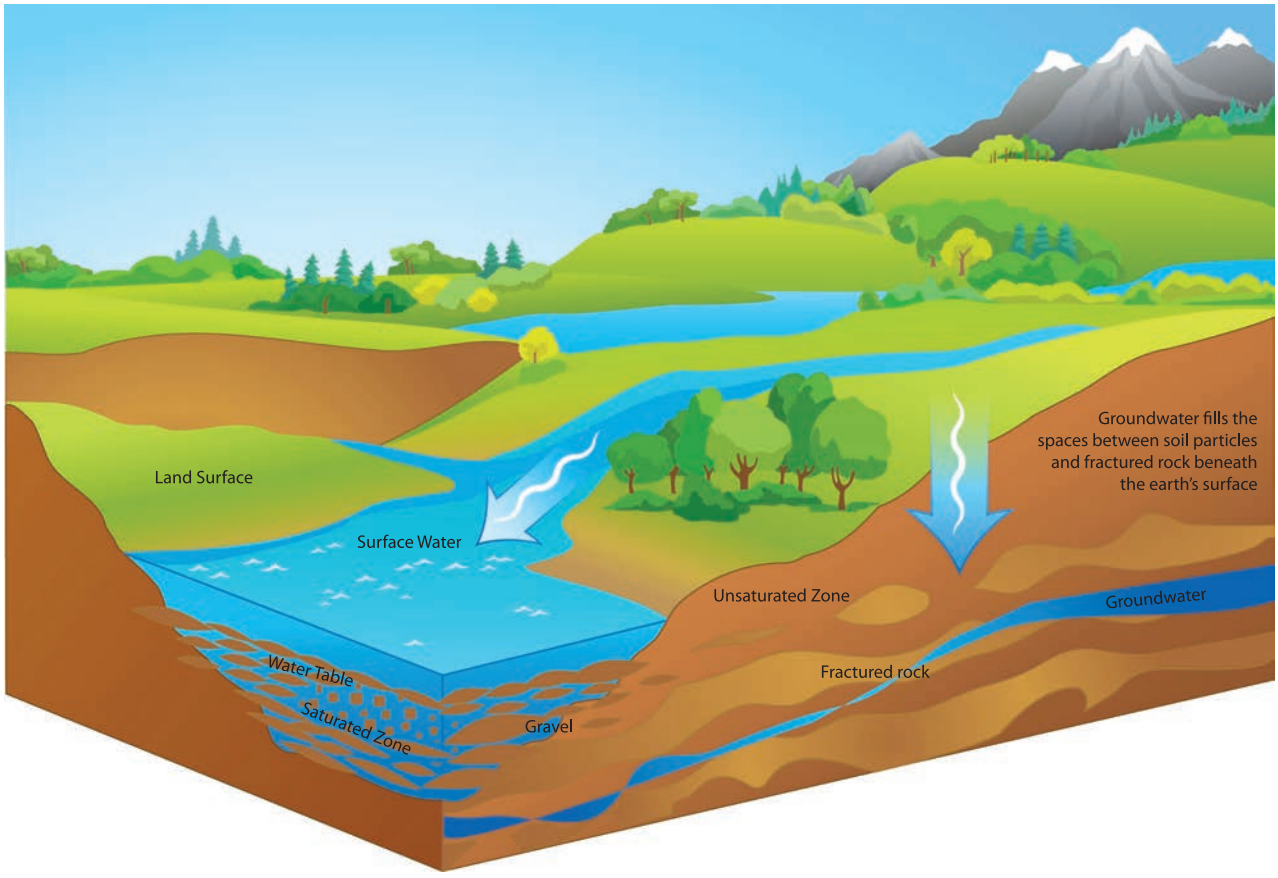
There is an immense amount of water below the Earth's surface. In fact, there is over a thousand times more water in the ground than there is in all the world's rivers and lakes.[50] However, it is not always easily accessible or fresh enough for use without treatment. Groundwater is stored in and moves slowly through formations called aquifers.[51, 52] An aquifer is a subsurface geologic formation(s) that allows water to be accessible at a usable rate.[53, 54] Some aquifers are small, only occupying a few hectares, while others can be huge, extending for thousands of square kilometres beneath the Earth's surface. There are different types of aquifers, including confined and unconfined aquifers. Confined aquifers are covered by impermeable (does not allow water or liquid to pass through it) rock or clay and usually occur at considerable depths. Unconfined aquifers are open to infiltration from the surface and are typically shallow.[55] Groundwater is naturally recharged by rain, or other forms of precipitation, and is the source of water for aquifers, springs, boreholes and wells.[56] Although most groundwater within a few hundred metres below the land surface is fresh, more than half of all groundwater under the globe's land surface is saline and, therefore, unsuitable for most types of water use.

Groundwater is constantly on the move. Often, groundwater flow in aquifers does not mirror the water flow on the surface. Groundwater may move in different directions below the ground than surface water flows.[57] In addition, groundwater flows much more slowly than surface water (for example, rivers). The speed at which groundwater moves can be affected by different factors, including the gradient of the

groundwater level and the permeability characteristics of the rock formation through which it moves. Groundwater can also be influenced by gravity. It tends to move from areas with a shallow water level to areas with a deeper water level.[58]

Groundwater can stay underground for hundreds or even thousands of years or flow and discharge as springs, rivers, lakes, or into the ocean. This process continues the cycle of water.

[50] USGS. 2018. Groundwater: What is groundwater? https://www.usgs.gov/special-topics/water-science-school/science/groundwater-what-groundwater
[51] Engel, K. 2023. Groundwater - the hidden treasure beneath our feet is key to water security', in Daily Maverick, https://www.dailymaverick.co.za/article/2023-09-20-groundwater-the-hidden-treasure-beneath-our-feet-is-key-to-water-security/.
https://www.dailymaverick.co.za/article/2023-09-20-groundwater-the-hidden-treasure-beneath-our-feet-is-key-to-water-security/?utm_source=socialshare&utm_medium=twitter
[52] Mvandaba, V., Mwenge Kahinda, J., Nzuza, P & Hobbs, P. 2019. Green Book – The impact of climate change on groundwater availability. Technical report, Pretoria: CSIR. https://pta-gis-2-web1.csir.co.za/portal/sharing/rest/content/items/d9e7cd5647fb4e15b6043e790d22d619/data
[53] https://groundwater.org/what-is-groundwater/
[54] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***
[55] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***
[56] The Groundwater Foundation. 2023. What is groundwater?
[57] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***
[58] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***



The area where water fills the aquifer is called the saturated zone (or saturation zone). The top of this zone is called the water table.

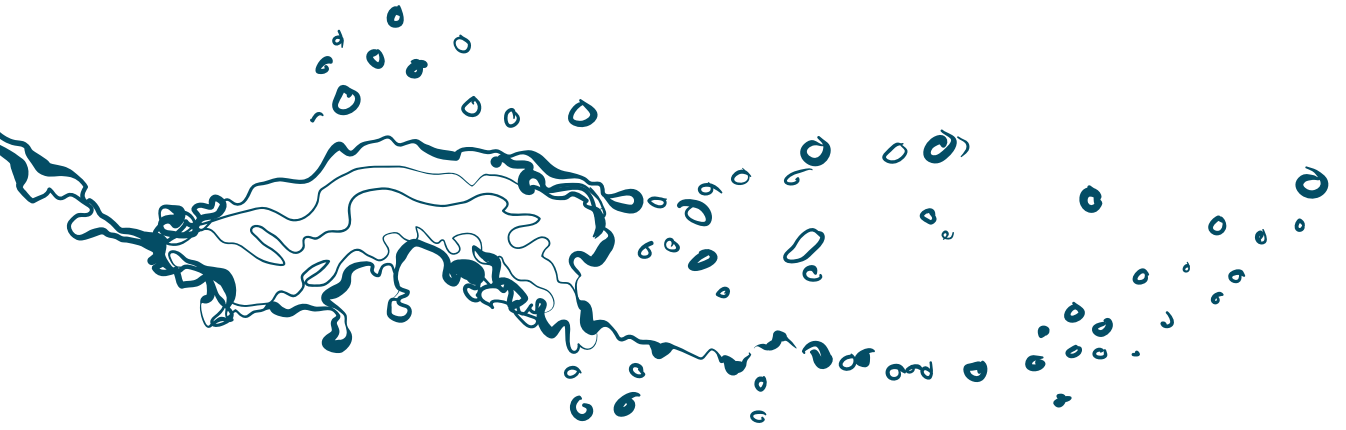
WATER SCARCITY – THE GLOBAL CHALLENGE

Water scarcity is an increasing problem on every continent, including Africa, not only due to the physical shortage of water but also because of infrastructure, quality and management issues. Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or are becoming too polluted to use.

These challenges have been compounded by the increasing use of water to meet the needs of growing populations worldwide. Freshwater extraction has been increasing in most regions around the world over the last century. The world's population is projected to reach 9 billion by 2050, which could lead to a 50% increase in demand for agricultural production and a 15% increase in water withdrawals.

This threatens the water security of countries. A recent report by the United Nations has revealed that 113 countries, mostly in Africa, are already considered water insecure.[59] The least water-secure regions in the world include the continent of Africa, including the Sahel, the Horn of Africa and parts of West Africa, South Asia and the small island developing states.

What is water security?
Water security is the capacity of a population to safeguard sustainable access to adequate quantities of the right quality water for sustaining livelihoods, human well-being and socio-economic development.



[59] MacAlister, C, Baggio, G, Perera, D, Qadir, M, Taing, L, Smakhtin, V. 2023. Global Water Security 2023 Assessment. United Nations, University Institute for Water. https://inweh.unu.edu/global-water-security-2023-assessment/

Source: UN Water[60]

What is Water Security?

"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."

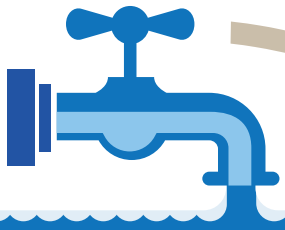
Working definition, UN-Water, 2013

GOOD GOVERNANCE

Adequate legal regimes, institutions, infrastructure and capacity are in place.

TRANSBOUNDARY COOPERATION

Sovereign states discuss and coordinate their actions to meet the varied and sometimes competing interests for mutual benefit.



DRINKING WATER AND HUMAN WELL-BEING

Populations have access to safe, sufficient and affordable water to meet basic needs for drinking, sanitation and hygiene, to safeguard health and well-being, and to fulfill basic human rights.

ECONOMIC ACTIVITIES AND DEVELOPMENT

Adequate water supplies are available for food and energy production, industry, transport and tourism.

ECOSYSTEMS

Ecosystems are preserved and can deliver their services, on which both nature and people rely, including the provision of freshwater.

WATER-RELATED HAZARDS AND CLIMATE CHANGE

Populations are resilient to water-related hazards including floods, droughts and pollution.

PEACE AND POLITICAL STABILITY

The negative effects of conflicts are avoided, including reduced water quality and/or quantity, compromised water infrastructure, human resources, related governance, and social or political systems.

FINANCING

Innovative sources of financing complement funding by the public sector, including investments from the private sector and micro-financing schemes.

[60] UN Water, https://www.unwater.org/sites/default/files/app/uploads/2017/05/unwater_poster_Oct2013.pdf

Poorer communities are most threatened by water security issues.

KEY FACTS ABOUT WATER SECURITY ACROSS THE WORLD

- **Mapped globally, there are huge differences in water security levels across different regions.** The least water-secure regions are Africa, including the Sahel, the Horn of Africa, parts of West Africa, South Asia, and small island developing states worldwide. Europe and the Americas are significantly more water-secure than other global regions.

- **Least-developed countries and small-island states face critical levels of water security.** Sudan, Ethiopia, Somalia, Madagascar, South Sudan, Niger, Sierra Leone, and Chad are among the countries that are considered critically water insecure. These countries face numerous challenges in achieving water security, including limited access to safe drinking water and sanitation services, poor water quality, inadequate water governance, and low water resource stability with high interannual variability and insufficient storage capacity.

- **Access to safely managed drinking water and sanitation is still a dream for more than half the global population.** More than 10% of people (close to 800 million) do not have access to basic drinking water, and more than 70% (close to 5.5 billion) do not have access to a safely managed drinking water service. More than a fifth of people (22%) do not have access to basic sanitation, and more than half do not have access to safely managed sanitation.[61]

- **Africa has the lowest levels of water, sanitation and hygiene worldwide.** In Africa, almost 31% (over 411 million) of people do not have access to a basic drinking water service.

- **Abundant natural water availability does not necessarily ensure water security.** Many countries that have an abundance of freshwater resources, with a water stress level of 10% or less, still struggle with low levels of water, sanitation, and hygiene access, as well as water treatment. Moreover, these countries are faced with high water rates, sanitation and hygiene-related deaths and low economic water value. In addition, they are vulnerable to high losses due to flood or drought impacts.

- **Globally, significantly more people die annually from a lack of safe drinking water, sanitation, and basic hygiene services than as a result of water disasters.** In Africa, as many as 25 countries are severely affected by mortality rates that can be attributed to a lack of access to basic water, sanitation, and hygiene services. These countries have estimated rates of over 40 deaths per 100 000 people annually.

- **Prosperity is not the main driver of water security.** National wealth, as measured by its gross

[61] MacAlister, C, Baggio, G, Perera, D, Qadir, M, Taing, L, Smakhtin, V. 2023. Global Water Security 2023 Assessment.

national income per capita, plays a significant role in determining a country's capacity to fund important water infrastructure and governance. However, it is important to note that national wealth is not the sole factor in ensuring water security, especially in cases where multiple determinants have reinforcing effects on each other.

- **High water values ('water use efficiency') do not always translate into water security.** Many national economies dominated by petroleum and mining activities have a high economic value per unit of water used. However, this does not necessarily result in increased water security in other components such as governance, water, sanitation, basic hygiene services, or storage infrastructure. This is particularly true in countries with high levels of economic water value in Africa, experts point out.

Source: Global Water Security 2023[62]

[62] MacAlister, C, Baggio, G, Perera, D, Qadir, M, Taing, L, Smakhtin, V. 2023. Global Water Security 2023 Assessment.

TOO MUCH WATER OR NOT ENOUGH?

It is a common misconception that water is an infinite resource. In reality, freshwater is a limit and precious resource on our planet.

The following are key threats to our freshwater resources:

- **Overexploitation**: Excessive use of freshwater resources beyond their natural recharge capacity can lead to many negative consequences. These include deteriorating water quality, creating shortages, and disrupting freshwater flows.
- **Destruction or degradation of habitat**: Loss of freshwater habitats and changes in land use, including alterations in and around rivers and wetlands, are leading to a reduction in biodiversity and a decline in the essential services provided by ecosystems for communities.
- **Invasive species**: The spread of non-native species can destabilise aquatic food chains and lead to biodiversity loss.
- **Saltwater intrusion**: The intrusion of saltwater into freshwater resources (including coastal aquifers) increases drinking water salinity, harms wildlife, and reduces certain crop yields.
- **Climate change**: Changes in temperature and precipitation due to climate change can have a significant impact on hydrological cycles, which in turn can result in reduced water availability and affect the functioning of freshwater ecosystems that support nature and human livelihoods.
- **Water pollution**: Agricultural and industrial activities, as well as human waste, are causing harmful algae blooms and 'dead zones', while acid rain and pollution are acidifying freshwater bodies. Emerging threats like microplastics and nanomaterials are also creating cause for concern.[63]
- **Flow modification and fragmentation**: Human-made diversions and infrastructure like dams and weirs used for hydropower and irrigation can disrupt the natural flow of rivers, causing biodiversity loss and altered sediment flows. This can also lead to freshwater species decline or even extinctions.
- **Infectious disease**s: Pollution, invasive pathogens, and the warming of water bodies can have a significant impact on the spread of infectious diseases. It's not just the wildlife populations that are affected, but also human health due to certain waterborne diseases.[64]

How does water insecurity affect us? Apart from not having enough water for household uses, such as drinking, washing and cooking, household water insecurity can make it hard for people to grow food, and raise animals. A lack of clean water and also affect health and hygiene.

[63] Guterres. A. 2023. United Nation. Press release. 16 March 2023. SG/SM/21727. https://press.un.org/en/2023/sgsm21727.doc.htm#:~:text=But%20drop%20by%20drop%2C%20this,havoc%20on%20water's%20natural%20cycle.
[64] WWF. 2023. High cost of cheap water. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/1o94sii9nx_WWF_High_Cost_of_Cheap_Water_FINAL_LR_.pdf?_ga=2.179356711.2063727574.1707317963-495741042.1707317963

Pollution threatens water resources around the world.

Does this mean that we are running out of water? On a global scale, the answer is no. But on a local and regional scale, scarcity of freshwater is worsening in many places. In addition, freshwater resources are unevenly distributed between regions.[65] Some regions are fortunate to have access to abundant surface water and precipitation, while others have limited surface water resources and experience little rainfall or snowfall.

Water issues are often super localised. This means that the global water crisis often needs creative and local solutions.[66] Water quality also often varies widely between different regions and within countries. Groundwater in one area may, for instance, be undrinkable and polluted, while people living only a couple of houses, streets, or blocks away from people experiencing such problems, can drink freely from their local water source.

All of us need to play our part to use our water resources sustainably. Alternative water sources such as wastewater, storm runoff and desalination, and measures such as water harvesting, can help relieve water stress. Safe wastewater reuse and recycling is a significantly untapped resource for industry and agriculture, but its use must overcome political and cultural barriers. Read more about wastewater, recycling and water harvesting in Chapter 3.

A CLIMATE OF CHANGE

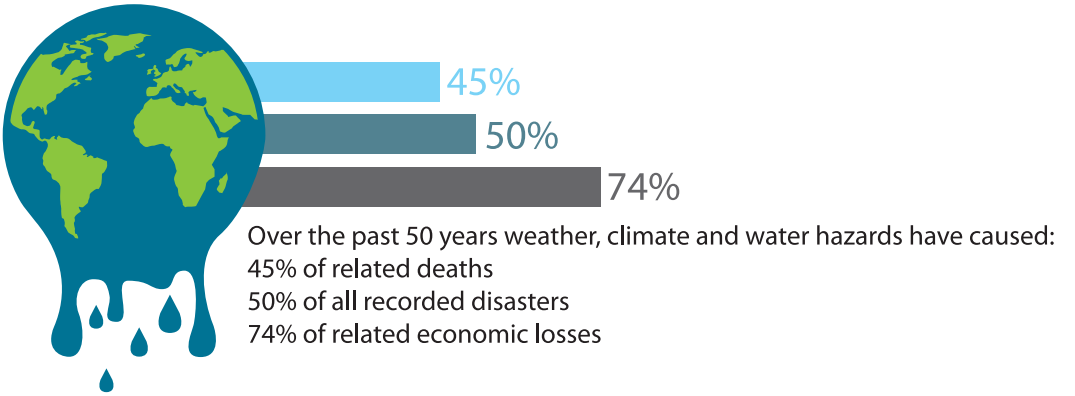
Our world is getting warmer. Global temperatures have soared in recent years as the world continues to burn planet-warming fossil fuels such as coal. The trend shows no sign of slowing. In it 2023 climate update, the World Meterological Organization (WMO) stated that between 2023 and 2027, there is a 66% chance that the planet's temperature will climb above 1.5°C of warming above pre-industrial levels for at least one year.[67]

Breaching the 1.5-degree threshold may only be temporary but would reportedly be the clearest signal yet of how quickly climate change is accelerating – hastening sea level rise, causing more extreme weather, and the demise of vital ecosystems, including our freshwater resources. Of particular concern is the potential for some aspects of climate change to become irreversible if specific thresholds are exceeded, including the melting of ice sheets in Antarctica.[68] Globally, climate and weather-related disasters, including tropical cyclones, storm surges, floods and droughts, are on the rise.[69] Over the past 50 years, rates of weather-related disasters have increased fivefold, and the associated damages have increased 70 times. During the same period, 50% of all recorded disasters, 45% of related deaths and 74% of related economic losses were due to weather, climate and water hazards.[70]

Some places feel the brunt much more than others, including in Africa. From 2000 to 2022, the continent had more floods and flood-related deaths than North America and Europe combined. (Only South and Southeast Asia experienced more weather-related disasters and deaths during this time, partly due to dense populations in flood-prone countries such as Bangladesh.)

[65] World Bank. 2023. The Atlas of Sustainable Development Goals 2023. https://datatopics.worldbank.org/sdgatlas/goal-6-clean-water-and-sanitation?lang=en
[66] Kurth. T. 2023. Navigating the Waters: Strategic Solutions for Water Resilience. https://web-assets.bcg.com/d3/9e/1f7c9f29463bad8e91ffda4e48bf/navigating-the-waters-strategic-solutions-for-water-resilience-sep-2023.pdf
[67] World Meteorological Organization (WMO). 2023. WMO confirms that 2023 smashes global temperature record. https://wmo.int/news/media-centre/wmo-confirms-2023-smashes-global-temperature-record
[68] Naish, T. 2023. Antarctic tipping points: the irreversible changes to come if we fail to keep warming below 2°C. https://theconversation.com/antarctic-tipping-points-the-irreversible-changes-to-come-if-we-fail-to-keep-warming-below-2-207410
[69] J. (et al). 2023. Flash floods: why are more of them devastating the world's driest regions? https://www.nature.com/articles/d41586-023-00626-9
[70] WMO. 2021. WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019). https://library.wmo.int/records/item/57564-wmo-atlas-of-mortality-and-economic-losses-from-weather-climate-and-water-extremes-1970-2019#.YS9CMNMzZBx

The effects of climate change on water are multifaceted and complex, ranging from erratic rainfall patterns to reduced ice sheets, elevated sea levels, and both floods and droughts. These impacts are felt throughout the hydrological cycle and affect the economy, society, and the environment. Some impacts are hard to model but could be nonlinear and, in some cases — such as glacier melting — irreversible.[71]



The heat is on

- Earth's climate is warming, and climate hazards are intensifying.
- In 2023, the world experienced the hottest global temperatures on record, breaking heat records in all continents through 2022.[72]
- Earth has already warmed by roughly 1.1 °C since the late 1800s (pre-industrial era).
- A small shift in the average temperature can hide dramatic changes at the extremes. Climate change is already having an impact on human, physical, and planetary systems.
- Climate models show a growing level of physical hazard globally.
- An estimated four billion people live in areas that suffer from severe physical water scarcity for at least one month per year.

Source: Climate risk and response: Physical hazards and socioeconomic impacts[73]

[71] Woetzel, J. 2020. Climate risk and response. Physical hazards and socioeconomic impacts. Mckinsey Global Institute. https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/climate%20risk%20and%20response%20physical%20hazards%20and%20socioeconomic%20impacts/mgi-climate-risk-and-response-full-report-vf.pdf

[72] Romanello, M. (et al) 2023. The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels.The Lancet. Volume 402. Issues 10419. P.2346-2394. December 16, 2023. 2023. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(23)01859-7/fulltext

[73] Woetzel, J. 2020. Climate risk and response. Physical hazards and socioeconomic impacts. Mckinsey Global Institute.

HOW IS CLIMATE CHANGE AFFECTING THE WORLD'S WATER RESOURCES?

The climate crisis is also a water crisis. By 2050, an estimated 4 billion people will live in water-stressed areas, and 1.6 billion will be exposed to floods.[74] Across the globe, rainfall patterns are changing, affecting water quantity and availability. Eight out of every ten climate events are water-related, including more frequent floods.[75]

As the Earth's temperature continues to increase due to climate change, the distribution of water across the planet becomes more uneven, with some areas experiencing heavy rainfall and others facing droughts. Heavy rainfall events can cause floods that damage water and sanitation infrastructure, carry runoff into stormwater systems and contaminate groundwater. On the other hand, extreme drought events or water scarcity also directly impact people, livelihoods and the natural systems humans depend on.

Water-related impacts caused by climate change include:

- **Rising sea levels** can lead to the intrusion of saline water from the ocean into freshwater systems, which can have a disruptive impact on agricultural activities and cause harm to surrounding ecosystems, including estuaries and soils.
- **Flooding** can affect essential infrastructure and services vital to daily life, particularly water-related facilities. Inundation can damage water points, wells, toilets, and wastewater treatment facilities, leaving people in need of essential services.
- **Droughts** can have far-reaching impacts on various aspects of our lives. For instance, they can lead to shortages in drinking water, food production, and energy supply, which can create health risks and financial losses for communities. Additionally, prolonged droughts can force people to leave their homes, which can create social and political challenges. It's also worth noting that droughts can lead to wildfires, loss of biodiversity, and damage to ecosystems.
- **Shrinking glaciers and ice caps** have a significant impact on meltwater flows, which are responsible for feeding river systems in many parts of the world. It's worth noting that half of the world's population relies on water from mountains. While the initial melting may lead to an increase in water availability, over time, the reduced volume of glaciers and snow fields will diminish the water supply. This will have an adverse impact on people and ecosystems, irrigation systems, and hydropower generation in some regions.
- **Our aquatic ecosystems are in peril.** Even small changes in rainfall and temperature can impact the lifecycles of various species in temperate regions, especially aquatic animals that rely on these cues for breeding and migration. Vulnerable species may be most affected. Extreme floods and droughts could lead to the extinction of many species unable to survive outside their native habitats.

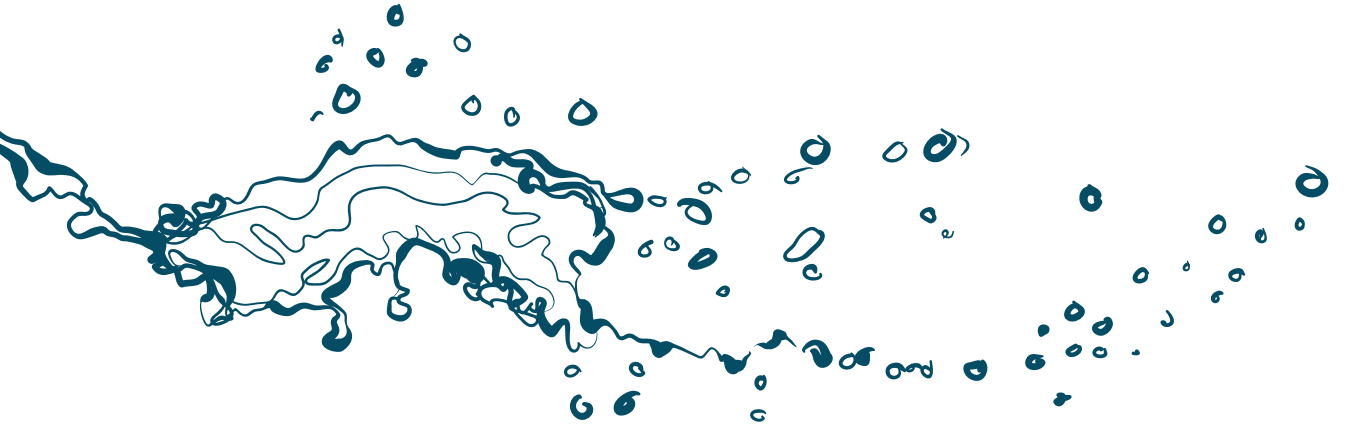
[74] UNEP. 2023. Disasters and climate change. https://www.unep.org/explore-topics/water/what-we-do/addressing-water-related-disasters-and-climate-impacts
[75] UNEP. 2023. Disasters and climate change.

Why are water-related disasters getting worse?

As global temperatures continue to rise due to climate change, water-related disasters are becoming increasingly severe. Flash droughts and floods are happening more frequently and with greater intensity. The degradation of natural environments and rapid urbanisation are exacerbating the situation, making us more vulnerable to flooding. With each additional degree of global temperature rise, the water cycle accelerates and makes water-related disasters worse. Flash drought and flash floods are becoming more extreme and are happening faster. In addition, the degradation of natural environments, loss of natural 'buffers' such as trees, riverbank-side vegetation, and wetlands reduce protection from flooding. Rapid urbanisation can concrete over large areas of land, channelling runoff too rapidly into stormwater drains, quickly overwhelming the system and leading to catastrophic flooding of streets and subways.

Source: UN-Water[76]

Climate change and its impact is everybody's business. There are many things that ordinary citizens can do to affect change. Members of the public can hold their governments accountable and lobby local politicians to support efforts to cut emissions and reduce carbon pollution, for example. In their own homes, people can aim to use water and energy more wisely, while reducing waste and recycling as much as possible.



[76] UN-Water. 2024. Questions people ask about water, climate change and disasters. https://www.linkedin.com/pulse/questions-people-ask-water-climate-change-disasters-un-water-t1odf

Chapter 2

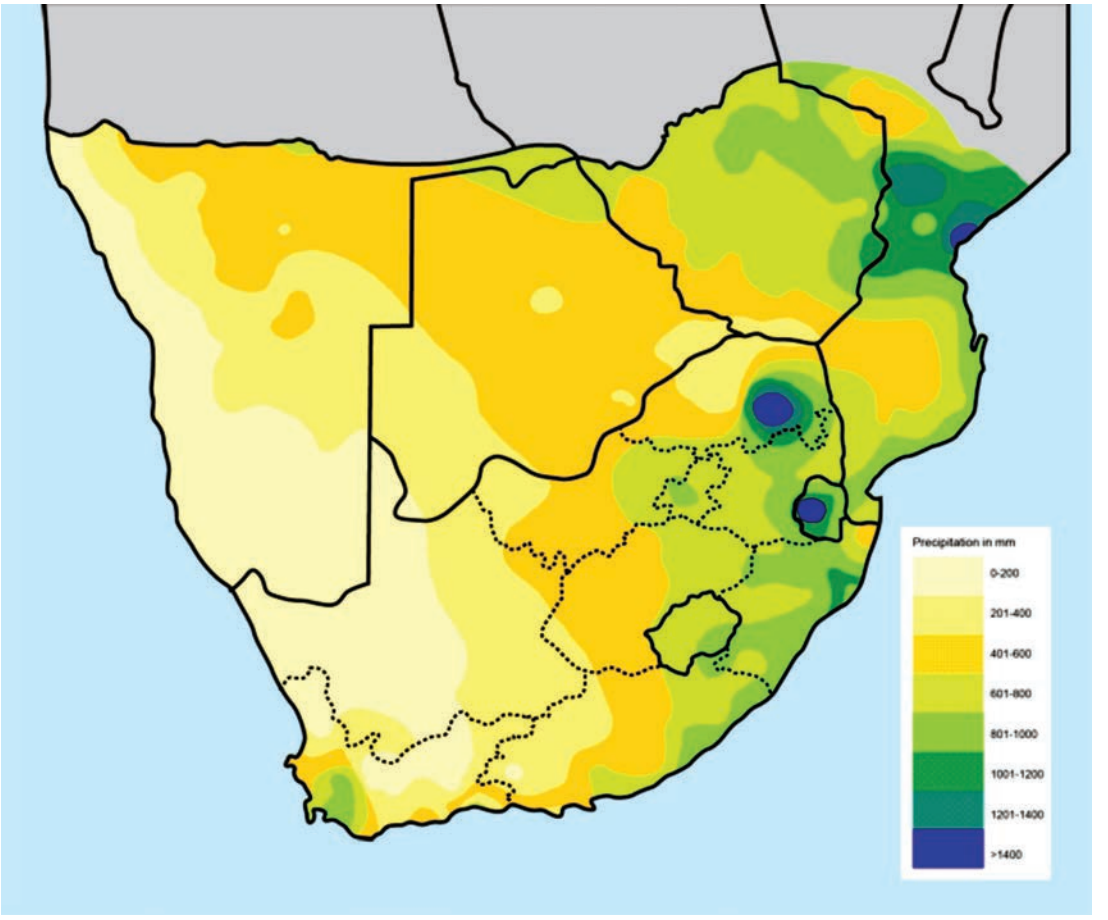
SOUTH AFRICA'S WATER – MORE PRECIOUS THAN GOLD

While South Africa is rich in many natural resources, water is not one of them. To ensure that there is enough to go around, now and in the future, we need to take care of the little water we have. In this chapter we look at the country's water resources, how they are used, as well as the biggest challenges to a water secure future.

South Africa is classified as a semi-arid country, receiving only about 450 mm of rainfall a year (compared to the world average of 860 mm a year). This modest rainfall is not evenly spread across the country or evenly over time. A fifth of the country receives less than 200 mm of rain a year.

These large fluctuations in rainfall result in the country having a high variability in available water resources. The drier interior of South Africa is separated from the narrow and wetter eastern and southern borders by a line of mountains ranging from the Soutpansberg in the north-east, through the Drakensberg to the Cedarberg in the south-west. The country also has high evaporation rates because of its average high temperatures. Only about 9% of rainfall reaches river systems. All of these characteristics result in South Africa being considered the fifth most water scarce country in sub-Saharan Africa.[1]

[1] King, J. and Pienaar H. (Eds). 2011. ***Sustainable use of South Africa's inland waters*** (WRC report no. TT 491/11). https://www.wrc.org.za/wp-content/uploads/mdocs/TT%20491-11.pdf



South Africa's annual rainfall. Note how the rainfall generally decreases from east to west.[2]

[2] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***

SOUTH AFRICA'S SURFACE WATER RESOURCES

RIVERS

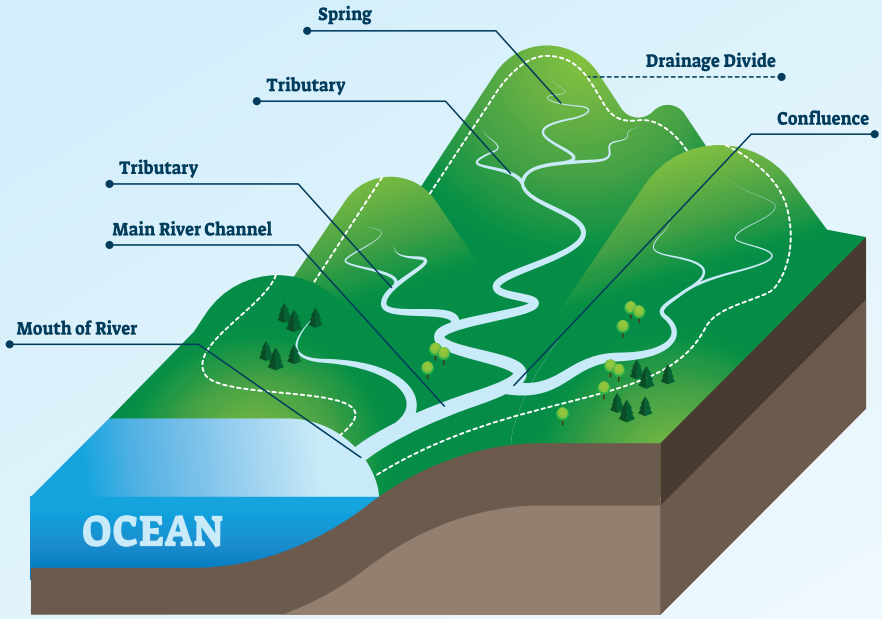
South Africa's surface water resources further illustrate its semi-arid nature. The country has a total mean annual runoff (meaning the water flow in all of its rivers) of only 49 210 cubic metres a year. This is roughly equal to the total mean annual runoff of the Zambezi River to the north of the country. Together, South Africa's rivers and their tributaries make up around 160 000 cubic kilometres. Main rivers make up 47% of this total length while tributaries constitute the remaining 53%. The density of South Africa's river network, as well as the volume of water carried, increases as we move across the country from the arid west to the wetter east. Only about a quarter of the country's rivers are perennial (in other words, flow throughout the year). These rivers are mainly located in the southern and southwestern Cape and on the eastern marginal slopes of the country and channel over 50% of South Africa's mean annual runoff.

Characteristics of a river

Rivers and their tributaries are the veins of the Earth, providing much needed freshwater as they meander across the landscape. In addition to providing water, they also support activities such as fisheries, tourism, recreation and agriculture. Rivers play an important role in the water cycle, acting as drainage channels for surface water. Rivers are also sculptors of the landscape, eroding mountains and depositing silt, creating fertile floodplains and sediments in the deep ocean basins. Every river has a source. From its source, it flows downhill as a small stream. The beginning of a river is called its headwaters, which often have small waterfalls and rapids. The energy of flowing river water comes from the force of gravity, which pulls the water downward. The steeper the slopes of a river, the faster the river moves and the more energy it has. A river passes through three zones on its way from its headwaters to the sea. As it flows from its headwaters, it goes through the upper reaches, middle reaches, and lower reaches. Each zone has its own unique processes and activities, which create habitats for a variety of organisms. As a river flows downstream, it becomes wider and less steep. The end of the river is called its mouth or delta. Here, the river empties into another body of water – usually the ocean. Here freshwater mixes slowly with the salt water, becoming brackish water. Many kinds of fish, clams, molluscs and other sea life in this water, known as estuaries. The shape of the river's mouth depends on the conditions of the sea where it flows into.

[3] Nel, J.L. & Driver, A., 2015, National river ecosystem accounts for South Africa, https://www.statssa.gov.za/wp-content/uploads/2016/08/National-River-Ecosystem-Accounts-Discussion-Document-FINAL.pdf

Catchments of life



The area from which a river receives its water is called a catchment or watershed. A catchment refers to the area from where water, including both surface and subsurface water, drains towards a common point. A river's surface and subsurface catchment areas may not be the same. The extent of catchment areas is defined by hydrological divides. As the river flows, it collects more water from the catchment and from the groundwater, and grows larger, flowing downstream towards the sea. Human activities in catchments affect rivers in many ways. Overgrazing and ploughing can cause sedimentation in the river. Irrigated lands can increase salt loads, while mining, industry, sewage works, and poor sanitation contribute pollutants.[4]

A river is normally divided into a main stem and a number of smaller rivers or streams that connect to the main stem, called tributaries. The point were a tributary meets the main stem is called the confluence.

[4] Palmer, C (et al). 2018. How to… establish and run a catchment management forum (CMF). https://www.wrc.org.za/wp-content/uploads/mdocs/SP%20118-18%20web.pdf

The Orange River.

South Africa's main river systems include the Orange, the Vaal and Limpopo rivers. At more than 2 000 kilometres long, the Orange River is the longest river in South Africa. Along with its main tributary, the Vaal River, the Orange River conveys almost a quarter of the total surface water of South Africa. The source of the Orange River lies in the Lesotho Highlands (where it is known as the Senqu River). While only about 3% of the Orange River basin lies in Lesotho, the high mean annual rainfall in this tiny area contributes much of the Orange River's annual flow (up to 60%). As the river enters South Africa it flows south and west, eventually meeting the arid coast a few kilometres north of Alexander Bay.[5] Arguably the most dramatic point on the river occurs at the 56 metre-high Augrabies Falls. When the river is in flood, the roar of the water over the falls can be heard from kilometres away.

The Orange River is the most developed of all the rivers in southern Africa. There are no less than 29 dams in the Orange River basin, with a total storage capacity of more than 12 million cubic metres. The largest of these is the Gariep Dam.

[5] Kotzé, P. 2022. 'Lower Orange's spectacular summer show draws attention to the plight of SA rivers', ***The Water Wheel***, March/April 2022. https://www.wrc.org.za/wp-content/uploads/mdocs/WW%20March2022_SOUTH%20AFRICAN%20RIVERS.pdf

The Vaal River (named after its naturally dull brown-grey colour) is the second-largest river in South Africa, and a tributary of the Orange River. The 1 200 km-long river crosses a number of provinces from its source in the eastern Highveld plains, namely Gauteng, the Free State, Mpumalanga and the Northern Cape before meeting up with the Orange River at Douglas.

Water from the Vaal River is supplied to all the most important industries in South Africa situated around Pretoria and Johannesburg. These industrial areas produce more than 50% of South Africa's wealth as well as more than 80% of the country's electricity requirements. Vaal River water is also used in the country's largest government irrigation scheme, namely Vaalharts.

The Limpopo River forms the border between Botswana and South Africa, then the border between Zimbabwe and South Africa, before passing into Mozambique at Pafuri. The river is over 1 750 km long and drains a catchment of around 408 250 square kilometres. The Limpopo River has 24 tributaries, the main tributary being the Olifants River, one of the largest rivers passing through the Kruger National Park.

Rivers in semi-arid regions

Healthy river ecosystems are not a luxury but the basis for sustaining livelihoods in semi-arid regions. Many communities are entirely dependent on limited groundwater supplies for their livelihoods. Non-perennial rivers and their riparian zones provide many ecological goods and services, including natural flood control and replenishing groundwater resources. Seasonal rivers are particularly vulnerable to changes in hydrology, as they are adapted to brief periods of inundation and flow. While rainfall drives the inundation period of the aquatic ecosystems in the area, surface-groundwater interactions are thought to be important for sustaining them. The seasonal rivers of the Karoo are, for instance, highly dependent on groundwater discharge, which occurs at springs and when groundwater recharge (through precipitation at higher elevations) allows the water table to intersect with river channels. The upper reaches of the Salt River (Beaufort West), the Kamdeboo, Sundays and Brak Rivers (De Aar) are all good examples of these groundwater-fed watercourses.

Source: Vanishing waters[6] and The Water Wheel[7]

[6] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***
[7] Bonthuys, J. 2019. 'On the hunt for the elusive riverine rabbit', ***The Water Wheel*** July/August 2019. https://www.wrc.org.za/wp-content/uploads/mdocs/2019%20WW%20July_August_web.pdf

The Drakensberg is one of the most important water source areas in South Africa.

STRATEGIC WATER SOURCE AREAS

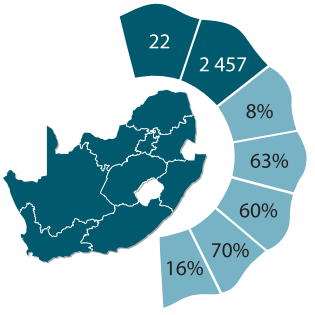
Most of South Africa's freshwater comes from catchments that receive the highest rainfall. These catchments are known as strategic water source areas – the country's water factories, if you will. Strategic water source areas provide a large volume of water per unit area, making them crucial assets in ensuring water security. These areas also underpin the ecological health of many landscapes.

South Africa has 22 surface strategic water source areas which, while only occupying 8% of the country's land area, and provide 50% of the surface runoff. These areas support the water needs of about 60% of the population and 67% of the national economic activity.[8] The Southern Drakensberg area generates the greatest recharge volume, followed by the Eastern Cape Drakensberg and the Boland Mountains areas. These areas vary in size, from the large Southern Drakensberg area (2 million hectares) to the small Table Mountain water source area (47 241 hectares).

The ecological health of South Africa's strategic water source areas has far-reaching implications. It is crucial to recognise that what happens in these areas significantly impacts the water quality and quantity downstream. These areas are of considerable value, especially those that are still functioning optimally and have not been modified by intensive land use or unsustainable practices. For example, what happens in the Maloti-Drakensberg strategic water source area in KwaZulu-Natal affects millions of people downstream, far removed from the source.[9]

The greater the proportion of land cover that has been modified (i.e. changed by human activities, such as agriculture and mining), the higher the likelihood of ecological functioning being compromised. This can have serious implications for the ability of highly modified areas to support water security in the region. The degree of intensively modified land cover differs drastically between areas.

The importance of South Africa's water source areas has been recognised in several national government policies and plans, although only about a fifth of these areas currently enjoy some form of protection.



About our water source areas:

22 The number of water source areas in South Africa

2 457 million cubic metres The total volume of water supplied by these areas a year

8% The percentage of land area taken up by these areas

63% The percentage of water source areas in natural condition

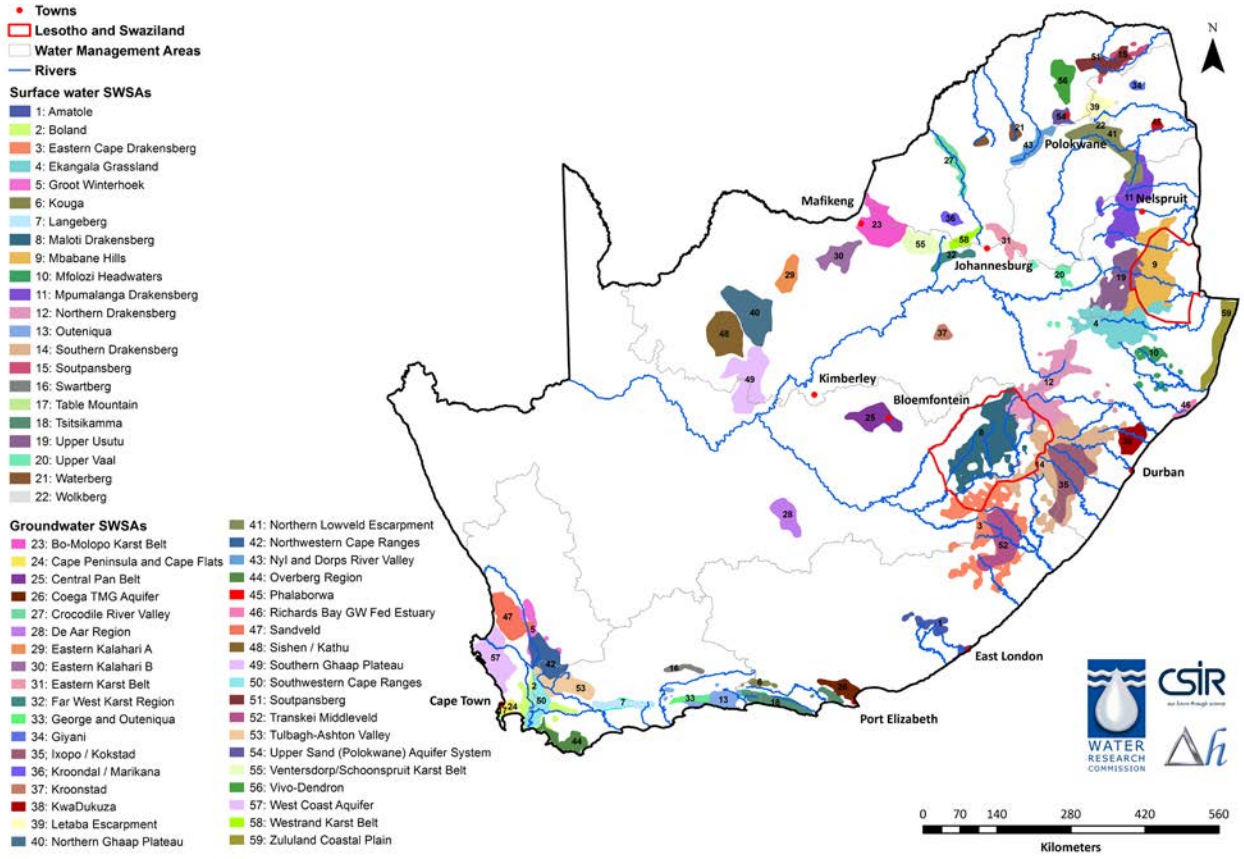
60% South Africa's population supported by its water source areas

70% The total percentage of irrigation water provided by the water source areas

16% The percentage of water source areas protected by law

[8] Department of Water and Sanitation. 2023. ***Revised Strategic Plan for 2020/21 to 2024/25***. https://www.dws.gov.za/documents/Other/Strategic%20Plan/2023/REVISED%20Strategic%20Plan%202020-21%20to%2024-25%20Mrt%202023_FINAL%2029%20Mrt%202023%20@09-00.pdf

[9] SANBI. 2023. Strategic water source areas count says STATS SA report. https://www.sanbi.org/media/strategic-water-source-areas-count-says-stats-sa-report/



The strategic water source areas of South Africa.

WETLANDS

Wetlands are recognised as one of the richest and most productive ecosystems on Earth. Also known as swamps, marshes, vleis, pans or seeps, wetlands are highly diverse and unique habitats. South Africa's wetlands cover about 2% of the country's surface area. An area can generally be recognised as a wetland if it is saturated by water either permanently or periodically (from time to time). Wetlands can be fed by surface- or groundwater sources. Wetlands vary greatly in size and plant cover, and their waters can vary in quality from pure to sweet to acidic or hypersaline[10] South Africa's wetlands have been classified into 135 distinct ecosystem types.

Wetlands are important in the protection, processing and regulation of runoff. A wetland acts as a sponge, holds back floodwaters, and releases it during drier periods. Wetlands, therefore, reduce flood damage and soil erosion. Wetlands are also groundwater recharge sites, and have the ability to remove pollutants from the water. In general, wetlands are protectors of the environment, providing breeding grounds and support a wide variety of species, which are totally reliant on wetlands for their survival.

South Africa was one of the 18 original signatories of the Ramsar Convention on Wetlands in 1971. This international treaty is aimed at the conservation and sustainable use of wetlands. A key commitment of the convention parties is to identify and place suitable wetlands onto the List of Wetlands of International Importance, also known as the Ramsar List. South Africa has 30 such wetlands.

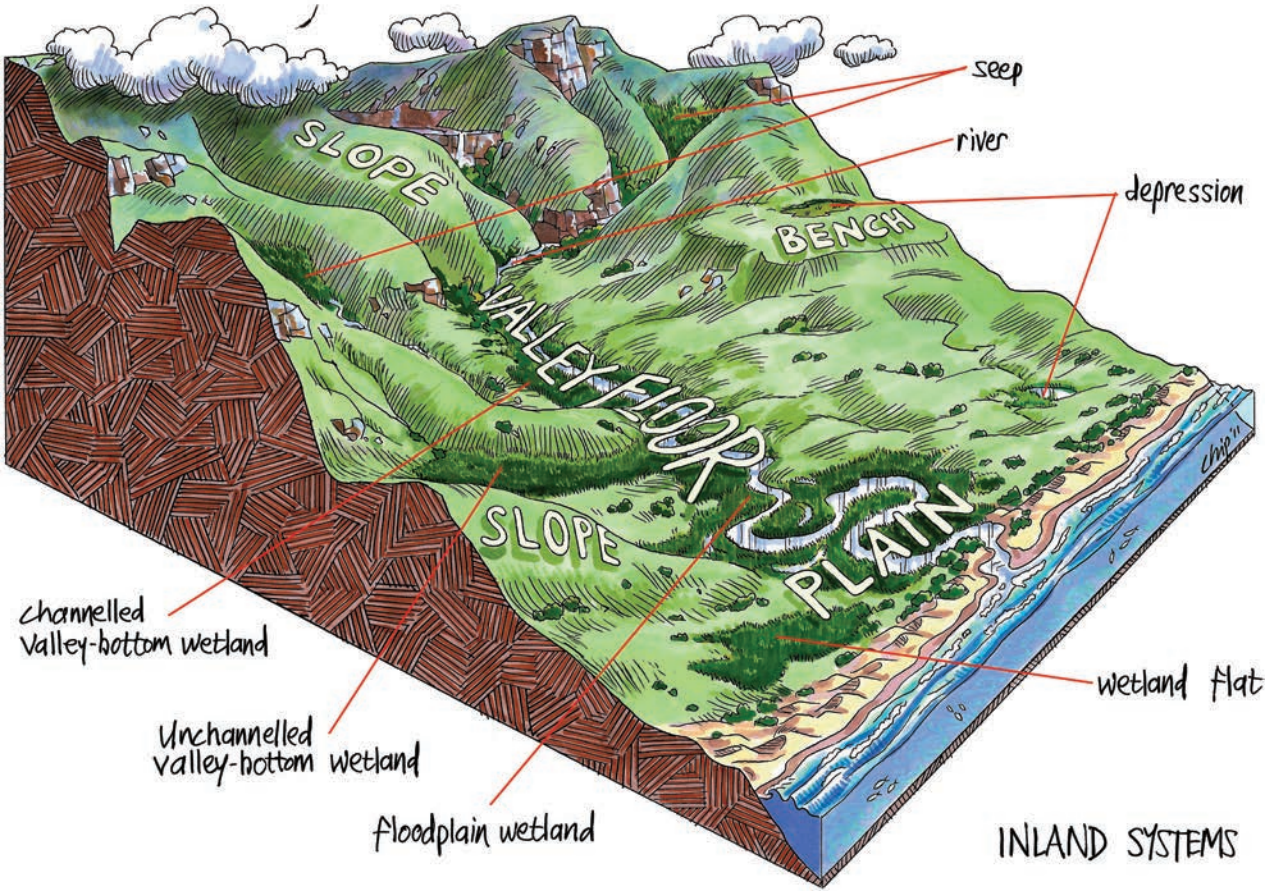
Wetlands are threatened habitats, and studies have shown that up to 60% of South Africa's wetlands have already been lost or severely degraded. There is also increasing concern about continued wetland loss and degradation. Agriculture, mining, rural practices and urban developments are factors destroying our wetlands. All these activities have an impact on water flow and water quality, which negatively impact on wetland health.[11]

Did you know?
The National Water Act (Act no 36 of 1998) defines wetlands as "land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated soil."

WRC archive

South Africa's wetlands are havens for scores of animals, birds, insects and plants.

[10] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***
[11] Van Ginkel, C.E. et al. 2010. ***Easy identification of some South African wetland plants***, WRC report no. TT 479/10. https://www.wrc.org.za/wp-content/uploads/mdocs/TT%20479%20web_smaller.pdf



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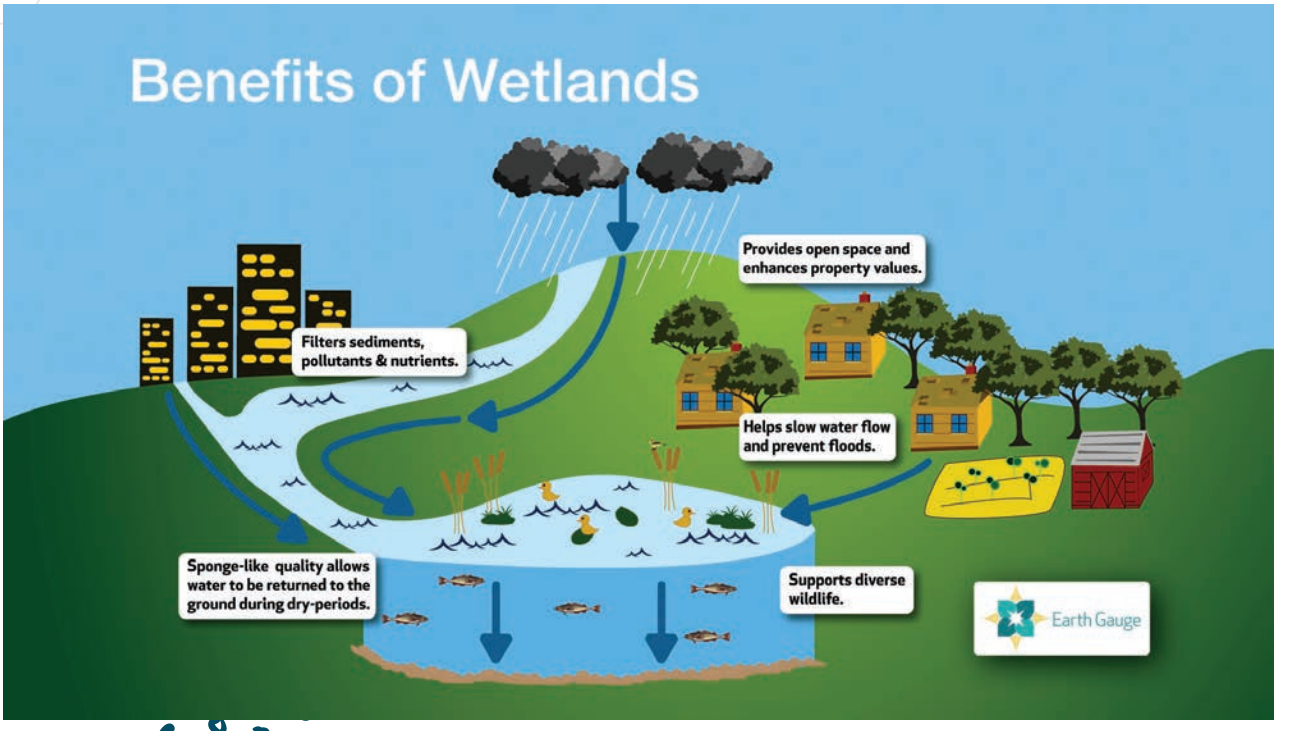
The different types of wetlands found in South Africa.


Benefits of Wetlands
Provides open space and enhances property values.
Filters sediments, pollutants & nutrients.
Helps slow water flow and prevent floods.
Sponge-like quality allows water to be returned to the ground during dry-periods.
Supports diverse wildlife.
Earth Gauge

WRC archive

A South African jewel – Verlorenvlei

Located 25 kilometres north of Lamberts Bay on the West Coast of South Africa, Verlorenvlei has been recognised as a Ramsar site of global significance since 1991. At 1 500 hectares, it is one of the largest wetlands in South Africa.[12] Technically, Verlorenvlei is defined as a partially closed coastal estuarine lake and marsh system. The wetland is considered an important bird area as it supports at least 189 bird species, of which 75 are waterbirds. The vlei occasionally hosts more than 4 000 birds, with the highest count reportedly being 11 891 birds. Although fed by three rivers, this system mainly relies on groundwater, making it slow-moving. Threats include excessive groundwater abstraction for agriculture, reduced water quality and hindrance of water flow by invasive alien vegetation. Verlorenvlei is one of South Africa's few coastal freshwater lakes and among the most important estuarine systems in the Western Cape. It rarely dries up completely, but in very dry years, the water level can drop extremely low. Until recently the estuary mouth was closed due to reduced water flow and sediment build-up.[13]

ESTUARIES

Estuaries and the lands surrounding them are places of transition from land to sea. Tides, rainfall and wave action constantly alter these dynamic systems. Water continuously circulates into and out of an estuary. Tides create the most significant flow of saltwater, while river mouths generate a flow of freshwater. When freshwater and seawater combine, the water becomes brackish or slightly salty.[14] Estuaries can be permanently or periodically (sometimes) open. Estuaries form the critical link between our inland catchment areas and the ocean.

South Africa has 290 estuaries and 42 micro-estuaries.

Estuaries are focal points for community and business activities along the coast as they provide us with a range of opportunities and benefits. They are an important location for cultural and recreational activities. Many businesses rely on estuaries to perform functions which have economic value, such as providing a nursery for marine fish and crustaceans (animals like prawns and crabs), for transport or for a place to provide facilities for tourists. In turn, this helps to support businesses and jobs in the coastal region (think of places such as Durban, Knysna and Kosi Bay).

Estuaries are often called the 'nurseries' of the sea. More than 100 species of fishes, prawns, and crabs in South Africa use

[12] Kotzé, P. 2011. 'Taking back the 'lost' wetland', ***The Water Wheel***, September/October, p22-27.
[13] Yield, J. 2021. West Coast's Verlorenvlei. What's lost when a wetland dries up? ***Daily Maverick***, 13 March, https://www.dailymaverick.co.za/article/2021-03-13-west-coasts-verlorenvlei-whats-lost-when-a-wetland-dries-up/
[14] National Geographic. 2023. Estuary. https://education.nationalgeographic.org/resources/estuary/

estuaries as nurseries and feeding grounds. The lifecycle of most of these species involve egg production at sea, often close inshore and near an estuary mouth. Should these habitats be degraded or destroyed, a drastic reduction in the number of these water species would occur.[15]

South Africa has several types of estuaries:

- **Permanently open estuaries:** Usually quite large systems with a perennial river and strong tidal exchange with the sea (examples include Breede and Swartkops estuaries).
- **Temporarily closed/open estuaries:** These estuaries are often closed for many months of the year and sometimes for more than a year at a time (examples include the Van Stadens and uMhlanga estuaries)
- **River mouths:** All rivers flowing into the sea have a river mouth. However, estuaries under this category are usually permanently open to the sea (such as the Orange and uThukela estuaries)
- **Estuarine lakes:** These estuaries occur where a coastal lake is connected to the sea by a channel of varying length and width. Local examples include St Lucia and Kosi Bay.
- **Estuarine bays:** These estuaries have wide mouths with strong tidal exchange resulting in a continuously open mouth, and the regular replacement of seawater in the lower and middle reaches (such as Knysna).

Water quality and ecological functioning of estuaries closely reflect human activity, not only along the estuarine sector itself, but also within its entire upstream catchment. Freshwater abstraction for human activities threaten the health and provision of ecosystem services supplied by estuaries. Estuaries are particularly sensitive to a reduction in freshwater inflow, which is the main driver of their dynamic, variable nature.[16]

WRC archive

St Lucia – South Africa's most iconic estuarine system

Located along the eastern coast of KwaZulu-Natal, the St Lucia estuarine system is 80 kilometres long and 23 kilometres at its widest point, making it Africa's largest estuarine system. More than 50% of all waterbirds in KwaZulu-Natal feed, roost and nest in this system. Of the 155 fish species that have been recorded in this system, 71 species use Lake St Lucia as a nursery area – and at least 24 of these are important in marine line fisheries.[17] More than 2 180 species of flowering plants have been documented here and it is home to many species of antelope such as waterbuck, reedbuck, kudu, nyala, impala and duiker.

[15] WRC. 2018. ***Splash** – **A water source for curious kids.***

[16] Kotzé, P. 2016. 'Protecting nature's nurseries – Study highlights importance of natural flow to estuaries', ***The Water Whee**l* July/August, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/WW%20July%202016_Estuaries.pdf

[17] iSimangaliso Wetland Park. 2024. Lake St Lucia. https://www.isimangaliso.com/index.php?option=com_zoo&view=category&layout=category&Itemid=1234

Knysna Estuarine Bay.

SOUTH AFRICA'S GROUNDWATER RESOURCES

Groundwater is an important water resource in South Africa. It is crucial in supporting economic development and sustaining water security in settlements entirely or partially dependent on groundwater supply. Groundwater currently contributes between 45% and 60% to domestic water supply.[18] It is also used in irrigated agriculture and mining and industrial uses (including power generation). Interestingly, Most of South Africa's rivers receive about 40% of their flow from groundwater.[19] A notable example is the Apies River, which flows through Pretoria.

The renewable groundwater volume in South Africa is estimated to be around 19 billion cubic metres per year. To give some context, the total capacity of the country's dams is approximately 32 billion cubic metres.[20] In some areas of the country, the available groundwater is already being used, but in most parts of South Africa, the groundwater resources are underutilised.[21]

South Africa's geohydrology is mainly characterised by six types of aquifers, namely the dolomites, Table Mountain Group sandstones, coastal sand deposits, basement granites, Karoo dolerites and alluvium along perennial rivers that have been broadly classified into karst, fissured, low permeability and unconsolidated intergranular deposits. Over 80% of the country is underlain by moderate to low-yielding, shallow, weathered and fractured-rock aquifer systems.

Groundwater can be extracted at relatively high rates from dolomitic and quartzitic aquifers in the northern and southern parts of the country, and from some primary aquifers situated along the coastline.[22] Due to growing demands on urban water resources, groundwater is increasingly being seen as a viable option for supporting urban communities. Groundwater resources are often relied upon during periods of drought to compensate for diminished and unreliable surface water supplies. Groundwater infrastructure is often also a more cost-effective and efficient option compared to surface water infrastructure.

Some South African towns and cities are already incorporating groundwater into their water resource strategies. This move aligns with international best practices and is crucial for ensuring a water-secure future, especially given the strain on surface water resources.[23] Understanding the quantity and quality of groundwater is equally important, which underscores the need for proper monitoring and management of groundwater resources.

THE IMPORTANCE OF PROTECTING OUR FRESHWATER ECOSYSTEMS

Freshwater ecosystems (rivers, wetlands, estuaries and so on) are not only important sources of water for people. These systems are also a habitat (place to live) for plants, animals and microbes. A freshwater ecosystem is an incredible network of various living creatures that interact with one another and the environment around them. South Africa's unique aquatic

[18] Mvandaba, V., Mwenge Kahinda, J., Nzuza, P & Hobbs, P. 2019. ***Green Book – The impact of climate change on groundwater availability.*** Technical report, Pretoria: CSIR. https://pta-gis-2-web1.csir.co.za/portal/sharing/rest/content/items/d9e7cd5647fb4e15b6043e790d22d619/data
[19] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***
[20] GEOSS. 2020. Understanding groundwater in South Africa. https://geoss.co.za/understanding-groundwater-in-south-africa/
[21] Nel, M. 2017. ***Groundwater: The myths, the truths and the basics.***
[22] Mvandaba, V., Mwenge Kahinda, J., Nzuza, P & Hobbs, P. 2019. ***Green Book – The impact of climate change on groundwater availability.***
[23] Kotzé, P. 2019. ***Water resilient cities.*** https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/SP%20130_Water%20Resilient%20Cities_web.pdf

animals have evolved to withstand the country's variable river flows. Aquatic animals seek out refuge pools when river flow stops, while invertebrates and fish may scuttle beneath the surface into moist layers of the riverbed. Many South African aquatic invertebrates have also developed a part of their lifecycle that can withstand long periods without water. When the river starts flowing again these species reproduce quickly to repopulate the aquatic habitat.[24]

In addition to supplying us with water, freshwater ecosystems also provide other 'services' such as enhancing soil health, protecting against extreme floods and droughts, providing carbon storage and sustaining biodiversity. Rivers are like mirrors that reflect the landscape around them and provide us

[24] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***

with valuable information about the environmental conditions of their catchments. It is essential to take into account what happens upstream as it directly impacts the water quality and quantity downstream.[25]

Unfortunately, overexploitation, pollution and degradation are threatening a large percentage of South Africa's freshwater systems. In fact, South Africa's freshwater systems are among the most threatened ecosystem types in the country, with freshwater fishes the country's most threatened species group.

Of the 118 freshwater fish species in South Africa, 25 are considered 'threatened', meaning that they are either classified as vulnerable, endangered or critically endangered.[26] This is especially concerning given the fact that half of the country's fish species are endemic, meaning they are found nowhere else in the world, with several species only occurring in single, small rivers. Freshwater populations are directly affected by water quality, habitat stressors and reduced river flows, affecting connectivity between the rivers and the sea. The latter especially affects the 100 or so migratory species.

WRC archive

Half of South Africa's freshwater fish species are endemic.

[25] WWF. 2023. Water stewardship. https://www.wwf.org.za/our_work/initiatives/water_stewardship/

[26] Kajee. M. et al. 2023. 'The status of South Africa's freshwater fish fauna: A spatial analysis of diversity, threat, invasion and protection', ***Fishes***, 8, 571. https://doi.org/10.3390/fishes8120571

Did you know?
Nowhere is the world's biodiversity crisis more acute than in freshwater ecosystems. Around a third of freshwater species are threatened with extinction. Only a third of the world's large rivers are still free-flowing and around 35% of wetlands have been lost in the past five decades.

The health of our rivers, wetlands and estuaries is threatened by several factors. These include:

- **Pollutants**: Freshwater systems are under attack from all angles. Pollution such as untreated domestic and industrial sewage, agricultural runoff (pesticides and fertilisers), toxins from mines, and solid waste all threaten the water quality and biodiversity in rivers, wetlands and estuaries.
- **Overabstraction**: Poor management has resulted in excessive water abstraction from river systems, mainly for irrigation. Some of South Africa's once-perennial rivers, such as the Sabie, Luvuvhu, Letaba and Limpopo rivers now dry up during parts of the year as a result. This despite the fact that South African water legislation makes provision for an 'ecological reserve' – a volume of water to remain in rivers to maintain environmental processes.
- **Chopped up rivers**: Artificial barriers, such as dams and weirs, are a threat to river ecosystems. Unless carefully designed, they prevent the natural flow of sediment and prevent migratory fishes from travelling up- and downstream to complete their lifecycles.
- **Sand mining**: River sand is often preferred for construction, however, excessive (and sometimes illegal) sand mining is not only destroying river habitats and causing physical and hydraulic changes to the river systems, but also impacting water quality.
- **Overfishing**: Destructive fishing methods are taking a toll on the population of several species.
- **Unnatural river flows**: Decisions related to water flow management, hydropower, dams and abstraction are harming freshwater species that depend on seasonal changes in flow quantity and timing for their lifecycles.
- **Climate change**: Freshwater ecosystems are particularly vulnerable to climate change because many freshwater species have limited abilities to disperse as the environment changes. Healthy systems are also central to climate adaptation and mitigation. Rainfall and river discharge have been extremely variable in southern Africa in recent times – between 50% above and 50% below historic levels. This has caused deep and mostly negative impacts across water-dependent sectors, from freshwater supply to people and agriculture, to availability of water for hydropower and tourism.

What is a free flowing river?
A free flowing river is largely unaffected by human-made changes to its flow and connectivity such as dams and weirs. Water, silt, and other natural materials can move along unobstructed. Animals, such as migratory fish, can swim up and down stream at will. And the river itself can swell and shrink naturally, flow at an organic volume and rate, and replenish groundwater sources. South Africa has only 62 free flowing rivers, which constitute only 4% of the country's river length.

It is important to realise that all water in an ecosystem has a purpose and is not wasted or surplus. All the water occurring naturally in a wetland, or running in a river, is for instance useful to the system – sometimes in subtle ways. While it may seem like excess water is flowing to the asea, it is actually an integral part of the natural system. Floodwaters, for example, have an important role to play in flushing out and cleaning up riverbeds.

The health of a river can be measured by its plants and organisms. Minimally altered, moderately altered and heavily altered health classes characteristically have different groups of plants and animals living in them. A scoring system has been developed for the invertebrates found in water ecosystems on a scale from a to 15, where 1 is very tolerant and 15 is very sensitive.[27] In rivers, as in all ecosystems, the nutrients available to organisms are important in determining which organisms can be found where. Healthy ecosystems have a mix of sensitive and tolerant organisms, while less healthy ones may only have tolerant ones. Tolerant organisms can survive in a variety of conditions, while sensitive organisms die quickly if conditions change.[28]

Water ecosystems are cleaned by organisms such as bacteria, fungi, filter feeders, and plants. Loss of natural biodiversity reduces ecosystem services, making it less adaptable, fragile, and easily damaged.[29] Rivers classified as heavily altered are 'workhorse' rivers. Their main function is to supply water for agriculture, industry and people, and to dilute, transport and process wastes. They generally provide few natural products because they have far fewer habitats for living organisms that could live there.[30]

[27] Palmer, C (et al). 2018. How to… establish and run a catchment management forum (CMF). https://www.wrc.org.za/wp-content/uploads/mdocs/SP%20118-18%20web.pdf
[28] Palmer, C (et al). 2018. How to… establish and run a catchment management forum (CMF).
[29] Palmer, C (et al). 2018. How to… establish and run a catchment management forum (CMF).
[30] Palmer, C (et al). 2018. How to… establish and run a catchment management forum (CMF).

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Restoring connectivity in the Kruger National Park

The Kruger National Park (KNP) is a hotspot for aquatic biodiversity. The park has 600 kilometres of perennial river systems and 30 000 kilometres of seasonal and ephemeral streams (rivers that only flow after rainfall events). These rivers are home to 48 freshwater fish species of which 20 are considered long-distance migratory species. In recent years efforts have been underway to improve connectivity in the KNP's river systems by removing redundant and obsolete dams and weirs. By 2021, 21 dam structures had already been demolished. The park has also constructed 16 fishways to assist the movement of its migratory species.[31]

THE THREAT OF INVASIVE SPECIES

Invasive alien species have been identified as a major threat to South African freshwater ecosystems and water security. Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem. They tend to impact negatively on biodiversity by outcompeting native species, through predation or transmission of pathogens. These species also disrupt local ecosystems and ecosystem functions.

The country has identified over 380 invasive alien plants. These water-thirsty plants are literally sucking catchments dry at the expense of humans and nature while water weeds are choking dams and waterways. Invasive alien plants also increase the severity of wildfires and, since they have no natural enemies, they outcompete indigenous vegetation.

Given the country's water risks, stopping the spread of these plants in crucial catchment areas should be a priority.

The seriousness of the problem is illustrated by the Western Cape example where over two thirds of the catchments supplying the Western Cape Water Supply System (which supplies Cape Town and surrounds with drinking water) are infested by alien plant infestations. These plants are reducing the amount of water that reaches the rivers and dams that feed the region by 55 billion litres a year. This volume of water is equivalent to a sixth of Cape Town's current water-supply needs. In the Cape Floristic Region, estimates show that available water resources have been reduced by 15% due to invasive alien plants. This could rise to 37% over the next three decades if invasions are allowed to continue unchecked.

[31] Bonthuys, J. 2021. 'New movement aimed at saving region's freshwater fish', ***The Water Wheel*** May/June, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/WWMay-June2021_freshwaterfish.pdf

When it comes to securing Cape Town's future water supply, clearing invasive alien plants in key water catchments has been shown to bring a better return on investment than building traditional engineering solutions, such as desalination plants, as an example.

South Africa does not only have troublesome plants. A total of 77 alien freshwater species have been identified in South Africa, of which 21 are fish species. Many of these species were introduced to South African freshwaters for the purposes of recreational angling, (e.g. rainbow trout, brown trout, and largemouth bass). Arguably the species that has had the greatest impact on indigenous fishes is the smallmouth bass (***Micropterus dolomieu***), a voracious piscivore (fish eater) originated from the USA. Authorities have started programmes to remove alien fish from certain priority rivers to allow especially endangered indigenous fish to reclaim their habitat.

Olaf Weyl / WRC archives

Eradicating alien fish at Rondegat River

The small Rondegat River rises in the Cederberg Wilderness before entering privately-owned farmland and flowing into the Clanwilliam Dam, in the Western Cape. The invasion of the river by smallmouth bass (***Micropterus dolomieu***) resulted in the local extinction of several native fish species in the lower reaches of the river. In a project led by CapeNature, Rotenone – a piscicide (fish killing chemical) – was successfully used to eradicate the alien invasive fish from the lower reaches of the river. Juvenile Clanwilliam yellowfish (***Labeobarbus capensis***) were recorded in the treated stretch of the river just three days after the initial treatment, and two months later both yellowfish and redfin minnow (Barbus Callidus) were recorded (the latter for the first time in probably 70 years).[32]

[32] Van Vuuren, L. 2012. 'Eradicating invasive alien fish – It can be done, project show', ***The Water Wheel*** November/December, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/07%20River%20rehab%20p%2020-25.pdf

Pieter Edelman/Flickr)

The weeds choking our waterways

A number of introduced water weeds, mostly stemming from South America, have become major economic pests in South Africa. They include Kariba weed (***Salvinia molesta***), water hyacinth (***Eichhornia crassipes***), parrot's feather (***Myriophyllum aquaticum***), and ***Azolla filiculoides***, a water fern. More recently, the Nile cabbage or water lettuce (***Pistia stratiotes***) has made its appearance in the Vaal River. All of these weeds have the potential for explosive growth, particularly in eutrophic conditions, and may cover and choke vast areas of standing or slowly-running water. They are widespread throughout South Africa and have already cost the country tens of millions of Rands in attempts to eradicate them. Water hyacinth, for example, prevents boating, angling and skiing, disrupts water flow and irrigation channels, and blocks sluices. It may also create ideal breeding habitat for malarial mosquitoes and bilharzia snails.

Chapter 3

WATER USE IN SOUTH AFRICA

Water is central to all life and, as such, the Constitution of South Africa provides that everyone has the right of access to at least basic water supply and sanitation. Water is also a critical input to almost all forms of socio-economic activity. This chapter looks at the main laws that guide the management of water, as well as the main users of water in South Africa.

As described in the previous chapter, South Africa is a semi-arid country, with limited access to water resources. Since groundwater resources are limited, and to overcome the uneven spread of water resources across the country as well as to mitigate against floods and droughts, South Africa has invested heavily in the development of bulk water infrastructure, mostly in the form of dams and related conveyance structures. This ability to regulate and manipulate the water available has been key to South Africa's progress and development.

Due to the high variability in river flow within a year and between years, storage needs to be provided to bridge low flow periods to regularly supply different sectors with enough water. No mining, urban and industrial development or power generation could be supported with water from a river, without storage being provided. Mega cities such as Johannesburg would probably have remained a small town had it not been for sophisticated engineered water systems. South Africa has a prolific history of dam development, especially in the last 100 years. At present, the country has 5 570 registered dams, with a total storage capacity of more than 33 900 million cubic metres (roughly equal to 70% of the surface mean annual runoff of the country). Most of these are small dams that serve farms and municipalities. The country's largest dams (about 500 in number) are managed by the Department of Water and Sanitation (DWS).

[1] South African National Committee on Large Dams (SANCOLD), Dams in South Africa, www.sancold.co.za
[2] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***

In South Africa, most of the main metropolitan and industrial growth centres developed around mineral deposits and seaports, far away from large rivers. This has led to the construction of a number of intricate inter-basin water transfer systems – where water is transferred from one catchment to another through a series of dams, tunnels and canals. The Orange River Project is one of these major inter-basin water transfer schemes, taking water from the Gariep and Vanderkloof dams on the Orange River through the Orange-Fish tunnel to the Sundays River catchment. South Africa's economic hub, Gauteng, is served by two inter-basin water transfer schemes, namely the Lesotho Highlands Water Project and the Thukela-Vaal Transfer Scheme.

While this sophisticated infrastructure provides a significant buffer in times of drought water users should always be aware that South Africa is a water scarce country. There are five main water use sectors in South Africa, namely agriculture, domestic, industries and mining, power generation and afforestation.

The Gariep Dam, in the Free State, is the largest dam in South Africa. Completed in 1972 the dam stores water from the Orange River. The dam wall is 88 metres high and contains about 1.73 million cubic metres of concrete. The dam has a capacity of 5 343 million cubic metres.

What is a dam?

In South Africa the word 'dam' refers to both the barrier that stops or diverts the flow of water along a river as well as the reservoir behind it. A typical dam is a wall of solid material (such as concrete, earth and rock) built across a river to block the flow of the river. Dams have been used for many purposes throughout history, such as to prevent flooding or redirect water to benefit agriculture and economic development. They can also provide essential resources such as water and electricity to nearby communities.[3] While seen as a sign of human ingenuity, dams have environmental downsides. They alter river functioning, harming aquatic populations, and impacting the river ecosystem.[4] Nearly 50 000 large dams have been built globally, storing five times the annual average volume of water flowing in all of the world's rivers combined. The two largest dams in southern Africa – Kariba on the border of Zimbabwe and Zambia and Cahora Bassa in Mozambique – both impound the Zambezi River.

[3] National Geographic. 2003. Understanding rivers. https://education.nationalgeographic.org/resource/understanding-rivers/
[4] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition***.

The difference between yield, reliability, available water and assurance of supply[5]

The yield from a water resource system refers to the volume of water that can be abstracted at a certain rate over a specific period of time. For water uses such as domestic, industrial and mining use, water is required at a relatively constant rate throughout the year. This is unlike irrigation water use, which will require more water during planting and growing season. South Africa has built numerous dams to overcome the large seasonal fluctuations in its rivers and streams. This means that water can be stored during periods of high flow for release during periods of low flow. This increases the rate with which water can be abstracted on a constant basis and, consequently, the yield.

The amount of water that can be abstracted without fail varies from year to year. The amount of water that can be abstracted reliably for 98 out of 100 years on average is referred to as the yield at a 98% assurance of supply. For a specific water resource infrastructure, the higher the assurance of supply required (or the smaller the risk of failure that can be tolerated), the smaller the yield that can be abstracted, and vice versa.

Available water refers to all water that could be available for practical application to desired uses.

When water is extracted from resources such as rivers at unsustainable levels, it reduces the amount of water flowing downstream. This affects the ability of the river ecosystem to properly absorb the byproducts associated with human life (for example, industrial discharge or fertiliser runoff). If this happens continuously over time, there can be substantial consequences not only for the aquatic environment but also for human development, including an increased risk of contracting a waterborne disease. Overexploitation in one area can have negative impacts in downstream communities.[6] Water systems that are overexploited for an extended period of time also become more vulnerable to the impact of external shocks such as droughts, floods and other extreme weather events.

[5] King, J. and Pienaar H. (Eds). 2011. ***Sustainable use of South Africa's inland waters.***
[6] Donneveld, Z. (et al). 2018. A delicate balance – Water scarcity in South Africa. https://issafrica.org/research/southern-africa-report/a-delicate-balance-water-scarcity-in-south-africa

that South Africa is a water scarce country. To ensure enough water at the right time and at the right quality requires sophisticated legislation and policies. Apart from the Constitution there are two main pieces of legislation that govern water resources in South Africa, namely the National Water Act (Act no 26 of 1998) and the Water Services Act (Act no 108 of 1997).

THE CONSTITUTIONAL RIGHT TO WATER

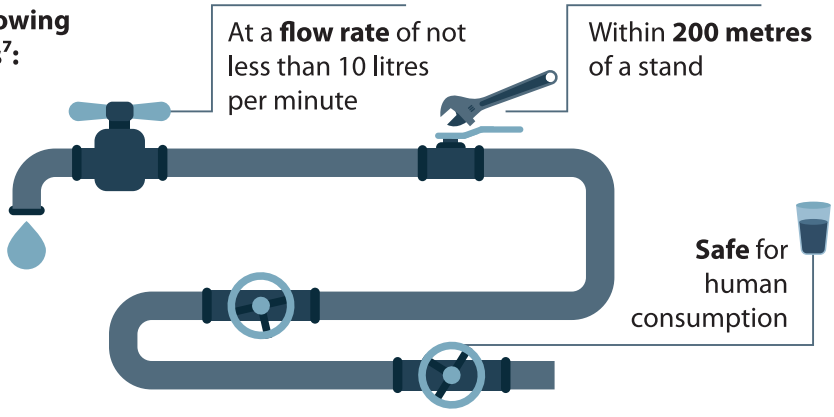
Access to water and sanitation are recognised by the United Nations as human right – fundamental to everyone's health, dignity and prosperity. In South Africa, the right to water is enshrined in Section 27(1)(b) of the Constitution which states that everyone has the right to have access to sufficient water. But what does that mean? It places a legal obligation on the government to ensure that all people living in South Africa have the right to sufficient water.

Did you know?
According to the World Health Organization, between 50 and 100 litres of water per person per day are necessary to ensure that most basic needs are met and few health concerns arise.

Government must provide the following basic water and sanitation services[7]:

At least **6 000 litres** per household per month:

No consumer may be without water or more than **7 days per year**



[7] Human Rights Commission, undated, The right to water and sanitation, https://www.sahrc.org.za/home/21/files/SAHRC%20Water%20and%20Sanitation%20revised%20pamphlet%2020%20March%202018.pdf

NATIONAL WATER ACT (NWA)

At the time of its promulgation, the NWA was hailed by the international water community as one of the most progressive pieces of water legislation in the world. Central to this legislation is the principle that water is a scarce natural resource that belongs to all of the people of South Africa, and that it must be used beneficially and in the public interest. The Act balances on the three legs of social benefit, economic efficiency and environmental sustainability, and sets out the legal framework for the national government to protect, use, develop, conserve, manage and control water resources in the country.[8]

The Act protects the rights of all people to have water for their basic needs, but also takes into account the needs of aquatic (water) ecosystems. The flow and water quality needed for basic human needs and for ecosystems to function is known as the 'Reserve'. Water for the Reserve is a right guaranteed by law. What does this mean in practice? Only after 1) the ecosystems are protected and 2) we are sure there is enough water basic human needs (such as drinking, washing and cooking), water is allocated to users. Water users include domestic households, industry, mining, and agriculture.

The NWA protects the rights of water ecosystems because they provide people with many free services necessary for life – water supply, waste processing and dilution, natural products (for example, fish, reeds and medicinal plants), flood control, recreation and places for beauty and religious rituals.

The purpose of the Act is to protect water resources to make sure we have sustainable resource use.[9]

It is important to realise that protection means 'to look after and use widely' – it does not mean 'to keep separate and do not use'. We must use water and water ecosystems for social and economic development. The Act, therefore, also identifies the need to establish suitable institutions to achieve its purpose (more about these below). In addition, it provides for the development of a National Water Resource Strategy (NWRS) which must be regularly reviewed. The first NWRS was published in 2004. The current, third edition of the NWRS was published in 2023, and sets out the following overarching goals:[10]

- That water must be protected, used, developed, conserved, managed and controlled sustainably and equitably.
- That water and sanitation must support development and the elimination of poverty and inequality.
- That water and sanitation must contribute to the economy and job creation.

[8] Schreiner, B., Viewpoint – Why has the South African National Water Act been so difficult to implement?, ***The Water Wheel,*** September/October 2013, pp 38-41, https://www.wrc.org.za/wp-content/uploads/mdocs/14%20Water%20law%20p%2038-41.pdf

[9] Palmer, C., H. Holleman & M Wolff. How to establish and run a catchment management forum (CMF), WRC report no. SP 118/18, https://www.wrc.org.za/wp-content/uploads/mdocs/SP%20118-18%20web.pdf

[10] DWS. March 2023, National Water Resource Strategy Third Edition, https://www.dws.gov.za/Documents/Gazettes/Approved%20National%20Water%20Resource%20Strategy%20Third%20Edition%20(NWRS3)%202023.pdf

The three main principles of the National Water Act:

Equity
(fairness to people living now)

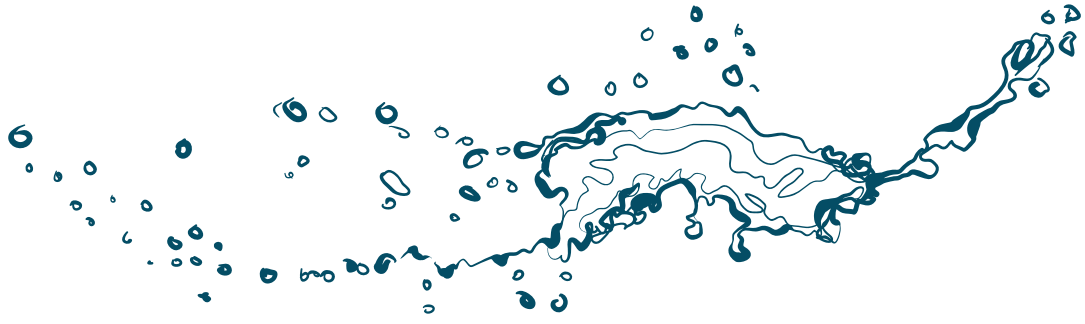
Sustainability
(fairness to people in the future and to the environment)

Efficiency
(when you do use water, use it responsibly)

WATER SERVICES ACT

While the NWA specifies how we manage, use and protect water resources for current and future generations, the Water Services Act (WSA) governs water delivery to people. In essence, the WSA prescribes the legislative duty of municipalities as water service authorities to supply water and sanitation according to national norms and standards. In addition, it regulates water boards as important water service providers. The Act further compels the Minister of Water and Sanitation to monitor the performance of water services and allows for departmental intervention should the need arise.

The two pieces of legislation places enormous tasks on the DWS to not only ensure that we have water secured as a country, but also that we have well-functioning water supply and wastewater management systems.



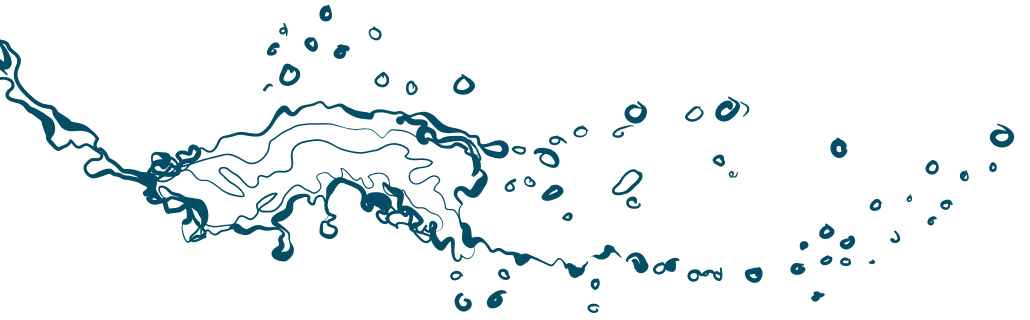
INSTITUTIONS RESPONSIBLE FOR WATER MANAGEMENT

In addition to the DWS, there are a number of institutions responsible for the management of South Africa's water resources. Some of these are described below.

Department of Water and Sanitation

National		Regional	Local
Resource management & development • Transboundry riversystem organsisations • CMAs • WUAs	**Resource development** • TCTA • Water Trading Entity • Strategic customers (e.g. agriculture & Eskom)	**Bulk infrastructure & distribution** • Water boards	**Distribution, wastewater treatment** • WSAs • WSPs

Main South African water management institutions.



DEPARTMENT OF WATER AND SANITATION

According to the NWA, South Africa's water belongs to all of its citizens. The DWS acts as the custodian of the nation's water resources. The mandate of the department is to ensure that the country's water resources are protected, used, developed, conserved and controlled. This is done by regulating and supporting the delivery of effective water supply and sanitation, in accordance with the requirements of water-related policies and legislation that are critical in delivering on people's right to have enough food and water, growing the economy, and eradicating poverty.

RESOURCE MANAGEMENT ORGANISATIONS

Transboundary river system organisations

South Africa shares four major river systems with neighbouring countries:

- The Orange-Senqu system is shared with Lesotho and Namibia;
- The Limpopo River is shared with Botswana, Zimbabwe and Mozambique
- The Incomati system is shared with eSwatini
- The Usutu/Pongola-Maputo system is shared with Mozambique and eSwatini.

South Africa's shared rivers

River system	Countries
Incomati	South Africa, Mozambique, eSwatini
Orange	South Africa, Namibia, Botswana, Lesotho
Limpopo	South Africa, Mozambique, Botswana, Zimbabwe
Maputo (Usuthu/Pongola)	South Africa, eSwatini, Mozambique

South Africa has signed and ratified the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, which promotes the principles of equitable and reasonable utilisation and the obligation not to cause significant harm (to downstream users). It also prescribes to the Southern African Development Community Protocol on Shared River Courses.

The management of internationally shared surface and groundwater resources is considered so important to South Africa that it has been taken up in the country's national laws (namely the National Water Act). This Act gives international requirements a priority that is second only to the basic human needs and the Ecological Reserve. This means that no infrastructure may be developed in any transboundary waters without considering the needs (or without the involvement) of the other countries involved.

In order to ensure the exchange of information and improve the joint management of the region's transboundary river systems, several transboundary river system organisations have been established in southern Africa. This includes the Limpopo Watercourse Commission (LIMCOM), Orange-Senqu River Commission (ORASECOM), the Komati Bain Water Authority, and the Incomati and Maputo Watercourse Commission (INMACOM).

The Limpopo River is one of the rivers that South Africa's shares with neighbouring countries.

Catchment management agencies

The National Water Act enables the establishment of catchment management agencies (CMAs) throughout South Africa. CMAs are responsible for the planning, implementation and management of water resources in a specific catchment. Secondly, they are tasked with coordinating the water-related activities of other water management institutions and water users within water management areas (WMAs). CMAs are governed by Governing Boards that are established by the Minister of Water and Sanitation.

South Africa has six CMAs. They are the Limpopo-Olifants, Vaal-Orange, Pongola-Umzimkulu, uMzimvubu-Tsitsikamma, Breede-Olifants and Inkomati-Usuthu CMA.

Water user associations

A water user association (WUA) is a co-operative association of individual water users who wish to undertake water-related activities for their mutual benefit. A WUA is governed by a management committee. Irrigation boards and certain stock watering related water boards are required to transform into WUAs, while other groups of users may join together in a proposal to the Minister for establishment according to a WUA constitution.

A fundamental change between a WUA and the former Irrigation Boards (established under the previous 1956 Water Act) is that the WUA should incorporate all water users of any water resource within its local area of jurisdiction not just agricultural water users. It is not appropriate for multiple WUA to be operating for different users within the same area. This implies that depending upon the definition of the WUA area, users of surface and groundwater may need to be considered, as well as recreational, waste discharge and domestic-industrial abstractors. In terms of the principles of redress, the needs of community subsistence agriculture and emerging farmers require particular attention, where these are relevant.

RESOURCE DEVELOPMENT ORGANISATIONS

TCTA

The Trans Caledon Tunnel Authority (TCTA) was established in 1986 as a specialised liability management entity. It is responsible for financing and implementing the development of bulk raw water infrastructure and providing treasury management services to the DWS. The authority plays an important role in providing financial advisory services such as structuring and raising project finance, managing debt and setting tariffs; project implementation services; and other technical support to the DWS and water boards.

Water trading entity

The Water Trading Entity is a subdivision of the DWS. The entity's main functions relate to the development, operation and maintenance of specific water resources infrastructure and managing water resources in specific water management areas.

[18] Amatola Water. Undated. Desalination an alternative solution to SA's water supply challenges, https://amatolawater.co.za/talking-water/details/desalination-an-alternative-solution-to-sas-water-supply-challenges

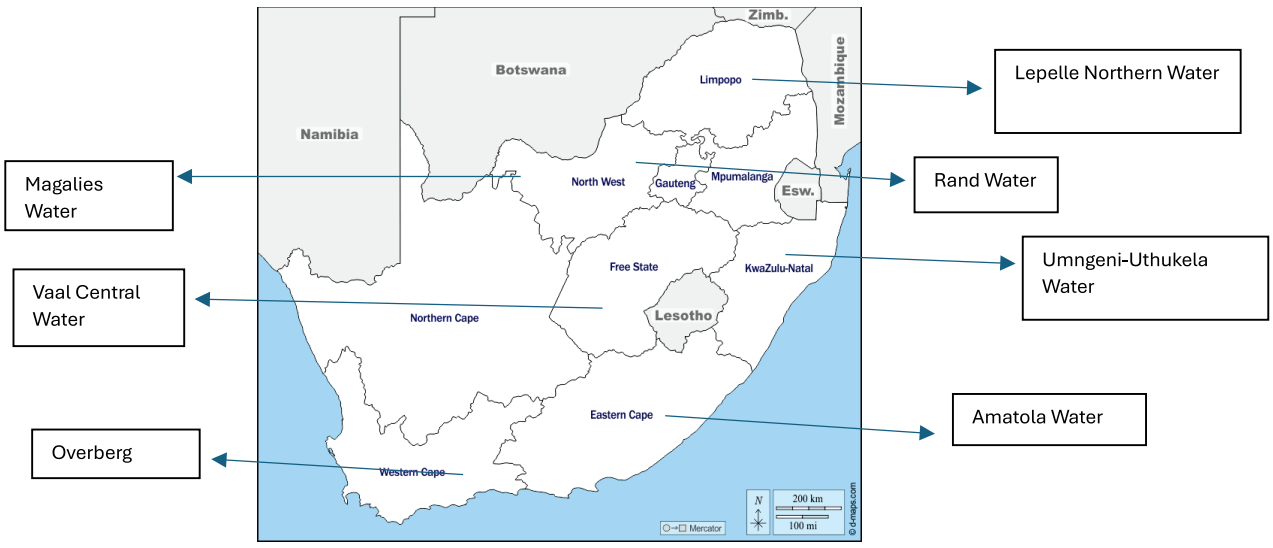
Roles and purpose of CMAs.

BULK INFRASTRUCTURE AND DISTRIBUTION

Water boards

Government-owned water boards play a key role in the South African water sector. They operate dams, bulk water supply infrastructure, some retail infrastructure and some wastewater systems. Some also provide technical assistance to municipalities. Through their role in the operation of dams they also play an important role in water resource management. The water boards report to the DWS.

There are seven water boards in South Africa. The three largest water boards in the country are Rand Water in Gauteng, Umngeni-Uthukela Water in Kwazulu-Natal and Overberg Water in the Western Cape.



The location of South Africa's water boards.

Water distribution and wastewater treatment

Most water users in South Africa are served by water service authorities (WSAs) and water service providers (WSPs).
A water service authority is defined as any municipality responsible for ensuring access to water services. Some WSAs also act as water service providers. In providing water services, a water service authority must prepare a water service development plan (WSDP) to ensure effective efficient, affordable and sustainable access to water services. The WSDP should be in line with the catchment management strategy of that water management area. The plan provides a linkage between water services provision and water resources management.

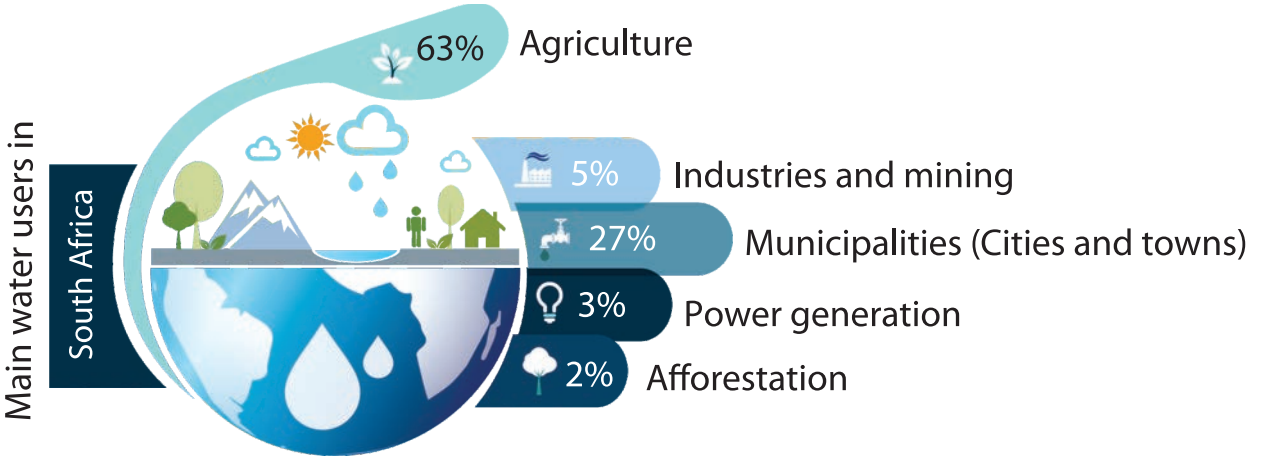
It is important for all water users to be involved in the development of WSDPs as their direct experience with the current system provides invaluable insights into the needs, concerns and priorities, ensuring that the new plans effectively address local challenges and deliver the most relevant water services for their community.

[20] M. Nel. 2017. *Groundwater: The myths, the truths and the basics.*

WATER USERS

Every citizen has a moral and legal obligation to protect the country's water resources and use it as efficiently as possible. There are five main water use sectors in South Africa, namely agriculture, domestic, industries and mining, power generation and afforestation.

DWS



AGRICULTURE

Every person needs 50 to 100 litres of water per day to meet basic drinking, cooking and hygiene requirements. By comparison, it takes 2 000 litres to 5 000 litres of water per person per day to grow the food to support diets of 2 800 kilocalorie daily, the benchmark for food security set by the United Nations Food and Agriculture Organisation (FAO).[11] Understandable then that agriculture is the largest water user in South Africa.

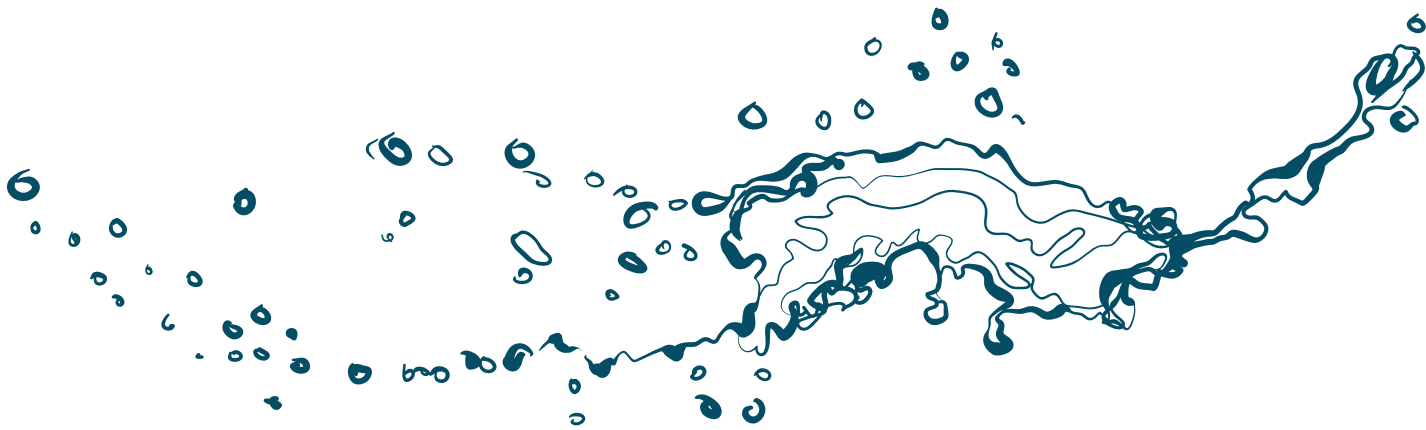
Most of the agricultural water use in South Africa is for irrigation. Most of South Africa's soil is not suitable to irrigation. Only about

[11] UNESCO World Water Assessment Programme. 2009. Water in a changing world: the United Nations world water development report 3. https://unesdoc.unesco.org/ark:/48223/pf0000181993

1.5% of the land is under irrigation, producing 30% of the country's crops. Up to 90% of irrigated areas are estimated to be planted with high-value crops (such as potatoes, vegetables, grapes and other fruit) of which up to 40% are industrial crops such as sugarcane and cotton.

Various irrigation methods are used for the irrigation of crops. This includes sprinklers, moving systems, micro irrigation, and flood irrigation. As the country's water resources are already highly developed and utilised, further allocation of water resources to irrigation development will only be made in exceptional cases. Given South Africa's water realities, the challenge is to produce more food with the same amount or less water. As our water resources become more constrained, the amount allocated to irrigation will come under greater pressure. This necessitates much improved overall management of especially surface water.

South African farmers are increasingly investing in more efficient irrigation technologies, such as drip irrigation. This involves the delivery of water and fertilizer across a field in pipes called dripperlines, emitted through drippers. The enriched drops of water are delivered directly to the plant's root-zone. Many farmers also practice irrigation scheduling. To avoid under- or overwatering their crops, farmers carefully monitor the weather forecast, as well as soil and plant moisture, and adapt their irrigation schedule to the current conditions. Smart water metering technologies and water monitoring allow farmers to identify leaks and water losses early and apply interventions that save water. Tools such as soil sensors, drones, and satellite imaging are some of the technologies that can be used to evaluate whether an irrigation block may be overwatering or underwatering. It is important for farmers to gather this information regularly, and use it as a foundation for decisions made on irrigation infrastructure and scheduling.



[22] DWS. 2023. National No Drop Report 2023. https://ws.dws.gov.za/IRIS/releases/ND_2023_Report.pdf
[23] M. Rabe, D. Maree. R. Ramano & G. Price. 2012. ***Compendium of water conservation and water demand management interventions and measures at the municipal level in South Africa.*** WRC Report no. TT 519/12, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20519-12.pdf

Netafim / WRC archives

Low flow drip irrigation in a citrus orchard.

WATER FOR INDUSTRY AND POWER GENERATION

Water is used by industries for various purposes such as a solvent, a coolant, a dust settler, a cleanser and even as a means of transport. However, some industrial processes require a lot of water, such as steel production, which takes about 150 cubic metres of water to produce a single ton of steel. A large amount of water used in industrial processes end up getting polluted and returned to the source as effluent.[12]

South Africa has an incredible wealth of minerals, including much of the global store of platinum metals, manganese, chrome, vanadium and gold, to name a few. The mining industry in South Africa is allocated about 2% of the country's water resources.

[12] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third Revised Edition.***

From an economic perspective, it is an important industry, contributing about 6% to the Gross Domestic Product, and employing about half a million people.[13]

Water is also a critical primary resource used in the generation of electricity. On average, it takes about 1.4 litres of water to produce 1 kWh (kilowatt hour) of electricity in South Africa.[14] This is on par with the world average. Eskom's base load power stations are primarily coal-fired and located inland (Mpumalanga, Free State and Limpopo) and is supplied with raw freshwater from several water-supply systems. This water is used for cooling, steam generation, ashing, washing and air emission and abatement.[15] The Vaal River system is the main supplier of water to Eskom, providing water to 11 of the company's power stations. Eskom uses around 320 000 megalitres of water a year in its coal-fired, nuclear and new-build power stations.[16]

Water can be used to generate electricity, although it is not common in South Africa. This is done in two ways. Firstly, conventional hydroelectric stations capture the electricity of falling water to generate electricity which is then fed into the transmission lines that link up with the national electricity grid. Secondly, pumped storage schemes use off-peak energy to pump water into an elevated dam from a lower dam from which it can be released to generate electricity when required.

As a result of South Africa's limited water resources and unreliable rainfall, the country has limited potential for large hydropower stations. Eskom's two power stations on the Orange River, the Gariep and Vanderkloof, are the only significant hydroelectric schemes in the country. These power stations supply power to the national grid during peak and emergency demand periods, as well as for base load energy when excess water poses a flood risk.

Power generation accounts for 2% of South Africa's freshwater use. The largest use of water in the energy sector is for cooling turbine exhaust steam.

[13] Minerals Council of South Africa. 2023. www.mineralscouncil.org.za
[14] Hattingh, M. 2021. 'Despite ageing infrastructure Eskom still on par with world water efficiency levels', ***The Water Wheel*** November/December, pp 14-17. https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/WW%20Nov%20-%20Dec%202021_WATER%20AND%20POWER%20GENERATION.pdf
[15] Eskom. 2018. Water supply factsheet. https://www.eskom.co.za/wp-content/uploads/2021/03/ENV0001RawWaterSupply.pdf
[16] Eskom. 2018. Water supply factsheet.

Controlling water pollution in South Africa

One of government's responsibilities is to manage the quality of water resources in South Africa. One way in which this is done is by way of licencing. Potential polluters (e.g. industries, wastewater treatment plants, mines etc.) are required to apply for a licence to discharge effluent (wastewater) into a water course such as a river. DWS also prescribes to the 'precautionary principle' and the 'polluter pays' principle. The **precautionary principle** essentially means that if a wastewater is likely to cause a problem in the receiving water, it will not be allowed to be discharged. The **polluter pays principle**, on the other hand, means that if an industry, mine or municipality is caught polluting it needs to either pay by cleaning the effluent on site at own expense, or pay a waste-discharge fee.

WATER AND TIMBER PLANTATIONS

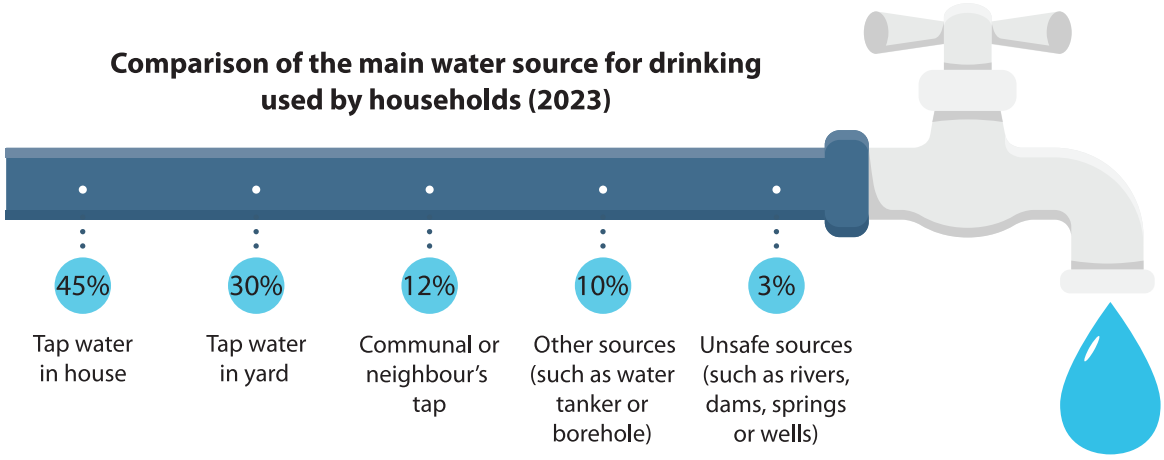
Although timber plantations in South Africa are not irrigated they use about 2% of the country's available water. While this usage is legally sanctioned through appropriate licensing processes, it is important to ensure that timber plantations are well designed and managed to reduce any negative impact on freshwater ecosystems.

Trees use soil water for photosynthesis and release it through transpiration. They also prevent some rainwater from reaching the ground, altering the area's water catchment. This is why the commercial forestry sector in South Africa pays a streamflow reduction tax.[17]

WATER FOR DOMESTIC USE

The provision of safe and readily available water is important for public health and poverty reduction. The South African Constitution provides that everyone has the right to have access to sufficient food and water. In order to give effect to this right Parliament has enacted the Water Services Act (Act no 108 of 1997). The purpose of this Act is to provide for the right to basic water supply and basic sanitation services (see a description of the Act above).

As at 2023, 87% of South African households had access to tap water either inside their house, on-site or off-site (i.e. outside the yard from either a neighbour's tap, public or communal taps).



Statistics South Africa [18]

[17] Forestry South Africa. 2023. Water use in forestry. https://www.forestrysouthafrica.co.za/wp-content/uploads/2018/11/171293-FSA-Inforgraphic-booklet-Final-low-res.pdf
[18] Statistics South Africa (Stats SA), General Household Survey 2023. (Stats SA: Pretoria, 2024)

The water and sanitation challenge

Access to clean water is one of our most basic human needs. However, one in four people in the world do not have access to safe drinking water. This is a major health risk.[19] Unsafe water is one of the most significant health and environmental problems in the world, especially for those who are struggling financially. Not having access to safe water sources is a major risk for infectious diseases such as cholera, hepatitis A, and typhoid.

Lacking access to safe water also makes malnutrition worse and leads to childhood stunting, which is a condition where children are too short for their age due to chronic or recurrent malnutrition. Lack of proper water, sanitation and hygiene facilitation is a common contributor to child growth failure.

Even worse, in low-income countries, unsafe water sources account for a significant share of deaths. More people die annually from a lack of safe drinking water, sanitation, and hygiene services than water-related disasters. Many such deaths could be prevented if everyone had access to safe drinking water, sanitation services and good hygiene.

A worrying fact is that, on average, the per person water consumption in South Africa is higher than the global average. One driver of this is the high level of non-revenue water in South Africa. Non-revenue water refers to the difference between the amount of water put into the distribution system and the amount of water billed to consumers. Non-revenue water can either refer to water that is 'lost' out of the system due to leaks of pipes, commercial losses due to water theft (i.e. illegal water connections) or unbilled consumption (i.e. water used legally but not paid for).[20]

The demand for water in the municipal sector is expected to grow substantially in the next few decades as the population grows, more people move into moves and cities, and more people gain access to piped water services.

[19] Ritchie, H. et al. 2024. Clean water. https://ourworldindata.org/clean-water
[20] Donneveld, Z. et al. 2018. A delicate balance – Water scarcity in South Africa.

THE GROWING GAP BETWEEN DEMAND AND SUPPLY

Certain areas of the country are suffering from far more severe water stress than others. In South Africa, the demand for water already exceeds supply in many areas. With 98% of the available resources allocated there is little room for increased extraction. The gap between water supply and demand is increasing due to factors such as population growth and climate change. It is estimated that by 2030, the demand for water will be 17% greater than what is available.

The main aim of water management is to achieve water security. The goal is to ensure that, even if there is a drought, both domestic and industrial water users can access enough water to meet their needs, while protecting the environment. To achieve this, it is essential that the available supply of bulk water is adequate as well as measures taken to keep supply and demand in balance.[21]

The South African government is exploring a number of alternative water sources to augment the country's current water supplies. They include:

- **Desalination** – Desalination of seawater or brackish groundwater is one option, especially for communities located at the coast.
- **Groundwater** – Groundwater remains an under-used resource in South Africa. There is potential to expand the amount of groundwater extracted. This could be particularly useful for the agricultural sector.
- **Water conservation** and **water demand management –** This means introducing new tools and technologies to make water use more efficient while reducing the demand for water.
- **Rainwater harvesting –** This involves collecting and storing rainwater for future use. The most common method of rainwater harvesting is to catch and store rainwater from the roofs of buildings.
- **Water reuse**

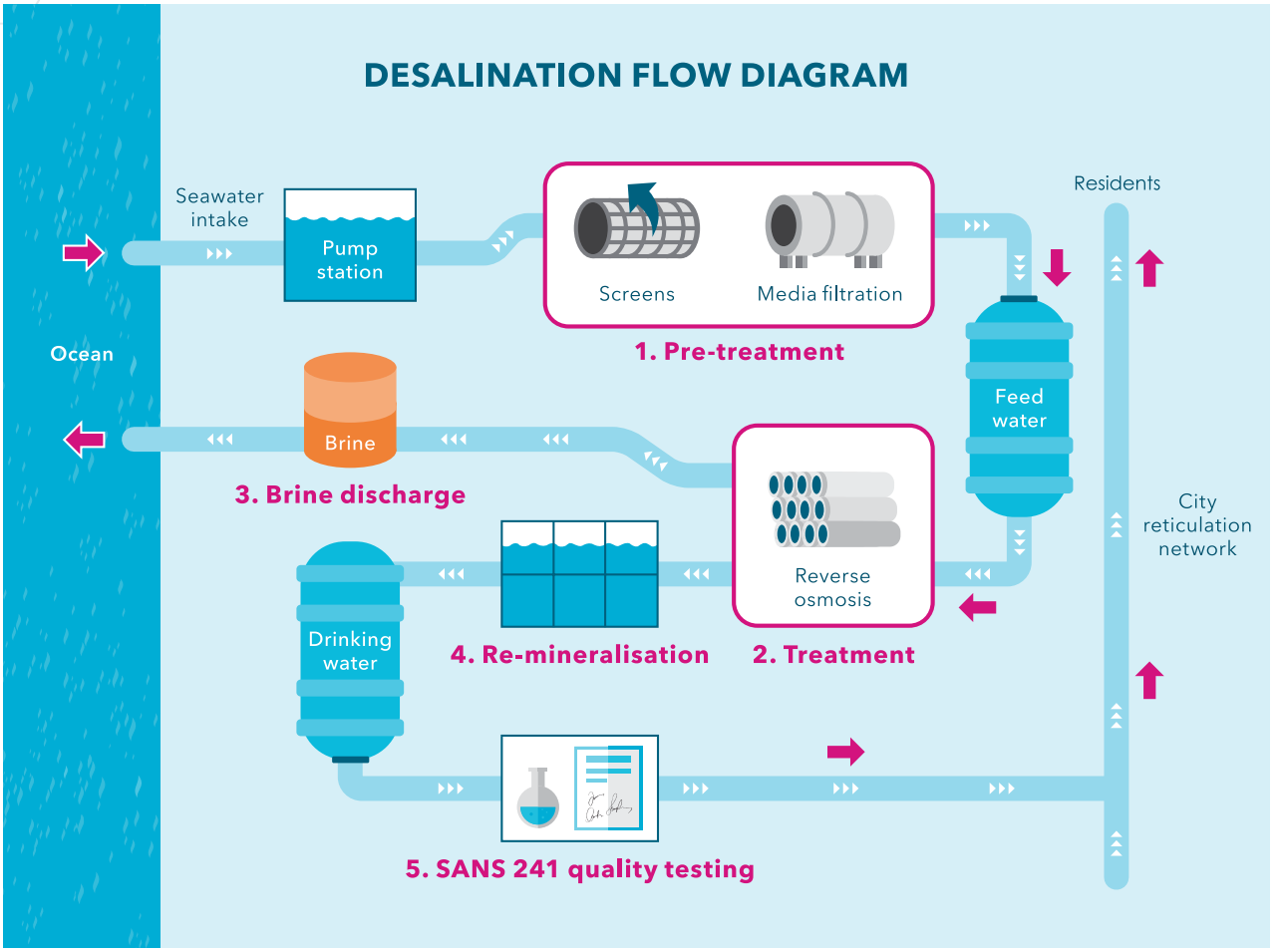
We all need to be more efficient in how we use our water.

DESALINATION

South Africa boasts a coastline of over 2 500 kilometres so the ocean should be considered as a water supply. Converting seawater to drinking water can be achieved by desalination. A proven technology in use all over the world, desalination involves removing the salinity (i.e. salts and minerals) from seawater or brackish water.

The most common form of desalination in South Africa is through reverse osmosis. This involves forcing water through cartridges that contain thin-film composite polyamide membranes, which trap salt and other impurities but allow the freshwater through. Desalination remains an expensive water-supply option, mainly as a result of the huge amount of energy required to push water through the membranes as well as the expertise required to run this sophisticated technology.[22]

[21] Muller, M. et al. 2019. Water security perspective for the Gauteng-city region. Gauteng City-Region Observatory: Johannesburg.
[22] Amatola Water. Undated. Desalination an alternative solution to SA's water supply challenges, https://amatolawater.co.za/talking-water/details/desalination-an-alternative-solution-to-sas-water-supply-challenges



How water treatment through desalination works. First seawater is pumped and cleaned through a number of pre-treatment steps to remove particles from the seawater, such as seashells, sand etc. The seawater is then fed under high pressure through fine membranes, which remove the salt and minerals from the water. The salt and minerals that are removed are contained in a fluid called brine, which is normally pumped back into the ocean. Minerals such as calcium are then added back to the treated water to stabilise it. Finally, the water is tested according to the national drinking-water quality standard (SANS 241). [23]

[23] City of Cape Town. 2020. Desalinated seawater, https://resource.capetown.gov.za/documentcentre/Documents/Graphics%20and%20educational%20material/Desalination_Booklet_English.pdf

At present, South Africa has about 10 desalination plants along the coast, most operated as small emergency schemes in use when there is drought. One of the oldest desalination plants in the country is located at Bushman's River Mouth in the Ndlambe Local Municipality, Eastern Cape. Owned and operated by Amatola Water, this plant was established in 1997, and serves the communities of Bushman's River, Harmony Park, Marselle, Kenton and Kenton Eco Estate.

GROUNDWATER USE

Groundwater is acknowledged as an integral part of South Africa's water resources and currently contributes about 15% of the total bulk water supply, although it contributes between 45% and 60% to domestic water supply. For many towns and rural communities, it is often the only available and affordable supply of water.

South Africa has a total of around 50 billion cubic metres a year potential available groundwater. When taking into account limitations such as groundwater quality; the potable groundwater exploitation of aquifers in South Africa is estimated at around 14,8 billion cubic metres a year. Groundwater is a major water-supply source for many Karoo and coastal towns. Dolomitic aquifers are a major freshwater source in the North West Province. Agricultural developments ranging from potatoes in the Sandveld, to tomatoes in Dendron, also depend on groundwater. Cape Town, Oudtshoorn and others have explored the Table Mountain Group Aquifer as a major source of water in conjunction with surface supplies. Even major cities, such as Pretoria and Johannesburg, still supplement their bulk water supplies with groundwater.[24]

Groundwater is available everywhere, but not always in usable quantities. However, generally, it is much cheaper to develop a groundwater resource within a 2 kilometre radius from potential users than to lay a pipeline from the closest dam or even to build a dam. Groundwater infrastructure is relatively cheap and can be put in place much faster than surface water infrastructure. In some in the country the available groundwater is already being utilised, but in the majority of areas in South Africa the groundwater resources are still underutilised.

Groundwater supplies are naturally replenished, or recharged, mainly by rain and snow melt. Groundwater depletion can occur when groundwater is pumped out faster than it is being recharged. Hydrogeologists can calculate the volume of recharge to a specific aquifer. This helps them to make recommendations to current and future groundwater users of the aquifer regarding a sustainable yield and to ensure fair distribution of the water available.

What is meant by the groundwater resource potential?
The groundwater resource potential refers to the maximum volume of groundwater that can be abstracted per unit per year without causing any long-term effects to the aquifer system.

[24] M. Nel. 2017. ***Groundwater: The myths, the truths and the basics.***

In addition, in many instances groundwater is fit to drink with little to no treatment although this is dependent on the chemical composition of the host rock in which the groundwater is found. For example, groundwater from the shales of the Malmesbury Formation in the southern parts of South Africa is unsuitable for most uses, due to naturally high total dissolved solids. Groundwater from granite aquifers often contains fluoride in high concentrations, whereas water from the dolomites is usually good drinking water, but quite hard. Groundwater from springs is used widely to deliver bottled water to consumers. These waters are usually of excellent quality, and rarely requires any treatment. Unfortunately, just like any source, groundwater can be contaminated as a result of human activities.[25]

Groundwater users should ask their local municipality the following questions:

- Are the water levels and groundwater quality being monitored on a regular basis?
- What potential contamination threats are currently in our community?
- Are there any measurements that I can take?
- Am I helping to keep the infrastructure secure and in good working order?

It is critical that water users get involved in the management of the groundwater resource. By contributing with information, being alert to damaging land-use activities and by being a responsible water user the overall task of groundwater management on a national and regional level becomes much more feasible.

Windmills are a common site in rural South Africa.

[25] M. Nel. 2017. ***Groundwater: The myths, the truths and the basics.***

WATER CONSERVATION AND WATER DEMAND MANAGEMENT

As a result of the infrastructure intensive supply systems needed at a national, regional and local level to deliver water to end-users, many municipalities across the country are struggling to sustainably meet consumer demand. While municipalities are struggling to meet demand, in contrast water losses in South Africa are at an all-time high. According to the latest available data from the DWS, South Africa's non-revenue water exceeds 46%, while water losses are at 41%.[26]

WSAs (i.e. municipalities) are required, through legislation to measure and monitor performance related to water use targets, non-revenue water, water losses and water use efficiency, while the DWS is tasked with regulating the WSAs' performance. Customers should be encouraged to report visible leaks to their municipality as soon as possible.

It is clear that there is a need for demand-side and supply-side interventions to reduce water use and water losses. This is known as water conservation and water demand management. **Water conservation** refers to the minimisation of loss or waste, the preservation, care and protection of water resources and efficient and effective use of water. **Water demand management** refers to the adaptation and implementation of a strategy by a water institution to increase the water use efficiency of users and thereby reduce the demand for water.[27] Water conservation and water demand management (WC/WDM) offer a viable option to create required efficiencies among existing users.

WC/WDM approaches usually address aspects such as:

- Efficient use of water whereby more 'work' is done with the same amount of water
- Institutional use of water and efficiency thereof
- Wasteful use of water, whereby wastage is reduced or halted
- Loss of water, in that water in the supply is limited or stopped, and
- Reuse and recycling of water.

It also includes technical interventions, such as on-property leak repairs, water reuse and end-user metering; financial interventions such as tariff formulation and structure, and credit control; institutional measures such as planning for droughts; and behavioural change measures, which aim to change habits relating to water use, and encourage the uptake of alternative technologies.

RAINWATER HARVESTING

When groundwater and surface water sources are in short supply, rainwater may be a sustainable alternative or supplement to conventional water supply. In the past two decades, there has been a growing recognition of the potential contribution of low-cost alternative water management technologies such as rainwater harvesting to improve the livelihoods of households, especially in semi-arid and arid parts of the country.

[26] DWS. 2023. National No Drop Report 2023. https://ws.dws.gov.za/IRIS/releases/ND_2023_Report.pdf
[27] M. Rabe, D. Maree. R. Ramano & G. Price. 2012. ***Compendium of water conservation and water demand management interventions and measures at the municipal level in South Africa.***

Rainwater harvesting has been shown to be effective in alleviating water scarcity for crop and livestock production, and for domestic use in arid areas. It is typically practiced to enable households to bridge dry spells and droughts, and to provide water supplied in regions where it is difficult or not feasible to provide public conveyance systems due to difficult terrain.

Some of the rainwater harvesting and conservation practices employed locally have been used for a long time (for example, rooftop rainwater harvesting and road runoff water harvesting) while others were more recently introduced (such as in-field rainwater harvesting in agriculture). Commonly, households use a set of or a combination of rainwater harvesting practices to meet their different needs.

Rainwater harvesting at home

A basic rainwater harvesting system with tanks usually relies on gravity to take the rainwater from a roof to water tanks via the gutters. A 'first-flush' rainwater filtering system is usually installed to prevent dirt and foreign matter from entering the tanks. Tanks can be installed against a wall of a house under the roof eaves, or underground with the help of a specialist. Rainwater can be pumped from the tanks to where needed, such as a garden.

The most efficient roof surface for harvesting rainwater is a metal roof, which may be corrugated iron or a flat iron sheet. Tiled roofs may also be used, although they are not as efficient as metal for collecting rainwater. Rainwater cannot be harvested from a thatched roof – partly due to the lack of guttering, as well as water discolouration, but mostly due to the lack of runoff from the roof.

The volume of rainwater collected depends largely on the roof area and the volume of rain that an area received. For example, one can obtain 500 litres of water if 5 millimetres of rain is collected on a 100 cubic metres roof. Due to possible suspended particles in the water, and increased acid levels in rainwater as a result of air pollution, it is not advisable to use rainwater for human consumption.

STORMWATER HARVESTING

The concept of urban stormwater harvesting is slowly starting to see popular uptake. In the majority of Australian cities and towns, for example, stormwater is now accepted as a valuable alternative water source where it is popularly used for irrigation of communal green spaces. In South Africa, stormwater remains a resource almost entirely untapped, though there are increasingly examples from across the country where stormwater runoff is being harvested from large parking lots and commercial properties.

Although stormwater can be treated to drinking water standards, this option can be costly. There is only one example of successful, large-scale harvesting of stormwater that has been ongoing in South Africa for decades. The award-winning Atlantis Water Resource Management Scheme has proven that reuse of stormwater is feasible, although it is a complex system dependent on expert management.

WATER REUSE

Water reuse (also known as water recycling or water reclamation) involves treating ('reclaiming') water from a variety of sources, such as wastewater, for the purposes of reusing the water for a number of purposes, such as agriculture, drinking water, groundwater replenishment, industrial processes and environmental restoration. Water reuse can provide alternatives to existing water supplies and be used to enhance water security, sustainability and resilience.

In South Africa, the recycling of water for any purpose is strictly regulated. Overall, our laws are not aimed at regulating reuse of wastewater but rather to protect and conserve the country's natural water resources. Thus, the goal is largely to return treated wastewater to the natural water environment in order to recover as much of the volume of water originally extracted, and ensure that this reclaimed water does not harm the aquatic environment.

What this means is that in South Africa, unplanned water reuse takes place in many areas where municipalities draw water supplies from rivers, such as the Vaal, that receive treated wastewater discharges from communities upstream. Planned water reuse involves redirecting treated wastewater and purifying it so that it can be used again, rather than releasing it all back into the rivers and the ocean.

Cities such as Cape Town, however, are strongly considering water reuse as part of its diversified mix of water sources to safeguard the municipality against future droughts, while cities such as eThekwini have been selling treated wastewater to industrial users for many years. In Namibia, Windhoek has been practicing water reuse since 1968. The Goreangab water reuse plant produces 21 million litres of water per day (25% of the total water consumed in Windhoek).

The Great Karoo town of Beaufort West was the first town in South Africa to have a direct potable reuse plant, where

treated wastewater effluent is conveyed directly to a water treatment facility for further treatment to drinking standard.[28] The plant was constructed in 2010 when the town's main water supply, the Gamka Dam, dried up during a drought.

The reuse of water offers many benefits. It reduces the need to abstract more water from surface or groundwater sources, or build new dams or interbasin transfer schemes, all of which have environmental and financial costs. It also reduces the volume of treated effluent discharged back into aquatic systems, where it may degrade natural water quality.

Chris Swartz

The Beaufort West water reclamation plant.

As responsible citizens we all have a role to play in ensuring a water secure future by using the little water we have carefully and efficiently.

[28] Matthews, S., 'Water – precious resource to be used again, and again and again…', ***The Water Whee***l May/June 2015, https://journals.co.za/doi/pdf/10.10520/EJC169675

The role of natural infrastructure

Communities have become over-reliant on built or 'grey' infrastructure. However, 'green' or nature-based solutions (also called ecological infrastructure) offer a vital means of moving beyond business-as-usual to tackle numerous water-related issues, while also providing extra benefits crucial for overall sustainable development. These types of solutions are inspired and supported by nature, and use, or mimic, natural processes to contribute to improved water management. It recognises water not as an isolated element, but as an integral part of a complex natural process.[29]

Nature-based solutions may involve the preservation or restoration of natural ecosystems, as well as the imitation or improvement of natural processes in modified or artificial ecosystems. The interventions can vary in scale, from building a dry toilet to restoring a wetland. These solutions may also include extensive land restoration projects and efforts to prevent habitat loss, address habitat fragmentation, and maintain ecosystem connectivity.[30]

For example, wetlands within urban environments lessen the impact of polluted stormwater runoff and wastewater while immobilising pollutants, often performing better than conventional grey solutions. By improving water storage capacity in landscapes, including in soils and groundwater, the impact of drought can be cushioned and the impact of seasonal variability of water availability, lessened. By improving water availability and quantity, natural systems can thus contribute greatly to improving the overall water security of an urban area.[31]

Unfortunately, some of the country's ecological infrastructure is under severe pressure from intensive agriculture, mining and urban sprawl, which ultimately leads to the loss or degradation of our ecosystems. The maintenance and restoration of freshwater ecosystems are essential in order to reap the socio-economic benefits it offers, in the same way built infrastructure needs to be maintained. Both types of infrastructure require upkeep and investment in order to function optimally and provide the greatest possible benefits to society.

In 2018, a study showed that investments in nature-based solutions, including controlling invasive alien plants and rehabilitating wetlands, can save the City of Cape Town 55 million cubic metres of water a year in five years – equivalent to two months of the city's current water-supply needs.[32]

[29] UNESCO. 2018. ***The United Nations world water development report 2018: nature-based solutions for water.*** https://www.unwater.org/publications/world-water-development-report-2018
[30] Kotzé, P. 2019. ***Water resilient cities***, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/SP%20130_Water%20Resilient%20Cities_web.pdf
[31] UNESCO. 2018. The United Nations World Water Development Report 2018: Nature-based solutions for water.
[32] The Nature Conservancy. 2018. Greater Cape Town Water Fund business case, https://www.nature.org/content/dam/tnc/nature/en/documents/GCTWF-Business-Case-April-2019.pdf

Chapter 4

THE WATER IN OUR CITIES – FROM DAM TO TAP

The primary goal of our national water infrastructure is to ensure an adequate supply of clean water for daily use while adequately treating wastewater to prevent pollution. From the most ancient civilisations to today's modern cities, water has been a key element enabling human civilisation to grow, prosper and flourish. This requires the identification, transportation, treatment, distribution and disposal of water. This chapter looks at urban water infrastructure and the journey of water from the source to our homes.

South Africa is largely urbanised, with around two thirds of people living in cities and towns.[1] Most urban dwellers are unaware of the long journey that water undergoes to get to their homes, and generally little thought is given to wastewater once it disappears down the toilet or the drain. A common assumption when living in a serviced city is that there will be water when the tap is opened, and when the toilet is flushed. Another assumption is that the water will disappear again down the drain once dirty.

In South Africa, municipal services are almost exclusively provided by municipalities in association with water boards, which own and operate large, centralised infrastructure. Because water users are mostly unaware of the complexities involved in the process of getting water to their taps, they often view water as an unlimited resource, assumed to always be available in ample supply, whenever necessary.[2] In actual fact, our urban water systems are complex, comprising water treatment works, pump stations, reservoirs and reticulation pipes, which all have to be operated together to provide a service.

[1] UN Habitat, South Africa, https://unhabitat.org/south-africa
[2] Kotzé, P., ***Water resilient cities.***

As an example let's look at the water and wastewater infrastructure of a city such as Johannesburg. To supply water and wastewater services to the 6 million residents of Johannesburg, the city has the following water and wastewater infrastructure:

- 128 reservoirs and water towers
- 12 364 km of water pipes
- 11 710 km of wastewater networks
- 38 sewer pumps stations
- 11 816 m of sewer collector network
- 6 wastewater treatment works

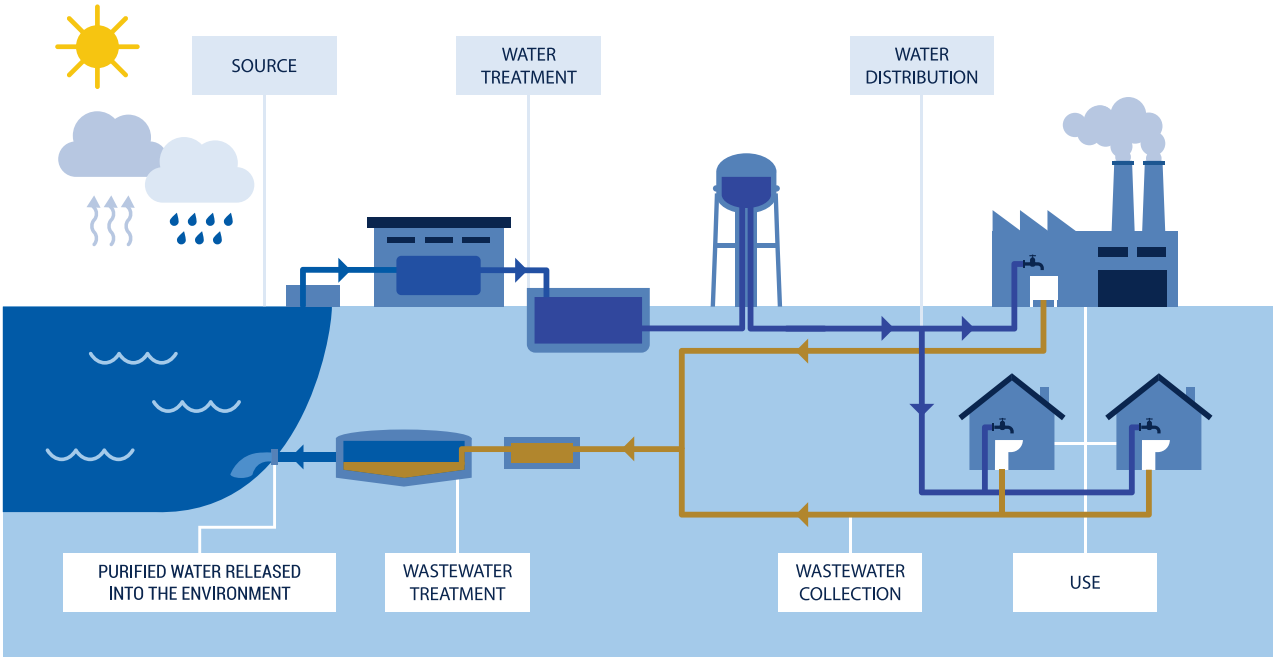
Lani van Vuuren

One of the wastewater treatment works providing services to the Johannesburg area.

THE URBAN WATER CYCLE

The urban water cycle relates to the collection, treatment, and distribution of water to meet the needs of an urban community. Let's look at the journey that water takes through the urban water cycle.

THE EIGHT MAIN STEPS OF THE URBAN WATER CYCLE



The urban water cycle.

1. Source
The water has to come from somewhere. Often, it comes from surface water like rivers and dams. But it doesn't have to. Groundwater can also be pumped up via wells. Most South African municipalities take water from various sources, including rivers, dams, groundwater, recycled water etc.

2. Treatment
Because water taken from open bodies may contain harmful microorganisms, it has to be treated before it reaches our homes. This process can involve a lot of steps. Typical surface water treatment involves chemical coagulation, filtration and disinfection. All drinking water in South Africa has to meet the South African National Standard for Drinking Water, known as SANS 241.

3. Distribution
After treatment and sufficient disinfection, the water is sent out via a pressurised system of lifts to the areas in the city where it is needed. A disinfectant residual (usually chlorine) must be maintained at all parts of the system.

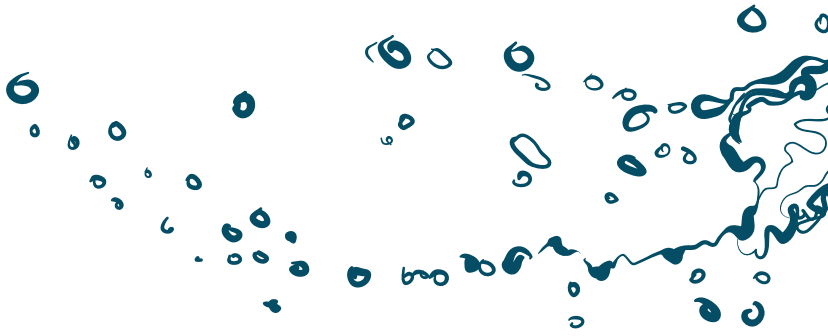
4. Storage
After being distributed, the water is stored in water towers (or reservoirs) before it is used. Water towers use gravity to make sure we have the water when and where we need it.

5. Use
We do it every day. We take showers, brush our teeth, water our lawns, clean our clothes and drink water.

6. Collection
Water leaves our homes by going down our drains and toilets. Sewer systems collect and convey the wastewater from our homes and businesses to wastewater treatment plants. The process is typically done using gravity.

7. Treatment
Because the water quality is reduced by usage, and because it has to be put back into the hydrologic cycle, it has to be treated. This is done through a variety of biological and chemical processes.

8. Discharge
Once the treated water (effluent) has been cleaned to regulatory standards, it is discharged back into the environment (usually a receiving river). When it gets back to the environment, the cycle starts again.

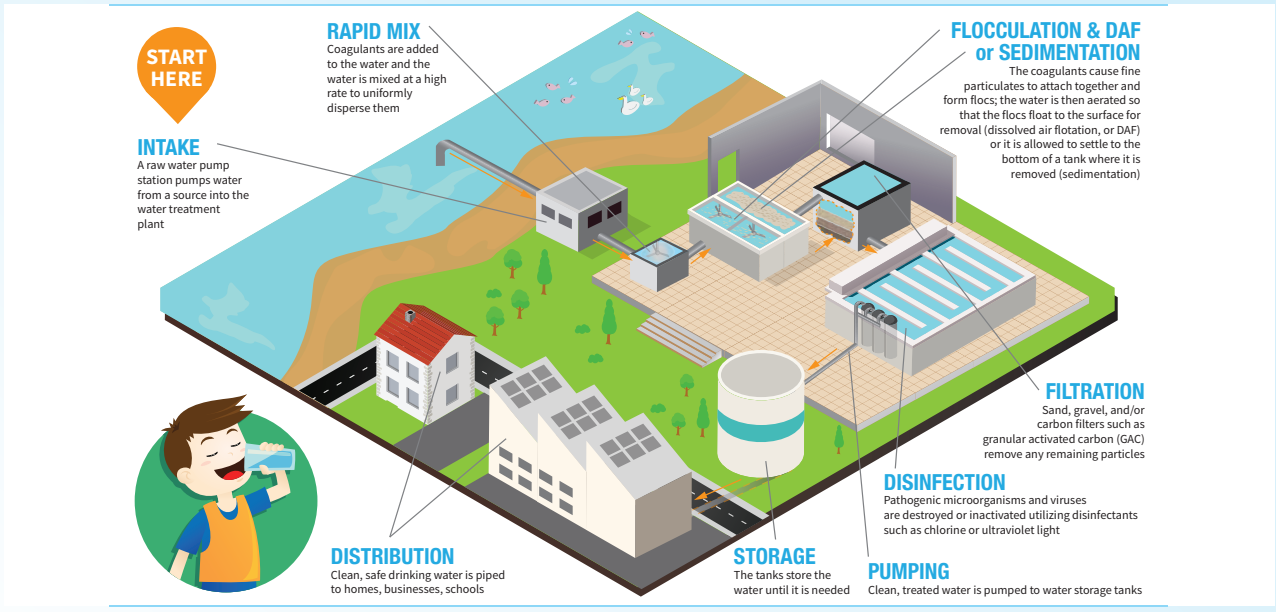


How is water from the river or dam made drinkable?
There are many different water treatment methods or processes that can be used, each on its own or in combination with others, to treat water for domestic use.

In general, water treatment processes can be classified into the following categories:

- **Clarification processes** that are used to remove suspended material from water. These processes include coagulation, flocculation, sedimentation, flotation, and filtration.
- **Disinfection processes** including chemical treatment with chlorine and chlorine compounds and advanced processes such as the use of ozone as well as physical processes such as ultraviolet irradiation.
- **Advanced / specialised processes** for the removal of dissolved inorganic substances including reverse osmosis, ion exchange and electrodialysis.
- Relatively simple processes that can be used for home treatment or during emergency situations.

These processes can be selectively combined in process trains to produce water of the required quality. They can be applied on a large or small scale. Most treatment plants in South Africa employ what is known as a series of conventional treatment processes.[3]



Tata & Howard

A typical water treatment plant.

[3] WRC, 2023, ***Basic drinking water treatment guide***, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/Basic%20drinking%20water%20treatment%20guide.pdf

There is a lot happening when we consider how clean water gets to all of us. The cities and water utilities responsible deserve a pat on the back. In addition to managing all the technicalities of operating and maintaining these sophisticated water and wastewater networks (which in a lot of cases is a few decades old), our city managers also have to cope with challenges such as growing demand due to rapid urbanisation, and climate change, which is placing water resources under pressure.

In South Africa, water managers also have to contend with issues, such as loadshedding. Power is required to pump water from low-level sources, such as rivers, to consumers located higher up in the catchment. During loadshedding pumping to the reservoirs on that particular grid stops, affecting supply. Loadshedding also affects operations at water and wastewater treatment plants. Despite these challenges, municipalities still manage to (most of time) provide us with safe, drinkable water on a regular basis.

VANDALISM – THE SCOURGE ON OUR INFRASTRUCTURE

Along with theft, vandalism of water infrastructure is a growing and disturbing trend worldwide. Vandalism refers to the intentional destruction of public property. Acts of vandalism are widespread in both urban and rural settings and take a number of forms. These include water theft through illegal connections, leading directly to a loss of revenue for the municipality, and the vandalism and theft of valuable metal pipes, fittings and manhole covers, leading to an increase in the municipality's maintenance costs.

Vandalism and theft of water infrastructure is costing our cities millions of Rand a year.

The majority of vandalism in South Africa is acquisitive – meaning damage is inflicted to public property in order to acquire a resource to be sold for profit (usually metal). Sanitation facilities can also be targeted, with equipment, materials, fittings and even signage being stolen from wastewater treatment plants and from public and communal toilet blocks.

A significant problem, especially where solid waste disposal services are inadequate, occurs when thieves remove and sell

Is my water safe to drink?

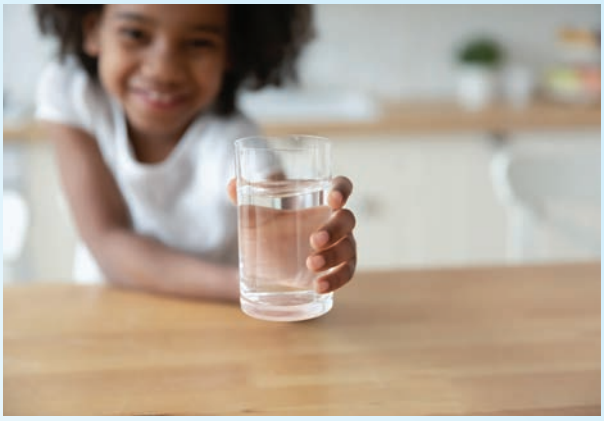
As a rule, the answer is yes.[4] If there is a continuous supply of water, the pressure in the pipe prevents contaminants from entering the pipeline, and if the water has residual chlorine in it, that generally means that the supply to your home is good. The most important aspect of water treatment is reducing the microbial content of the water and eliminating any harmful microorganisms. Water treatment facilities use filtration to remove visible contaminants from drinking water and chemicals such as chlorine to kill invisible bacteria and viruses. Unfortunately, some, especially smaller, municipalities have been experiencing operational and maintenance problems at their water treatment plants.

A few years ago, the DWS introduced the Blue Drop certification process, an incentive-based programme aimed at improving the performance of the country's water treatment works. If you want to check the performance of your municipality's water treatment plants, you can access the latest (2023) report here, https://ws.dws.gov.za/iris/releases/BDN_2023_Report.pdf

If you are still uncertain about the quality of your drinking water, there are a few steps you can take other than buying bottled water:

- **Boil the water** – Water can be used if it is boiled and then allowed to cool. The water should preferably be boiled for 10 minutes.
- **Add bleach** – Add one teaspoon of bleach to 20 litres of water. Allow to stand for 2 hours (not in sunlight).
- **Invest in a home water treatment device** – Home water treatment devices use various technologies to remove pollutants from water, including, among others, activated carbon filter, reverse osmosis, ion exchange, microfiltration and distillation. Choosing the right fit for your household can be daunting task. The University of Johannesburg has created a free downloadable brochure, which can provide guidance on this decision. Click here, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/water%20filter%20brochure21.pdf
- **Test your water** – If it is within your means, you can have your water analysed by a certified laboratory

From time to time municipalities may send out a 'boil' alert when things go wrong at the water treatment plant. It is very important that these alerts are adhered to.



[4] De Wet, P. & Spies, M. 14 August 2023. 'We've been quietly testing drinking water quality in 6 cities for a month. Here's what we've found. https://www.news24.com/news24/specialreports/water/weve-been-quietly-testing-drinking-water-quality-in-6-cities-for-a-month-heres-what-weve-found-20230810

cast iron sewer manhole covers. This action leaves the sewer open and easily accessible for the dumping of solid waste by local residents. Such behaviour can result in hard-to-clear blockages, which may, in turn, lead to flooding and further problems for local residents and for the municipality. The vandalism and theft of electricity infrastructure also has an impact on water supply. For example, when electric cables are cut and electrical components stolen from reservoirs and pump stations, no water can be pumped to communities.

When you steal or damage a water-supply component you are stealing money from the municipality as it is responsible for repairing the damage. And because the municipality now has to use money budgeted for other purposes – that of servicing – the community, you are in effect stealing from your neighbour. What's more, you are infringing on the Constitutional right of your family, friends and neighbours to clean, potable water as well as an environment that is not harmful to them.

Theft and vandalism typically lead to:

- Increased risk to public health due to no water being available or due to sewage leaks
- Increased operation and maintenance costs – from the need for repair or replacement of vandalised pipes, fixtures and fittings (which means less money for other services)
- Increased non-revenue water – from water losses due to either water theft or leakage from the damaged network
- Reduced customer satisfaction – from more frequent service interruptions and / or rise in tariffs to cover increased costs, which may in turn lead to further dissatisfaction and lost revenue from customers' refusal to pay[5]

Acts of theft or vandalism should never be tolerated, and these activities should be immediately reported to the authorities (e.g. policy or metro police).

The cost of vandalism

In 2024, the City of Cape Town revealed just how much it had been spending on repairing the damage to water and sanitation infrastructure caused by theft and vandalism. In one year the city had to repair or replace more than 10 000 pieces of water and sanitation infrastructure, costing R2 million across the city's formal and informal areas. In addition, it cost nearly R12 million of taxpayers' money to replace 3 755 missing manhole covers, 2 809 stolen water meters, 649 meter covers, 1 204 hydrant covers, 1 034 stolen taps, and 257 vandalised and missing toilet parts, among others. In the same year the city also attended to 64 149 sewer blockages, the vast majority of which was due to misuse.[6]

[5] WSUP & NWSC, May 2014, Reducing vandalism of water and sanitation infrastructure: experience from Zambia's Copperbelt, https://assets.publishing.service.gov.uk/media/57a089e6ed915d622c000453/TB013_ReducingVandalism.pdf

[6] City of Cape Town, 12 May 2024, More than 10 000 items of water and sanitation infrastructure vandalised or stolen costing residents R12m, https://www.capetown.gov.za/Media-and-news/More%20than%2010%20000%20items%20of%20water%20and%20sanitation%20infrastructure%20vandalised%20or%20stolen%20costing%20residents%20R12m

WATER POLLUTION AND HEALTH

Water pollution is a serious issue that affects our environment and the health of living beings that depend on it. It happens when a substance is introduced into a river, stream, lake or ocean that harms the natural resources in those environments (such as plants and animals). The lack of infrastructure, skills, and poor maintenance of water resources exacerbates the situation, leading to untreated sewage flowing into water resources that South Africans depend on for their livelihoods and economic development.

Our rivers and waterways are being polluted by chemicals, sewage and household waste, which can cause serious harm to animals and humans. Agricultural practices, urban runoff, and atmospheric deposition often cause this pollution. Human waste is landing in aquatic systems because of communities lacking toilet facilities, leaking and faulty sewerage pipelines, and overflowing sewage treatment works. This situation can lead to water-related diseases such as cholera and diarrhoea.

Disposing of sewage into rivers and wetlands is also a significant problem and one of the causes of water pollution. Wastewater for industries and mines is another source of pollution. Factories and mines are known to be point sources of water pollution, but quite a lot of water is polluted by ordinary people from nonpoint sources. Even detergents used in washing machines and dishwashers eventually end up in our rivers, along with the pesticides we use in our gardens.

Water pollution is all about quantities: how much of a polluting substance is released and how big a volume it is released into. A small amount of a toxic chemical may have little impact if spilt into the ocean from a ship. But the same amount of the same chemical can have a much more significant effect if pumped into a river, where there is less water to disperse it. There are two different ways in which pollution can occur. If pollution comes from a single location, such as a discharge pipe attached to a factory, it is known as point-source pollution. Unfortunately, much water pollution happens not from one source but from many scattered sources. This is called 'non-point source pollution'.

South Africa prescribes to the 'polluter pays principle'. The polluter pays principle is the commonly accepted practice that those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment. For instance, a factory that produces a potentially poisonous substance as a by-product of its activities is usually held responsible for its safe disposal.

EFFECTIVE STORMWATER MANAGEMENT[7]

Our cities upset the natural water cycle. When a city is developed natural vegetation makes way for hard surfaces such as roads, sidewalks and roofs. While the original land cover was porous and accepted water like a sponge, the latter is mostly impermeable (i.e. not letting water through). This means that much less rain can infiltrate the soil. Instead,

[7] This section has been taken from Kotzé, P., 2019. ***Water resilient cities***.

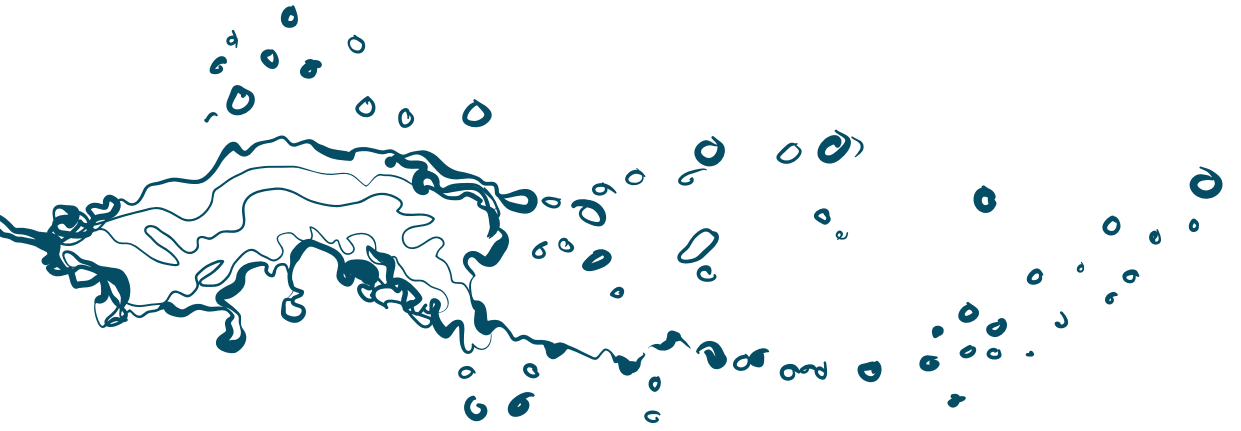
when rainwater hits a hard surface, it rapidly accumulates to run down the most suitable channel, such as a street. In cities, rainwater thus becomes stormwater. It is reported that urbanisation can increase the runoff rate by up to 50% compared to natural conditions. In extreme cases, flow can be as much as 6.8 times that prior to development.

The main purpose of stormwater management and infrastructure is to keep people safe from flooding. Traditionally, this mean quickly diverting stormwater into streams and other water bodies via roads and storm drainage systems. This system has resulted in a number of detrimental impacts. For example, stormwater is highly polluted. Though rainfall usually contains very little contamination, this changes drastically as soon as it hits the surface or an urban development. Here, the water picks up microbial pathogens and other hazardous substances that can easily spread via the receiving water bodies (rivers, lakes and wetlands) that the stormwater is destined for. In fact, urban stormwater has become one of the largest sources of contaminants to surface waters throughout the world.

In recent years, an alternative stormwater management approach has been introduced, namely to use stormwater as a potential resource. One such alternative is sustainable drainage systems or SuDS. SuDS attempt to manage surface water drainage systems holistically in line with the ideals of sustainable development. They are designed to mitigate many of the negative environmental impacts of stormwater.

There are three key stages in the treatment train, each having slightly different combinations of SuDS options to control the stormwater:

- **source controls** manage stormwater runoff as close to its source as possible, typically on site. Typical SuDS options include: green roofs, rainwater harvesting, permeable pavements and soakaways.
- **local controls** manage stormwater runoff in the local area, typically within the road reserves. Typical SuDS options include: bio-retention areas, filter strips, infiltration trenches, sand filters and swales.
- **regional controls** manage the combined stormwater runoff from several developments. Typical SuDS options include: constructed wetlands, detention ponds and retention ponds.[8]



[8] Sustainable drainage systems, https://wsudsa.org/resources/key-concepts/sustainable-drainage-systems-suds/

If not managed properly, stormwater can lead to flooding and pollution.

Stop dumping waste in our stormwater systems

The dumping of litter and other items into toilets, stormwater drains, and sewer manholes causes a massive headache for municipalities. Overflowing stormwater drains are generally found to be blocked by illegal materials and rubbish dumped directly into the drain causing damage and flooding down the line. It is not unusual for municipal staff to clear items such as branches, tyres, rocks, mattresses and even car engine parts from city stormwater drains.

One of the main reasons for blocked drains and sewage spills is the wrong stuff being flushed down toilets or thrown into manholes. Items that should never be flushed down toilets include baby nappies, sanitary pads and tampons, newspaper, cloth and fabric, fatty food or fat. Dumped trash can end into stormwater drains, which oftentimes flow directly into river systems. Solid waste material can clog our waterways, with leaching microplastic and chemicals being very toxic to our aquatic water systems.

As responsible citizens, there are a number of things we can do to positively impact our water infrastructure:

- Garden refuse such as grass and tree clippings should never be swept into a stormwater drain or onto a street. They provide excess nutrients and promote unnecessary algae growth which, in turn, can cause severe negative impacts to the rest of water ecosystems.
- Properly dispose of chemicals – Things like motor oil and batteries can be recycled. Other products that should be brought to a facility for proper disposal include paint, herbicides, and swimming pool chemicals. Be careful to clean up any spills and avoid allowing chemicals to reach stormwater drains.

WATER TARIFFS

A 'water tariff' refers to the price assigned to water supplied by a municipality through a piped network to its customers. The tariff is based on how much water you use, which is normally calculated by reading the home's water meter once a month. The tariff is not charged merely for the water itself, but also to recover the costs of water treatment, storage, transporting, as well as billing and collection. Registered indigent (i.e. poor) households receive the first 6 kilolitres of water used per month free. Municipalities charge different tariffs for their water services. There are two types of tariffs in South Africa:

- A **volumetric tariff**, where water metering is applied; and
- A **flat rate**, where no water metering is applied.

In many township areas people are still dependent on communal water points. Water from these points are free of charge. Some South African municipalities, such as the City of Cape Town, make use of sliding tariffs or a stepped tariff, meaning the more water you use per month, the more expensive the tariff. This is an incentive for households to use less water.

Non-indigent households may also pay a fixed basic charge. This is a monthly amount payable for being connected to the municipality's water-supply service. The charge is based on the size of the meter connection to your property and has been calculated to cover some of the fixed costs that are associated with supplying water to your home.

WATER RESTRICTIONS

Municipalities may alert communities of the need to save water through posters like these.

In water scarce South Africa, we should always use water carefully even when water restrictions are not in place. Municipalities may enforce water restrictions from time to time as a way of managing water use, especially in times of high demand and drought. Municipalities impose fines, restrict water supply or disconnect water supply to consumers who do not comply with the water restrictions.

There are generally three levels of water restrictions in South Africa. While these restrictions might differ from city to city, they generally comprise the following:

- **Level 1**: During this level, gardens may not be irrigated between 06:00 and 18:00 and hosepipes may not be used to clean driveways or patios or wash cars. Further, swimming pools and water features may not be topped up.
- **Level 2**: The following is prohibited: irrigation of gardens, cleaning of patios and driveways as well as cars with a hosepipe. Swimming pools and water features may also not be topped up. During this level, municipalities may also raise water tariffs
- **Level 3**: Municipal water to be used for human consumption only. No watering of gardens or washing of vehicles allowed. Residents and businesses to restrict their usage to 20 kilolitres a month. Residents using more than 20 kilolitres a month to be identified and instructed to install water restrictive devices and/or fined.

TAKING THE 'WASTE' OUT OF WASTEWATER

Raw wastewater is hazardous and must be treated to prevent impacts on water resources and public health and safety. Wastewater is treated to improve the physical, chemical and microbiological quality of the water.[9] South Africa has a vast system of wastewater collection sewers, pumping stations and treatment plants. Sewers collect the wastewater from homes, businesses and many industries and deliver it to plants for treatment. Most treatment plants are built to clean wastewater for discharge into streams or other receiving waters.

The country has around 850 municipal wastewater treatment plants. There are two basic stages of wastewater treatment, namely primary and secondary. In the primary stage, solids are allowed to settle and removed from wastewater while the secondary stage uses biological processes to further purify wastewater.

PRIMARY TREATMENT

As sewage enters a plant for treatment, it flows through a screen, which removes large floating objects, such as rags and sticks that might clog pipes or damage equipment. After sewage has been screened, it passes into a grit chamber, where cinders, sand and small stones settle to the bottom. A grit chamber is particularly important in communities with combined sewer systems where sand or gravel may wash into sewers along with stormwater.

Lani van Vuuren

A typical wastewater inlet. Inflowing wastewater is screened to remove large floating objects.

[9] Award. 2015. Overview of wastewater treatment in South Africa, https://award.org.za/wp/wp-content/uploads/2020/07/AWARD-Tech-Report-42-Overview-of-waste-water-treatment-in-South-Africa-2015-v1.pdf

After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids. These solids are minute particles that can be removed from sewage in a sedimentation tank. When the speed of the flow through one of these tanks is reduced, the suspended solids will gradually sink to the bottom, where they form a mass of solids (known as sludge). This sludge is usually removed from tanks by pumping, after which it may be further treated for use as a fertilizer or disposed off in a landfill or incinerated.

SECONDARY TREATMENT

The secondary treatment stage removes about 85% of the organic matter in sewage by making use of the bacteria in it. The main secondary treatment techniques used in secondary treatment are the trickling filter and the activated sludge process.

After effluent leaves the sedimentation tank in the primary stage it flows or is pumped to a facility using one or the other of these processes. A trickling filter (also called a bio-filter) is simply a bed of stones through which sewage passes. Bacteria gather and multiply on these stones until they can consume most of the organic matter. The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria.

Lani van Vuuren

Trickling filters are part of the secondary treatment process.

In turn, the activated sludge process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with sewage. After the sewage leaves the settling tank in the primary stage, it is pumped into an aeration tank, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time the bacteria break down the organic matter into harmless byproducts. From the aeration tank, the partially treated sewage flows to another sedimentation tank for removal of excess bacteria.

A third common type of secondary treatment is ponds or constructed wetlands. The effluent is purified as it flows through a bed of granular material, often with reeds consuming the nutrients and converting ammonia to

nitrogen gas. Ponds effectively function to polish and disinfect wastewater. In addition to improving the quality of the final effluent, ponds and wetlands can also serve as a buffer in case of a breakdown at the wastewater treatment plant.

To complete secondary treatment, effluent is usually disinfected with chlorine before being discharged into receiving waters. Alternatives such as ultraviolet light or ozone are also used at some wastewater treatment works.

To learn more about wastewater treatment technologies available in South Africa, visit: https://www.wrc.org.za/wp-content/uploads/mdocs/TT%20651%20-%2015.pdf

This chapter looked at the intricacies of our urban water and wastewater infrastructure and the role we as citizens can play to ensure the sustainable operation and maintenance of our water and sanitation services.

Personal actions to stop sewage pollution in your community

Caring for wastewater infrastructure is all of our responsibility. Regardless of the type of sewage infrastructure (whether on- or off-site) that services your community, there are many actions we can all take to better care for our wastewater systems.

- **Only flush the three P's**. Nothing other than pee, poo and toilet paper should ever be flushed down a toilet. Foreign objects (including so-called 'flushable' wipes) can prevent the normal flow and treatment of wastewater and result in sewage backing up into streets, yards and even your bathroom.
- **Don't pour cooking grease or oils down the drain**. Fat and grease can build up and cause blockages. Instead collect cooking grease in a container, let it cool down and throw it in the trash.
- **Conserve water inside your home**. Many sewage failures occur because too much water is flow into the wastewater system. When too much water enters the wastewater system its capacity can be exceeded and it can overflow, which introduces harmful bacteria, viruses and excess nitrogen into groundwater and surface waters.
- **Practice good septic tank care.** Septic tanks are commonly used in South Africa, especially in rural and peri-urban areas where there might not be access to centralised sewer systems. It is recommended that you inspect and pump your septic tank regularly (evert 3-5 years), depending on the amount of use and soil type in your area. Don't use septic additives as they actually make septic systems less effective.
- **Support local green stormwater infrastructure projects.** Green infrastructure employs strategies to allow rain to soak into the ground instead of becoming runoff. This protects local waterways from both polluted runoff as well as sewage overflows caused by stormwater.

Chapter 5

BEING A RESPONSIBLE (WATER) CITIZEN

Whether you live in an urban or a rural area, whether you live inland or at the coast, South Africa's precarious water situation affects us all. It is not the government's role alone to manage the country's water resources. As citizens we all have a role to play in contributing to South Africa's water security.

PROTECTING THE SOURCE – CITIZEN SCIENCE

Deteriorating water quality, water outages, major unfixed leaks and water losses affect everyone. Unlike electricity for which many alternatives exist, there is no alternative for water. This means that we have to take particular care of the water resources we have. While the challenges are huge and may seem insurmountable at times, we should not become complacent and accepting of the state of affairs. Citizens have an important role to play in managing South Africa's water resources, both in terms of keeping government accountable as well as to contribute to water security.[1]

Citizen science is defined as the active and voluntary participation of the public in scientific research. Citizen science, especially in South Africa, has also empowered communities to tackle their water and environmental issues, and take an active role in the management and protection of their water resources.

Citizen science has been around for a long time, however, it has gained particular importance in the last decade or so due to the growing value of co-developing knowledge and solutions both for and with people. A particularly exciting development has been the advances in citizen science for water quality monitoring. As Mark Graham and co-authors point out, "citizen science

[1] WaterCan, 2024. Citizen science leads the way in water monitoring and protection, https://watercan.org.za/citizen-science-leads-the-way-in-water-monitoring-and-protection/#:~:text=The%20key%20action%20on%20this,in%20stormwater%20drains%20and%20rivers.

engages people in identifying and solving local problems with their water and environment…Citizen science water quality monitoring has the potential to improve people's environmental awareness, scientific literacy and understanding of the mechanisms and importance of water-related concerns, and opens channels for communication with water authorities."[2]

South Africa has seen excellent advances in citizen science tools and programmes. One of the most exciting tools is the mini stream assessment scoring system (miniSASS). Developed in South Africa, miniSASS is a simple and accessible citizen science tool for monitoring the water quality and health of stream and river systems. Citizens collect a sample of aquatic macroinvertebrates (small, but large enough to see animals with no internal skeletons) from a site in a stream or river. The community of these aquatic macroinvertebrates present then tells them about the water quality and health of the stream or river based on the concept that different groups of aquatic macroinvertebrates have different tolerances and sensitivities to disturbance and pollution.

A miniSASS application (app) has been developed, and recently the use of artificial intelligence (AI) was piloted to assist the use in identifying aquatic macroinvertebrates sampled and photographed with a smartphone.[3] With simple online training, a net, a tray and other simple tools, citizen scientists can conduct miniSASS surveys that are submitted to an online database. This contributes to a global database and map or river quality measurements available on the miniSASS website. Using these tools, citizens can see how rivers are impacted on a scale from 'natural' to 'very poor'.[4]

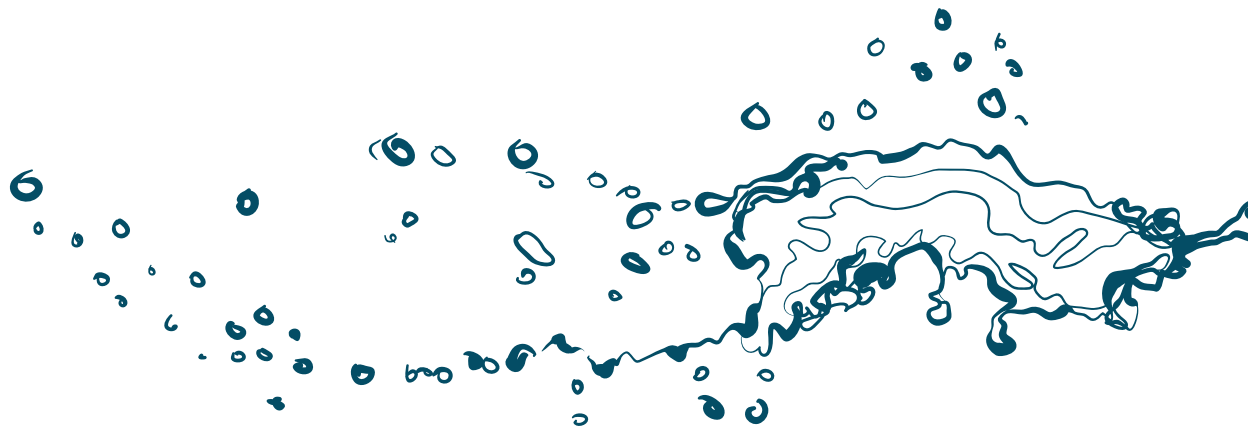
WRC archives

Learners using miniSASS to establish the health of their local river.

[2] Graham, P.M. et al, 2024. 'The value of citizen science for a just and sustainable water future', ***South African Journal of Science,*** 120 (9/10), https://doi.org/10.17159/sajs.2024/19185
[3] https://minisass.org/
[4] Perera, T. 2024. Join the citizen science movement for healthy rivers, https://www.iwmi.cgiar.org/join-the-citizen-science-movement-for-healthy-rivers/

Tools such as these are used with great success by non-governmental organisations to make a difference to catchments across the country. Organisations such as the Duzi uMgeni Conservation Trust (DUCT) is illustrating that South African citizens need not sit back and be silent witnesses to the degradation of the catchments in which they live, but can in fact play in a significant, active role, in reversing this condition. The organisation was established in 2006 after a group of paddlers participating in the Duzi canoe marathon witnessed the deteriorating quality of the uMngeni and uMsunduzi rivers.

DUCT functions in different ways. The organisation lobbies for higher priority to be given to any actions and programmes which will improve river health, such as the removal and control of invasive alien plants, the improvement of waste management systems and the implementation of the environmental flow provisions of the National Water Act of 1998. In many instances, it provides skills and manpower to give the effect to those actions and programmes, particularly where there is something new that needs to be tried out or demonstrated. Further, DUCT monitors matters which have a direct bearing on river health, such as sewage pollution, uncontrolled sand mining operations and illegal dumping. The organisation also works on raising the public awareness of river health issues through the education of school groups, public campaigns and the use of the media. Finally, DUCT provides access to a network of highly experienced professionals with relevant skills, and uses these skills to formulate proposals and to manage programmes which are making a difference.[5]



[5] Van Vuuren, L. 2014. 'Refusing to DUC(T) for cover – how one organisation is making a difference to KZN's river', ***The Water Wheel,*** March/April 2025, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/WaterWheel_2015_2_March.pdf

Simple actions to protect the quality of our water resources

1. **Get informed!** Find out about the state of water quality of your water source and drinking water. A good start is the DWS Blue Drop report.[6]

2. **Keep water authorities accountable.** Report leaks, overflowing manholes and no water. Find out how funds are allocated for water and sanitation infrastructure, operation and maintenance. Also report companies dumping waste into stormwater drains and rivers.

3. **Get involved.** Participate in volunteer activities such as monitoring programmes to help track the condition of your local rivers, streams, lakes, and other waters. You can also join a beach, stream or wetland cleanup. South Africa has numerous 'friends of nature', youth and environmental NGOs which could use your support.

4. **Use and dispose of harmful materials properly**. Don't pour hazardous waste down the drain, on the ground, or into stormwater systems. For example, unused or expired medication should be taken to your pharmacy to be disposed of safely rather than be thrown away or flushed down the toilet.

5. **Think twice about garden chemicals**. Limit the use of pesticides and fertilizers and always follow the label directions. Many fertilizers and pesticides contain harmful chemicals which can travel through the soil and contaminate groundwater or run off in stormwater to rivers and streams.

6. **Properly maintain your septic system**. Groundwater can be contaminated by poorly or untreated household wastewater, which poses dangers to drinking water and the environment.[7]

[6] DWS, 2023. National Blue Drop Report, https://ws.dws.gov.za/iris/releases/BDN_2023_Report.pdf
[7] . EPA. Undated. How can you help protect source water?, https://www.epa.gov/sourcewaterprotection/how-can-you-help-protect-source-water#:~:text=Don't%20pour%20hazardous%20waste,Motor%20oil

Used motor oil must be disposed of properly. The simplest way to do this is to put it inside the container your new oil came in, and take it to a designated point to be recycled, such as those licenced by the Rose (Recycling Oil Saves the Environment) Foundation.[8]

[8] www.rosefoundation.org.za

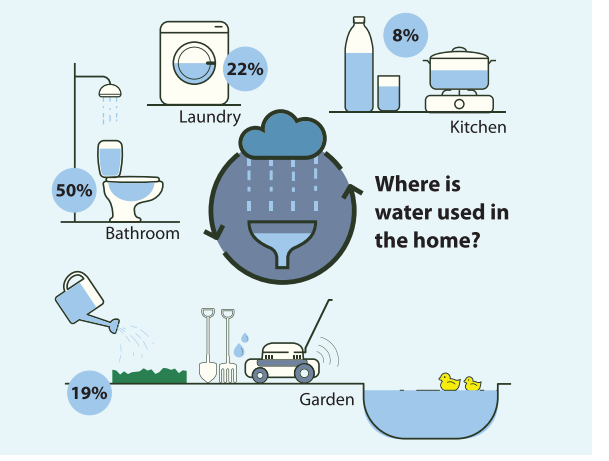
Citizen science in action in Limpopo

In the Limpopo villages of Ga-Komape and Ga-Manamela, academics and residents have worked together to find out more about the areas' groundwater resources. This is important data: 74% of people in rural areas like these depend on groundwater for their crops and domestic water supply. People use this water but there's very little knowledge about how much there is, how it recharges, whether it is clean and so forth. Over a period of three years, residents from the villages were trained to capture groundwater data. They used a simple dip meter, recorded rainfall levels from rain gauges and took images of water flows in rivers. This data was captured on smart phones and relayed to a website where it is available for government, researchers and planners who can use this to better understand what is going on under the ground – after all, you can't manage what you can't measure.[9]

SAVING WATER IN THE HOME

You don't even have to leave your house to support water security in your area. By simply saving water inside your home, you could make a huge difference to the country's water security. If we use more water than we should, the storage, supply and wastewater treatment facilities will have to be enlarged sooner than planned for – increasing the cost of water. Using less water in our lives has two impacts. It relieves pressure on water resources, which are put under increasing stress by climate change and increasing demand. And two, it reduces amount of energy used by water treatment and supply systems and therefore lowers greenhouse gas emissions. (And it also saves us money on our water bill – win-win!)

There are various ways in which you can conserve water. First, find and repair any leaks. Second, use the available water more efficiently. Finally, if you are in the process of building or renovating, plan for water-saving fittings, such as low-flow shower heads, and dual flush toilets.



[9] J. Goldin, South Africa groundwater project shows the power of citizen science, ***The Water Wheel***, January/February 2022, https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/WW%20Jan%20-%20Feb%202022%20web_GROUNDWATER%20AND%20SOCIETY.pdf

STOP THE LEAKS

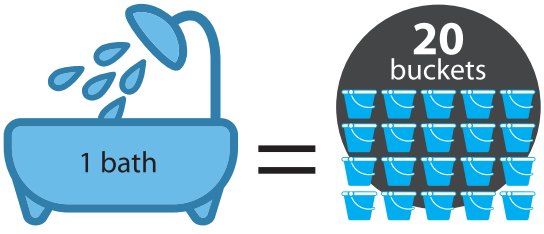
A leaking tap can waste much as 60 litres of water a day.

The metered water arriving on your premises is used both indoors and outdoors. The first step in saving water is to check for leaks. Studies have shown that dripping taps and leaking toilets can account for as much as 5% of all water used inside the home. For example, a dripping tap can waste as much as 60 litres of water a day or 1 800 litres a month!

Leaks are not only wasteful but also expensive, particularly if it is hot water that is leaking (the water replacing the leaking hot water in the geyser needs to be heated. Geysers can use half the electricity in your home). Fortunately, most leaks are relatively easy and inexpensive to repair. By reducing leaks you can reduce your water consumption at home by as much as 40%.

USING WATER MORE EFFICIENTLY

Since the bathroom uses the most water, it is the perfect place to start using water more efficiently. Except for the occasional soak, baths should preferably be avoided. Baths hold up to 200 litres when filled to the overflow level whereas showers only use about 20 litre of water per minute. If you don't have access to a shower, or prefer a bath, don't fill it up more than halfway. Where practical, family members should use the same water. You can also use the previous night's bath water for pre-soaking dirty washing.



One of the easiest ways to save water and electricity in the bathroom is by taking a short, quick shower instead of a bath. Reduce the shower flow rate to the minimum necessary for a comfortable shower and cut showering to a maximum of 5 minutes. A further saving could be achieved by turning off the shower taps while you soap up, only opening them up again to rinse off. You can also shower standing in a plastic tub. This would allow you to collect the water for some other purpose (see the section on greywater below).[10]

Do you leave the wash basin tap running when you shave, brush your teeth or wash your hair? Rather run a suitable quantity of water into your wash basin.

The toilet can be a formidable water-waster. A toilet is the single biggest user of indoor water. Toilets use up to 10 litres of water when flushed. To be sure that your toilet cistern flushes effectively, check that the float valve maintains the water level at about 20 millimetres below the overflow pipe to optimise the energy available for the flush. To reduce the water in the cistern, you can place one or two one-litre plastic bottles in the cistern (some people use bricks, although this is not advisable as they tend to disintegrate).

Only flush the toilet when necessary. Let the 'yellow mellow' and never use the toilet as a dustbin.

You can also save water in the kitchen. When washing dishes in a two-bowl sink, run water from the top tap into the 'rinse' bowl until it is warm, and then swing the tap nozzle over the 'wash' bowl. Do not rinse dishes under running water. Rather use the sink bowl or a plastic tub in which to dip them. When preparing to place dishes in the dishwasher, scrape them off rather than rinsing them.

A family of four showering instead of bathing can save up to 400 litres of water a day.

Do not use a hosepipe to wash your car. A bucket, sponge and car shampoo are adequate. Also, do not hose down driveways, courtyards and swimming pool surrounds.

When watering your garden, always do it in the early morning or late afternoon, when evaporation is at its lowest. Be sure to apply enough water to reach the roots of the plants – a good watering once a week is more valuable to plants than a sprinkling every day. Sandy soils should be well mulched to improve water retention.

[10] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third revised edition.***

The use of micro-irrigation systems with micro-sprinklers and drippers may save as much as 40% of the water as compared to a hosepipe.[11] By planting water thrifty plants you will also reduce the irrigation needs of your garden.

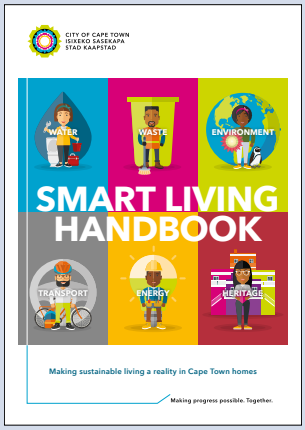
By covering your pool you can reduce evaporation loss by as much as a third. Catch rainwater runoff from the roof in storage tanks in the garden and for topping up the pool.

NOTE! This water may be polluted and should never be used for domestic purposes.

Water saving resources

For more guidance on how to save water home, download these great, free online resources:

How to save water, a householder's handbook from the WRC can be downloaded here https://bit.ly/4iuP35T



The City of Cape Town's, ***Smart living handbook*** can be downloaded here https://bit.ly/49rtu29

[11] Day, J. and Davies, B. 2023. ***Vanishing Waters. Third revised edition.***

SAFELY REUSING GREYWATER

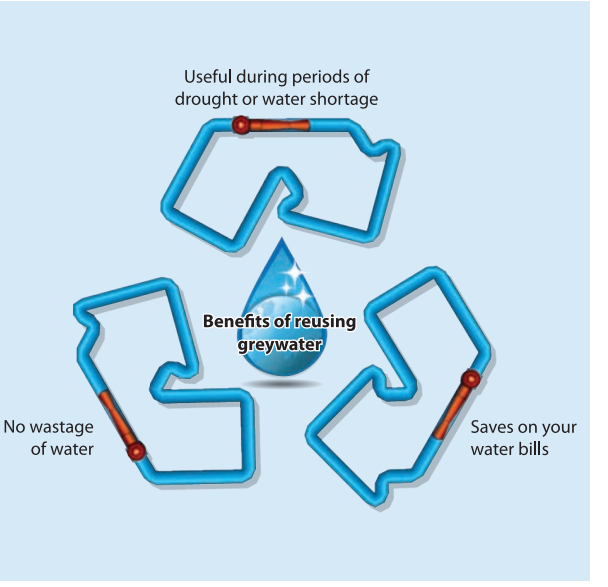
Every day the water we use in our homes ends up becoming wastewater. Some of this water is safe to reuse (greywater) while other water is too contaminated and must be steered clear from (blackwater). By reusing greywater we can save water and money.

Blackwater is the wastewater from toilets or urinals which consist of urine and faecal matter. Water from kitchens and dishwashers can also be classified as blackwater due to the presence of pathogens and grease.

This type of wastewater is unfit for human and animal consumption and must not be used for any household purposes or recycled. Blackwater is the wastewater that is treated by municipal wastewater treatment plants or through on-site systems, such as septic tanks.

Greywater is the wastewater from baths and showers (body washing) and handwash basins. Laundry water from washing machines is only considered greywater when environmentally-friendly detergents are used. Greywater can contain dirt, detergents, soaps and chemicals, salts and harmful microorganisms. Greywater can be used to flush toilets, clean vehicles, and for garden irrigation (since greywater contains some nitrogen and phosphorus it is also a potential source of nutrients for plant growth). It is particularly when greywater is used for toilet flushing that a lot of water can be saved as toilet flushing is responsible for up to 50% of the water used inside the household.

The simplest way to collect water is in a bucket from your washing machine or shower. Care should be taken when reusing greywater. For example, when reusing water to flush the toilet, a jug should be used to carefully pour the greywater directly into the toilet bowl. Avoid splashing as it may spread pathogens through aerosols. When using greywater for gardens, ensure that the reused water never comes into contact with the above-ground part of the plants. Greywater should never be consumed.[12]



[12] Carden, K. et al. Guidelines for greywater use and management in South Africa (WRC report no. TT 746/17), https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20746-17.pdf

There are also a couple of 'do's and don'ts' when it comes to greywater reuse. These include:

- When applying greywater to the garden, it should be applied directly to the soil, not through a sprinkler or any method that would allow contact with the above-ground portion of the plants. Don't use greywater to irrigate fruit, vegetables or any plants you plan to eat.
- When using greywater for flushing pour it directly into the toilet bowl. Don't pour greywater into the cistern as it may siphon back into the freshwater supply if water pressure decreases suddenly.
- Do not store greywater for longer than 24 hours as this will lead to bad odour, slime buildup, and health risks. Water stored for longer periods needs to be treated as advised by a specialist.
- Do not use greywater if anyone in the household is ill.
- Don't allow children or animals to come into contact with greywater.
- Don't ever ingest or swallow greywater.
- Don't spray greywater as this disperses pathogens through the air.
- Don't allow greywater to leave the property and flow into stormwater drains or river systems.
- Always wash your hands properly after contact with any form of greywater.
- Once you have used some greywater, don't use that same greywater for anything else.[13]

Water from washing your pets is not considered safe for reuse as it may contain pathogens.

The difference between greywater and blackwater

Greywater

Used water from sinks, showers, bath and laundry

Blackwater

Water from toilets or containing harsh chemicals

[13] City of Cape Town, Safe use of greywater, https://resource.capetown.gov.za/documentcentre/Documents/Graphics%20and%20educational%20material/Safe%20Use%20of%20Greywater%20booklet.pdf

Water that is safe to reuse	Water that is not safe to reuse
• 'Warm up' or lag water (cold water that runs while waiting for warm water from the tap) • Shower and bath water • Laundry water (particularly rinse water) • Hand basin washing water • Vegetable and fruit rinsing water	• Water that has been used to wash nappies or other clothing soiled by faeces and / or urine • Water from the kitchen sink to wash dishes or food as it is highly contaminated with grease, bacteria, and chemicals • Water that has been used to wash cloths or brushes used for painting or for maintaining machinery and vehicles • Water used to wash domestic animals as it typically has high concentrations of organisms that can cause disease

Ensuring that we have enough water for present and future generations requires simple behaviour changes. Let us all do our bit to ensure a water secure South Africa.

USEFUL CONTACTS

GOVERNMENT ORGANISATIONS

Breede-Olifants Catchment Management Agency
Visit: https://breedegouritzcma.co.za/
DWS – National Department of Water and Sanitation
Visit: https://www.dws.gov.za/
IUCMA – Inkomati-Usuthu Catchment Management Agency (IUCMA)
Visit: https://iucma.co.za/
Johannesburg Water
Visit: https://www.johannesburgwater.co.za/
Magalies Water
Visit: https://magalieswater.co.za/
Rand Water
Visit: https://www.randwater.co.za/
uMngeni-uThukela Water
Visit: https://www.umngeni-uthukela.co.za/
TCTA – Trans Caledon Tunnel Authority
https://www.tcta.co.za/
Overberg Water
Visit: https://magalieswater.co.za/
Vaal Central Water
https://vaalcentralwater.co.za/
WRC – Water Research Commission
Visit: https://www.wrc.org.za/

PROFESSIONAL ORGANISATIONS

BWA – Borehole Water Association of South Africa
Visit: https://bwa.co.za/
GWD – Groundwater Division of GSSA
Visit: https://gwd.org.za/
SA Hydrological Society
Visit: https://southafricanhydrologicalsociety.org.za/
SANBWA – South African National Bottled Water Association
Visit: https://www.sanbwa.org.za/
SANCID – South African National Committee on Irrigation and Drainage
Visit: https://www.sancid.org/
South African Wetland Society
Visit: https://sawetlandsociety.org/
Southern African Society of Aquatic Scientists
Visit: https://www.riv.co.za/sasaqs/
WISA – Water Institute of Southern Africa
Visit: https://wisa.org.za/

'FRIENDS' GROUPS

Friends of Colbyn Valley – A community group formed to protect the interests of the Colbyn Valley Wetland, Pretoria
Visit: https://www.facebook.com/profile.php?id=100064695218445
Friends of Groenkloof en Klapperkop nature reserves –
Visit: https://www.facebook.com/FriendsofGroenkloofNatureReserve/
Friends of Free Wildlife – Wildlife centre run by passionate and qualified wildlife rehabilitators and volunteers.
Visit: https://www.friendsoffreewildlife.co.za/
Friends of the Haenertsburg Grasslands – advocates for the conservation, rehabilitation, study and sustainable use of the critically endangered Woodbush Granite Grasslands, its associated indigenous forests and water catchments.
Visit: https://www.frohg.org/
Friends of Kloofendal – focused on environment and community projects and activities within Kloofendal Nature Reserve.
Visit: https://kloofendalfriends.org.za/
Friends of Moreleta Kloof - Volunteers who band together to conserve, rehabilitate or prevent destruction of the Moreleta Kloof.
Visit: https://moreletakloof.co.za/friends/
Friends of Rietvlei – provides assistance and support for the management of the Table Bay Nature Reserve, Cape Town
Visit: https://friendsofrietvlei.co.za/
Friends of Rietvlei (Pretoria) - Assists with the management of the Rietvlei Nature Reserve, Tshwane, with planning and execution of various projects to add value and to assist in maintenance of the Reserve.
Visit: https://friendsofrietvlei.org/
Friends of Table Mountain – advocates for the sustainable use of Table Mountain National Park.
Visit: https://www.friendsoftablemountain.org/
Friends of the Fairie Glen Nature Reserve – Assists with the management of the Fairie Glen Nature Reserve, Pretoria.
Visit: https://ffgnr.wordpress.com/

Friends of the Liesbeek – creates awareness of the importance of the Liesbeek River, Cape Town, as a green corridor in an urban setting and to rehabilitate, enhance, and conserve it and its environs.
Visit: https://fol.org.za/
Friends of the rivers of Hout Bay – Dedicated to the rehabilitation and conservation of the Hout Bay river system, Cape Town.
Visit: https://friendsoftheriversofhoutbay.co.za/
Friends of the Wilds – An organisation that works towards the preservation of The Wilds, a 40 acre reserve along the ridges between Houghton, Parktown and Killarney, Johannesburg.
Visit: https://www.facebook.com/groups/1582183308538762/
Friends of Verloren Valei – A group of volunteers whose primary aim is to support the management of the Veloren Valei Nature Reserve, Mpumalanga.
Visit: https://verlorenvalei.org.za/

NON-GOVERNMENTAL GROUPS

Centre for Environmental Rights – Activist lawyers who defend the right of communities and civil society organisations to an environment not harmful to health or wellbeing for present and future generations.
Visit: https://cer.org.za/
Conservation South Africa – Works with various stakeholders to implement sustainable landscape management strategies to restore degraded ecosystems, while supporting the creation of green enterprises, green jobs, and green skills.
Visit: https://www.conservation.org/south-africa
Duzi-uMngeni Conservation Trust (DUCT) – A non-profit public benefit organisation championing the environmental health of the uMsunduzi and uMngeni Rivers.
Visit: https://www.duct.org.za/
Earthlife Africa – seeks a better life for all people without exploiting other people or degrading their environment**.**
Visit: https://earthlife.org.za/
The Federation for a Sustainable Environment – A prominent environmental activist stakeholder in the mining industry.
Visit: https://fse.org.za/
Fynbos Fish Trust – Conserves freshwater fishes and their habitats in South Africa's Cape Fold Ecoregion Biodiversity Hotspot.
Visit: https://fynbosfishtrust.org/
Hennops Revival – Focuses on reviving, restoring and healing the Hennops River, in Pretoria, in collaboration with the government, other NGOs, NPOs and Forums, the private sector and the public.
Visit: https://hennopsrevival.co.za/
Rivers of Life - An aquatic research organisation that undertakes evidence based research on aquatic ecosystems and their response to multiple stressors for the sustainable future.
Visit: https://riversoflife.co.za/
Save the Vaal Environment (SAVE) – Raises public awareness about pollution issues and the importance of preventing pollution of the Vaal River.
Visit: https://www.save.org.za/
WaterCAN – A growing network of citizen science activists who are committed water guardians and willing stewards

advocating for clean, safe and sustainable water.
Visit: https://watercan.org.za/
Water for the Future – Focuses on rehabilitation of the upper Jukskei River through community participation, green technology, and enterprise.
Visit: https://www.waterforthefuture.co.za/
Wildlife & Environment Society of South Africa (WESSA) – Plays a significant role in creating awareness and providing platforms for people to act and get involved in helping to solve environmental issues.
Visit: https://www.wessa.org.za/
Wildtrust – explores innovative conservation and development pathways that underline the interconnectedness between people and planet.
Visit: https://www.wildtrust.co.za/
WWF South Africa – Part of one of the world's leading conservation organisations.
Visit: https://www.wwf.org.za/

YOUTH GROUPS

Green Youth Indaba - South Africa's largest greening summit organised by youth for youth
Visit: https://www.greenyouthindaba.co.za/about-us/
Youth 4 the Environment – aims to connect young people with nature.
Visit: https://contourenviro.co.za/youth4enviro/
Young Water Professionals
Visit: https://wisa.org.za/empowerment/young-water-professionals-ywp/

WATER
RESEARCH
COMMISSION