Alaska State Envirothon

Aquatic Ecology

Alaska Aquatic Ecology Learning Objectives

1) Know the processes and phases for each part of the water cycle and understand the water cycles role in soil nutrient erosion, climate influences, and natural hazards.

2) Understand the concept and components of watersheds and be able to identify stream orders and watershed boundaries. Know the factors of a healthy watershed and an unhealthy watershed.

3) Know how to perform and interpret chemical water quality tests, including pH, dissolved oxygen, and suspended sediment. Understand why and how aquatic organisms and water quality is affected by the physical, chemical and biological conditions of the water.

4) Understand the concept of water conservation and explain ways Alaskans can reduce their water usage.

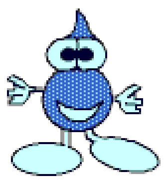
5) Identify common aquatic macroinvertebrate species and explain how they contribute to the overall picture of a stream's health.

6) Understand how soil is impacted by point and non-point source pollution and the importance of soil management to agriculture and clean water.

Water Cycle

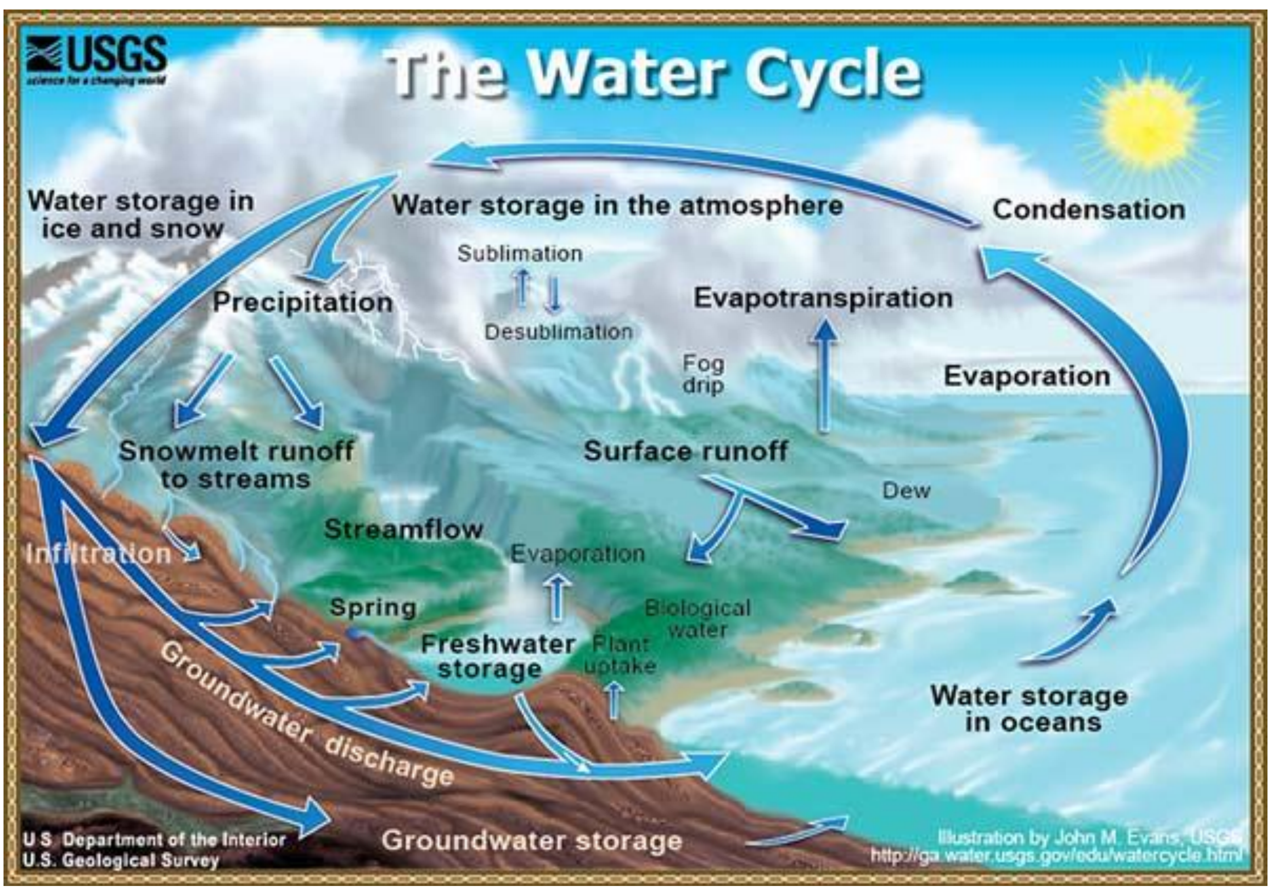
http://ga.water.usgs.gov/edu/watercyclesummary.html

What is the water cycle?



What is the water cycle? I can easily answer that—it is "me" all over! The water cycle describes the existence and movement of water on, in, and above the Earth. Earth's water is always in movement and is always changing states, from liquid to vapor to ice and back again. The water cycle has been working for billions of years and all life on Earth depends on it continuing to work; the Earth would be a pretty stale place to live without it.

Where does all the Earth's water come from? Primordial Earth was an incandescent globe made of magma, but all magmas contain water. Water set free by magma began to cool down the Earth's atmosphere, until it could stay on the surface as a liquid. Volcanic activity kept and still keeps introducing water in the atmosphere, thus increasing the surface- and ground-water volume of the Earth.

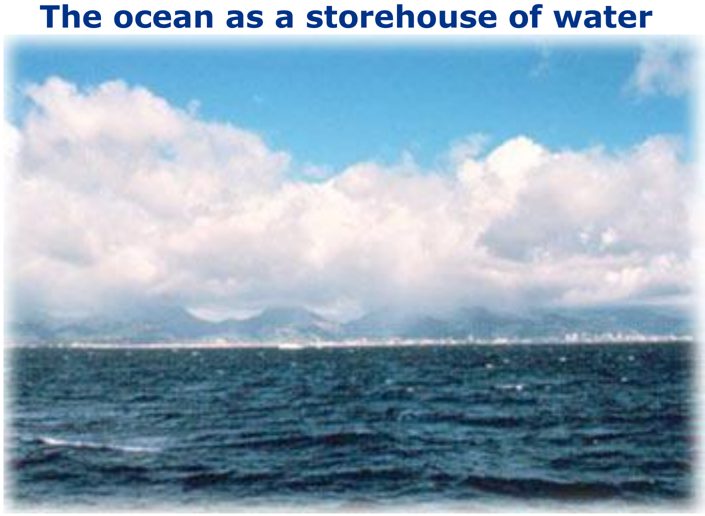


The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds.

Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow packs in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle "ends" ... oops - I mean, where it "begins."

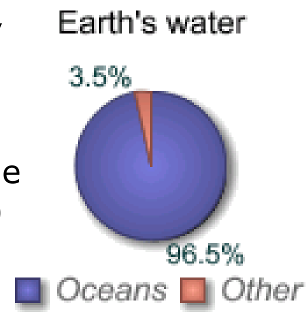
Water storage in oceans: Saline water existing in oceans and inland seas

The ocean as a storehouse of water



The water cycle sounds like it is describing how water moves above, on, and through the Earth ... and it does. But, in fact, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,600,000 cubic miles (mi^3) (1,386,000,000 cubic kilometers (km^3)) of the world's water supply, about 321,000,000 mi^3 (1,338,000,000 km^3) is stored in oceans. That is about

96.5 percent. It is also estimated that the oceans supply about 90 percent of the evaporated water that goes into the water cycle.



During colder climatic periods more ice caps and glaciers form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age glaciers covered almost one-third of Earth's land mass, with the result being that the oceans were about 400 feet (122 meters) lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 18 feet (5.5. meters) higher than they are now. About three million years ago the oceans could have been up to 165 feet (50 meters) higher.

Oceans in movement

If you have ever been seasick (we hope not), then you know how the ocean is never still. You might think that the water in the oceans moves around because of waves, which are driven by winds. But, actually, there are currents and "rivers" in the oceans that move massive amounts of water around the world. These movements have a great deal of influence on the water cycle. The Kuroshio Current, off the shores of Japan, is the largest current. It can travel between 25 and 75 miles (40 and 121 kilometers) a day, 1-3 miles (1.4-4.8 kilometers) per hour, and extends some 3,300 feet (1,000 meters) deep. The Gulf Stream is a well known stream of warm water in the Atlantic Ocean, moving water from the Gulf of Mexico across the Atlantic Ocean towards Great Britain. At a speed of 60 miles (97 kilometers) per day, the Gulf stream moves 100 times as much water as all the rivers on Earth. Coming from warm climates, the Gulf Stream moves warmer water to the North Atlantic.

Evaporation: The process by which water is changed from liquid to a gas or vapor

Credit: Kidzone Fun Facts

Evaporation and why it occurs

Evaporation is the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in our atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration.

Heat (energy) is necessary for evaporation to occur. Energy is used to break the bonds that hold water molecules together, which is why water easily evaporates at the boiling point (212° F, 100° C) but evaporates much more slowly at the freezing point. Net evaporation occurs when the rate of evaporation exceeds the rate of condensation. A state of saturation exists when these two process rates are equal, at which point, the relative humidity of the air is 100 percent. Condensation, the opposite of evaporation, occurs when saturated air is cooled below the dew point (the temperature to which air must be cooled at a constant pressure for it to become fully saturated with water), such as on the outside of a glass of ice water. In fact, the process of evaporation removes heat from the environment, which is why water evaporating from your skin cools you.

Evaporation drives the water cycle

Evaporation from the oceans is the primary mechanism supporting the surface-to-atmosphere portion of the water cycle. After all, the large surface area of the oceans (over 70 percent of the Earth's surface is covered by the oceans) provides the opportunity for such large-scale evaporation to occur. On a global scale, the amount of water evaporating is about the same as the amount of water delivered to the Earth as precipitation. This does vary geographically, though. Evaporation is more prevalent over the oceans than precipitation, while over the land, precipitation routinely exceeds evaporation. Most of the water that evaporates from the oceans falls back into the oceans as precipitation. Only about 10 percent of the water evaporated from the oceans is transported over land and falls as precipitation. Once evaporated, a water molecule spends about 10 days in the air. The process of evaporation is so great that without precipitation runoff, and discharge from aquifers, oceans would become nearly empty.

Cobden Unit School District #17, Illinois

Sublimation: The changing of snow or ice to water vapor without melting

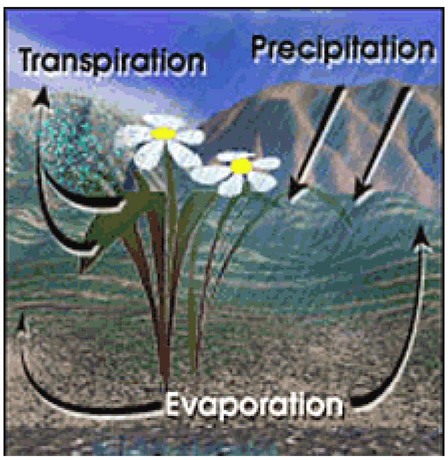
For those of us interested in the water cycle, sublimation is most often used to describe the process of snow and ice changing into water vapor without first melting into water. Sublimation is a common way for snow to disappear in certain climates.

It is not easy to actually see sublimation happen, at least not with ice. One way to see the results of sublimation is to hang a wet shirt outside on a below-freezing day. Eventually the ice in the shirt will disappear.

Actually, the best way to visualize sublimation is to not use water at all, but to use carbon dioxide instead, as this picture shows."Dry ice" is solid, frozen carbon dioxide, which sublimates, or turns to gas, at the temperature -78.5 °C (-109.3°F). The fog you see in the picture is a mixture of cold carbon dioxide gas and cold, humid air, created as the dry ice sublimates.

Sublimation occurs more readily when certain weather conditions are present, such as low relative humidity and dry winds. It also occurs more at higher altitudes, where the air pressure is less than at lower altitudes. Energy, such as strong sunlight, is also needed. If I was to pick one place on Earth where sublimation happens a lot, I might choose the south side of Mt. Everest. Low temperatures, strong winds, intense sunlight, very low air pressure - just what is needed for sublimation to occur.

Evapotranspiration: The process by which water vapor is discharged to the atmosphere as a result of evaporation from the soil and transpiration by plants.



Hailey King, NASA, GFSC

Although some definitions of evapotranspiration include evaporation from surface-water bodies, such as lakes and even the ocean, on this Web site, evapotranspiration is defined as the water lost to the atmosphere from the ground surface and the transpiration of groundwater by plants through their leaves.

Transpiration: The release of water from plant leaves

Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. Transpiration is essentially evaporation of water from plant leaves. It is estimated that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration.

Credit: Ming kei College, Hong Kong

Plant transpiration is an invisible process—since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathing". During a growing season, a leaf will transpire many times more water than its own weight. A large oak tree can transpire 40,000 gallons (151,000 liters) per year.

Water storage in the atmosphere: Water stored in the atmosphere as vapor, such as clouds and humidity

The atmosphere is full of water

The water cycle is all about storing water and moving water on, in, and above the Earth. Although the atmosphere may not be a great storehouse of water, it is the superhighway used to move water around the globe. There is always water in the atmosphere. Clouds are, of course, the most visible manifestation of atmospheric water, but even clear air contains water—water in particles that are too small to be seen. One estimate of the volume of water in the atmosphere at any one time is about 3,100 cubic miles (mi^3) or 12,900 cubic kilometers (km^3). That may sound like a lot, but it is only about 0.001 percent of the total Earth's water volume. If all of the water in the atmosphere rained down at once, it would only cover the ground to a depth of 2.5 centimeters, about 1 inch.

Condensation: The process by which water is changed from vapor to liquid

Condensation is the process in which water vapor in the air is changed into liquid water. Condensation is crucial to the water cycle because it is responsible for the formation of clouds. These clouds may produce precipitation, which is the primary route for water to return to the Earth's surface within the water cycle. Condensation is the opposite of evaporation.

You don't have to look at something as far away as a cloud to notice condensation, though. Condensation is responsible for ground-level fog, for your glasses fogging up when you go from a cold room to the outdoors on a hot, humid day, for the water that drips off the outside of your glass of iced tea, and for the water on the inside of your home windows on a cold day.

Condensation in the air

Even though clouds are absent in a crystal clear blue sky, water is still present in the form of water vapor and droplets which are too small to be seen. Depending on meteorological conditions, water molecules will combine with tiny particles of dust, salt, and smoke in the air to form cloud droplets, which grow and develop into clouds, a form of water we can see. Cloud droplets can vary greatly in size, from 10 microns (millionths of a meter) to 1 millimeter (mm), and even as large as 5 mm. This process occurs higher in the sky where the air is cooler and more condensation occurs relative to evaporation. As water droplets combine (also known as coalescence) with each other, and grow in size, clouds not only develop, but precipitation may also occur. Precipitation is essentially water cloud in its liquid or solid form falling from the base of a cloud. This seems to happen too often during picnics or large groups of people gather at swimming pools.


Photograph by the National Weather Service, Grand Junction Weather Forecast Office, Colorado, U.S.A.

You might ask ... why is it colder higher up?

As we said, clouds form in the atmosphere because air containing water vapor rises and cools. The key to this process is that air near the Earth's surface is warmed by solar radiation. But, do you know why the atmosphere cools above the Earth's surface? Generally, air pressure, is the reason. Air has mass (and, because of gravity on Earth, weight) and at sea level the weight of a column of air pressing down on your head is about 14 ½ pounds (6.6 kilograms) per square inch. The pressure (weight), called barometric pressure that results is a consequence of the density of the air above. At higher altitudes, there is less air above, and, thus, less air pressure pressing down. The barometric pressure is lower, and lower barometric pressure is associated with fewer molecules per unit volume. Therefore, the air at higher altitudes is less dense. Since fewer air molecules exist in a certain volume of air, there are fewer molecules colliding with each other, and as a result, there will be less heat produced. This means cooler air. Do you find this confusing? Just think, clouds form all day long without having to understand any of this.

Precipitation: The discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Most precipitation falls as rain.

How do raindrops form?

Storm near Elko, Nevada. NOAA

The clouds floating overhead contain water vapor and cloud droplets, which are small drops of condensed water. These droplets are way too small to fall as precipitation, but they are large enough to form visible clouds. Water is continually evaporating and condensing in the sky. If you look closely at a cloud you can see some parts disappearing (evaporating) while other parts are growing (condensation). Most of the condensed water in clouds does not fall as precipitation because their fall speed is not large enough to overcome updrafts which support the clouds. For precipitation to happen, first tiny water droplets must condense on even tinier dust, salt, or smoke particles, which act as a nucleus. Water droplets may grow as a result of additional condensation of water vapor when the particles collide. If enough collisions occur to produce a droplet with a fall velocity which exceeds the cloud updraft speed, then it will fall out of the cloud as precipitation. This is not a trivial task since millions of cloud droplets are required to produce a single raindrop.

Water storage in ice and snow: Freshwater stored in frozen form, generally in glaciers, icefields, and snowfields

Ice caps around the world

NASA

Although the water cycle sounds like it is describing the movement of water, in fact, much more water is in storage at any one time than is actually moving through the cycle. By storage, we mean water that is locked up in its present state for a relatively long period of time, such as in ice caps and glaciers.

The vast majority, almost 90 percent, of Earth's ice mass is in Antarctica, while the Greenland ice cap contains 10 percent of the total global ice-mass. The Greenland ice cap is an interesting part of the water cycle. The ice cap became so large over time (about 600,000 cubic miles (mi^3) or 2.5 million cubic kilometers (km^3)) because more snow fell than melted. Over the millennia, as the snow got deeper, it compressed and became ice. The ice cap averages about 5,000 feet (1,500 meters) in thickness, but can be as thick as 14,000 feet (4,300 meters). The ice is so heavy that the land below it has been pressed down into the shape of a bowl. In many places, glaciers on Greenland reach to the sea, and one estimate is that as much as 125 mi^3 (517 km^3) of ice "calves" into the ocean each year—one of Greenland's contributions to the global water cycle. Ocean-bound icebergs travel with the currents, melting along the way. Some icebergs have been seen, in much smaller form, as far south as the island of Bermuda.

Ice and glaciers come and go

The climate, on a global scale, is always changing, although usually not at a rate fast enough for people to notice. There have been many warm periods, such as when the dinosaurs lived (about 100 million years ago) and many cold periods, such as the last ice age of about 20,000 years ago. During the last ice age much of the northern hemisphere was covered in ice and glaciers, and, as this map from the University of Arizona shows, they covered nearly all of Canada, much of northern Asia and Europe, and extended well into the United States.

Snowmelt runoff to streams: The movement of water as surface runoff from snow and ice to surface water

Hetch-Hetchy basin near Yosemite, California. Photo by David Gay

In the world-wide scheme of the water cycle, runoff from snowmelt is a major component of the global movement of water. In the colder climates much of the springtime runoff and stream flow in rivers is attributable to melting snow and ice. The effect of snowmelt on potential flooding, mainly during the spring, is something that causes concern for many people around the world. Besides flooding, rapid snowmelt can trigger landslides and debris flows.

Surface runoff: Precipitation runoff which travels over the soil surface to the nearest stream channel

Surface runoff is precipitation runoff over the landscape

Many people probably have an overly-simplified idea that precipitation falls on the land, flows overland (runoff), and runs into rivers, which then empty into the oceans. That is "overly simplified" because rivers also gain and lose water to the ground. Still, it is true that much of the water in rivers comes directly from runoff from the land surface, which is defined as surface runoff.

Overland runoff from disturbed areas often contains excessive sediment in addition to water. (USGS)

When rain hits saturated or impervious ground it begins to flow overland downhill. It is easy to see if it flows down your driveway to the curb and into a storm sewer, but it is harder to notice it flowing overland in a natural setting. During a heavy rain you might notice small rivulets of water flowing downhill. Water will flow along channels as it moves into larger creeks, streams, and rivers. This picture gives a graphic example of how surface runoff (here flowing off a road) enters a small creek. The runoff in this case is flowing over bare soil and is depositing sediment into the river (not good for water quality). The runoff entering this creek is beginning its journey back to the ocean.

As with all aspects of the water cycle, the interaction between precipitation and surface runoff varies according to time and geography. Similar storms occurring in the Amazon jungle and in the desert Southwest of the United States will produce different surface-runoff effects. Surface runoff is affected by both meteorological factors and the physical geology and topography of the land. Only about a third of the precipitation that falls over land runs off into streams and rivers and is returned to the oceans. The other two-thirds is evaporated, transpired, or soaks into ground water. Surface runoff can also be diverted by humans for their own uses.

Streamflow: The movement of water in a natural channel, such as a river

The U.S. Geological Survey (USGS) uses the term "streamflow" to refer to the amount of water flowing in a river. Although USGS usually uses the term "stream" when discussing flowing water bodies, in these pages we'll use "rivers" more often to describe flowing creeks, streams, and rivers, since that is probably what you are more familiar with.

Importance of rivers

Rivers are invaluable to not only people, but to life everywhere. Not only are rivers a great place for people (and their dogs) to play, but people use river water for drinking-water supplies and irrigation water, to produce electricity, to flush away wastes (hopefully, but not always, treated wastes), to transport merchandise, and to obtain food. Rivers are indeed major aquatic landscapes for all manners of plants and animals. Rivers even help keep the aquifers underground full of water by discharging water downward through their streambeds. And, we've already mentioned that the oceans stay full of water because rivers and runoff continually refreshes them.

Watersheds and rivers

When looking at the location of rivers and also the amount of streamflow in rivers, the key concept to know about is the river's "watershed". What is a watershed? Easy, if you are standing on the ground right now, just look down. You're standing, and everyone is standing, in a watershed. A watershed is the area of land where all of the water that falls in it and drains off of it goes into the same place. Watersheds can be as small as a footprint in the mud or large enough to encompass all the land that drains water into the Mississippi River where it enters the Gulf of Mexico. Smaller watersheds are contained in bigger watersheds. It all depends of the outflow point—all of the land above that drains water that flows to the outflow point is the watershed for that outflow location. Watersheds are important because the streamflow and the water quality of a river are affected by things, human-induced or not, happening in the land area "above" the river-outflow point

Freshwater storage: Freshwater existing on the Earth's surface

One part of the water cycle that is obviously essential to all life on Earth is the freshwater existing on the land surface. Just ask your neighbor, a tomato plant, a trout, or that pesky mosquito. Surface water includes the streams (of all sizes, from large rivers to small creeks), ponds, lakes, reservoirs (man-made lakes), and freshwater wetlands. The definition of freshwater is water containing less than 1,000 milligrams per liter of dissolved solids, most often salt.

The amount of water in our rivers and lakes is always changing due to inflows and outflows. Inflows to these water bodies will be from precipitation, overland runoff, ground-water seepage, or tributary inflows. Outflows from lakes and rivers include evaporation and discharge to ground water. Humans get into the act also, as people make great use of diverted surface water for their needs. So, the amount and location of surface water changes over time and space, whether naturally or with human help. Certainly during the last ice age when glaciers and snowpacks covered much more land surface than today, life on Earth had to adapt to different hydrologic conditions than those which took place both before and after. And the layout of the landscape certainly was different before and after the last ice age, which influenced the topographical layout of many surface-water bodies today. Glaciers are what made the Great Lakes not only "great," but also such a huge storehouse of freshwater

Surface water keeps life going

As this satellite picture of the Nile Delta in Egypt shows, life can even bloom in the desert if there is a supply of surface water (or ground water) available. Water on the land surface really does sustain life, and this is as true today as it was millions of years ago. I'm sure dinosaurs held their meetings at the local watering hole 100 million years ago, just as antelopes in Africa do today. And, since ground water is supplied by the downward percolation of surface water, even aquifers are happy for water on the Earth's surface. You might think that fish living in the saline oceans aren't affected by freshwater, but, without freshwater to replenish the oceans they would eventually evaporate and become too saline for even the fish to survive.

Usable freshwater is relatively scarce

Freshwater represents only about three percent of all water on Earth and freshwater lakes and swamps account for a mere 0.29 percent of the Earth's freshwater. Twenty percent of all freshwater is in one lake, Lake Baikal in Asia. Another twenty percent is stored in the Great Lakes (Huron, Michigan, and Superior). Rivers hold only about 0.006 percent of total freshwater reserves. You can see that life on Earth survives on what is essentially only a "drop in the bucket" of Earth's total water supply!

Infiltration: The downward movement of water from the land surface into soil or porous rock

Ground water begins as precipitation

Anywhere in the world, a portion of the water that falls as rain and snow infiltrates into the subsurface soil and rock. How much infiltrates depends greatly on a number of factors. Infiltration of precipitation falling on the ice cap of Greenland might be very small, whereas, as this picture of a stream disappearing into a cave in southern Georgia, USA shows, a stream can act as a direct funnel right into ground water!

Some water that infiltrates will remain in the shallow soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material. Eventually it might enter a stream by seepage into the stream bank. Some of the water may infiltrate deeper, recharging ground-water aquifers. If the aquifers are shallow or porous enough to allow water to move freely through it, people can drill wells into the aquifer and use the water for their purposes. Water may travel long distances or remain in ground-water storage for long periods before returning to the surface or seeping into other water bodies, such as streams and the oceans.

Subsurface water

As precipitation infiltrates into the subsurface soil, it generally forms an unsaturated zone and a saturated zone. In the unsaturated zone, the voids—that is, the spaces between grains of gravel, sand, silt, clay, and cracks within rocks—contain both air and water. Although a considerable amount of water can be present in the unsaturated zone, this water cannot be pumped by wells because it is held too tightly by capillary forces. The upper part of the unsaturated zone is the soil-water zone. The soil zone is crisscrossed by roots, openings left by decayed roots, and animal and worm burrows, which allow the precipitation to infiltrate into the soil zone. Water in the soil is used by plants in life functions and transpiration, but it also can evaporate directly to the atmosphere. Below the unsaturated zone is a saturated zone where water completely fills the voids between rock and soil particles.

In places where the water table is close to the land surface and where the water can move through the aquifer at a high rate, aquifers can be replenished artificially

Groundwater storage: Water existing for long periods below the Earth's surface

Stored water as part of the water cycle

Large amounts of water are stored in the ground. The water is still moving, possibly very slowly, and it is a part of the water cycle. Most of the water in the ground comes from precipitation that infiltrates downward from the land surface. The upper layer of the soil is the unsaturated zone, where water is present in varying amounts that change over time, but does not saturate the soil. Below this layer is the saturated zone, where all of the pores, cracks, and spaces between rock particles are saturated with water. The term ground water is used to describe this area. Another term for ground water is "aquifer," although this term is usually used to describe water-bearing formations capable of yielding enough water to supply peoples' uses. Aquifers are a huge storehouse of Earth's water and people all over the world depend on ground water in their daily lives.

To find water, look under the table ... the water table

I hope you appreciate my spending an hour in the blazing sun to dig this hole at the beach. It is a great way to illustrate the concept of how at a certain depth the ground, if it is permeable enough to hold water, is saturated with water. The top of the pool of water in this hole is the water table. The breaking waves of the ocean are just to the right of this hole, and the water level in the hole is the same as the level of the ocean. Of course, the water level here changes by the minute due to the movement of the tides, and as the tide goes up and down, the water level in the hole moves, too.

In a way, this hole is like a dug well used to access ground water, albeit saline in this case. But, if this was freshwater, people could grab a bucket an supply themselves with the water they need to live their daily lives. You know that at the beach if you took a bucket and tried to empty this hole, it would refill immediately because the sand is so permeable that water flows easily through it, meaning our "well" is very "high-yielding" (too bad the water is saline). To access freshwater, people have to drill wells deep enough to tap into an aquifer. The well might have to be dozens or thousands of feet deep. But the concept is the same as our well at the beach—access the water in the saturated zone where the voids in the rock are full of water.

Groundwater discharge: The movement of water out of the ground

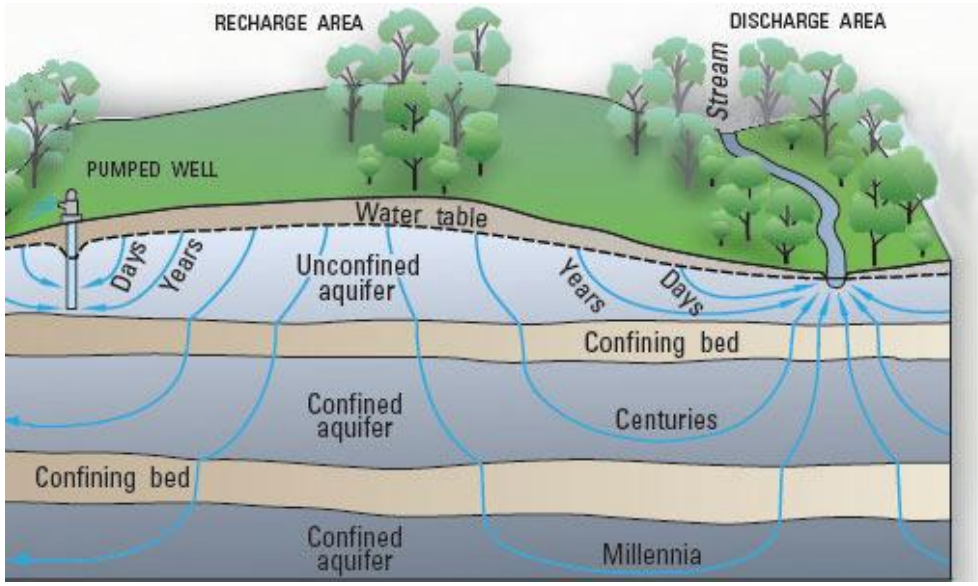
Ground-water discharge in Snake River Plain, Idaho, USA

There's more water than just what you can see

You see water all around you every day as lakes, rivers, ice, rain and snow. There are also vast amounts of water that are unseen—water existing in the ground. And even though ground water is unseen, it is moving below your feet right now. As part of the water cycle, ground water is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals. People have been using ground water for thousands of years and continue to use it today, largely for drinking water and irrigation. Life on Earth depends on ground water just as it does on surface water.

Ground water flows underground

Some of the precipitation that falls onto the land infiltrates into the ground to become ground water. Once in the ground, some of this water travels close to the land surface and emerges very quickly as discharge into streambeds, but, because of gravity, much of it continues to sink deeper into the ground. If the water meets the water table (below which the soil is saturated), it can move both vertically and horizontally. Water moving downward can also meet more dense and water-resistant non-porous rock and soil, which causes it to flow in a more horizontal fashion, generally towards streams, the ocean, or deeper into the ground.



As this diagram shows, the direction and speed of ground-water movement is determined by the various characteristics of aquifers and confining layers (which water has a difficult time penetrating) in the ground. Water moving below ground depends on the permeability (how easy or difficult it is for water to move) and on the porosity (the amount of open space in the material) of the subsurface rock. If the rock has characteristics that allow water to move relatively freely through it, then ground water can move significant distances in a number of days. But ground water can also sink into deep aquifers where it takes thousands of years to move back into the environment, or even go into deep ground-water storage, where it might stay for much longer periods.

Credit: Jo Schaper, Missouri Springs

Spring: Place where a concentrated discharge of ground water flows at the ground surface

What is a spring?

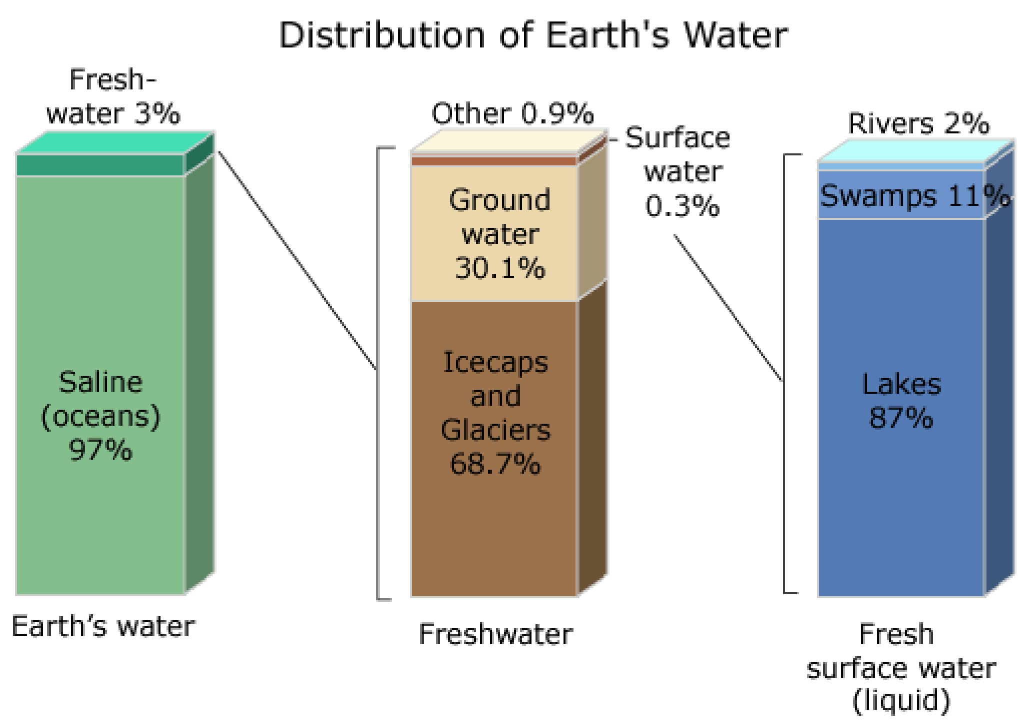
A spring is a water resource formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of ground water at or below the local water table, below which the subsurface material is saturated with water. A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface. They range in size from intermittent seeps, which flow only after much rain, to huge pools with a flow of hundreds of millions of liters per day.

Springs may be formed in any sort of rock, but are more prevalent in limestone and dolomite, which fracture easily and can be dissolved by rainfall that becomes weakly acidic. As the rock dissolves and fractures, spaces can form that allow water to flow. If the flow is horizontal, it can reach the land surface, resulting in a spring.

Global water distribution

For a detailed explanation of where Earth's water exists, look at the chart and data table below. By now, you know that the water cycle describes the movement of Earth's water, so realize that the chart and table below represent the presence of Earth's water at a single point in time. If you check back in a thousand or million years, no doubt these numbers will be different!

Notice how of the world's total water supply of about 332.6 million cubic miles of water, over 96 percent is saline. And, of the total freshwater, over 68 percent is locked up in ice and glaciers. Another 30 percent of freshwater is in the ground. Fresh surface-water sources, such as rivers and lakes, only constitute about 22,300 cubic miles (93,100 cubic kilometers), which is about 0.0067 percent of total water. Yet, rivers and lakes are the sources of most of the water people use everyday.



Common water measurements

Water-quality meter to measure multiple parameters in the field.

The U.S. Geological Survey has been measuring water for decades. Millions of measurements and analyses have been made. Some measurements are taken almost every time water is sampled and investigated, no matter where in the U.S. the water is being studied. Even these simple measurements can sometimes reveal something important about the water and the environment around it.

The results of a single measurement of a water's properties are actually less important than looking at how the properties vary over time. For example, if you take the pH of the creek behind your school and find that it is 5.5, you might say "Wow, this water is acidic!" But, a pH of 5.5 might be "normal" for that creek. It is similar to how my normal body temperature (when I'm not sick) is about 97.5 degrees, but my third-grader's normal temperature is "really normal" -- right on the 98.6 mark. As with our temperatures, if the pH of your creek begins to change, then you might suspect that something is going on somewhere that is affecting the water, and possibly, the water quality. So, often, the ***changes*** in water measurements are more important than the actual measured values.

Water temperature

Water temperature is not only important to swimmers and fisherman, but also to industries and even fish and algae. A lot of water is used for cooling purposes in power plants that generate electricity. They need cool water to start with, and they generally release warmer water back to the environment. The temperature of the released water can affect downstream habitats. Temperature also can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants.

pH

pH is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in "logarithmic units," like the Richter scale, which measures earthquakes. Each number represents a 10-fold change in the acidity/basicness of the water. Water with a pH of 5 is ten times more acidic than water having a pH of six.

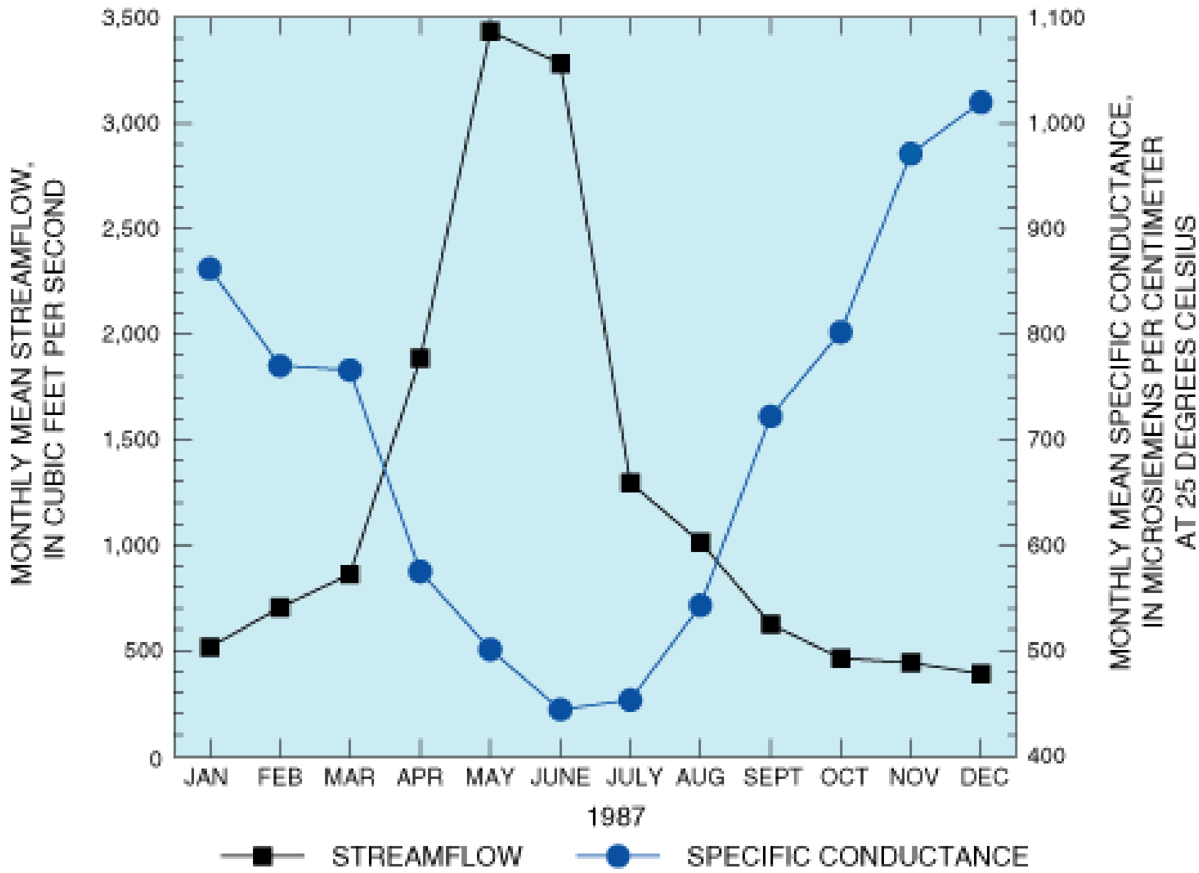
Pollution can change water’s pH, which in turn can harm animals and plants living in the water. For instance, water coming out of an abandoned coal mine can have a pH of 2, which is very acidic and would definitely affect any fish crazy enough to try to live in it! By using the logarithm scale, this mine-drainage water would be 100,000 times more acidic than neutral water -- so stay out of abandoned mines.

Specific conductance

Meter to measure specific conductance in the field and lab

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water. Pure water, such as distilled water, will have a very low specific conductance, and sea water will have a high specific conductance. Rainwater often dissolves airborne gasses and airborne dust while it is in the air, and thus often has a higher specific conductance than distilled water. Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water.

High specific conductance indicates high dissolved-solids concentration; dissolved solids can affect the suitability of water for domestic, industrial, and agricultural uses. At higher levels, drinking water may have an unpleasant taste or odor or may even cause gastrointestinal distress. Additionally, high dissolved-solids concentration can cause deterioration of plumbing fixtures and appliances. Relatively expensive water-treatment processes, such as reverse osmosis, are needed to remove excessive dissolved solids from water.



Relation of streamflow to specific conductance for the Arkansas River near Avondale, 1987.

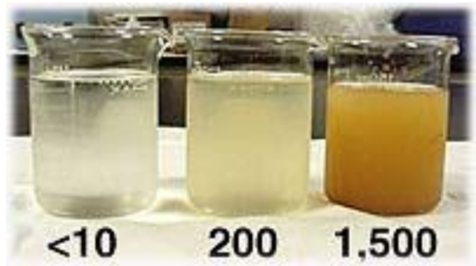
Agriculture also can be adversely affected by high-specific-conductance water, as crops cannot survive if the water they use is too saline, for instance. Agriculture can also be the cause of increases in the specific conductance of local waters. When water is used for irrigation, part of the water evaporates or is consumed by plants, concentrating the original amount of dissolved solids in less water; thus, the dissolved-solids concentration and the specific conductance in the remaining water is increased. The remaining higher specific-conductance water reenters the river as irrigation-return flow. In a USGS study in Colorado, USA, specific conductance was found to vary during the year as a result of the temporal variability of streamflow. As this chart shows, specific conductance generally was lowest in the Arkansas RIver near Avondale, Colorado, in May to August, when streamflow generally was largest, and increased with decreasing streamflow in the fall, winter, and spring.

Often in school, students do an experiment where they connect a battery to a light bulb and run two wires from the battery into a beaker of water. When the wires are put into a beaker of distilled water, the light will not light. But, the bulb does light up when the beaker contains salt water (saline). In the saline water, the salt has dissolved, releasing free electrons, and the water will conduct an electrical current.

Turbidity

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include:

- clay
- silt
- finely divided organic and inorganic matter
- soluble colored organic compounds
- plankton
- microscopic organisms



Turbidity makes the water cloudy or opaque. The picture to the left shows highly turbid water from a tributary (where construction was probably taking place) flowing into the less turbid water of the Chattahoochee River in Georgia. Turbidity is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidities.

Turbidity can be measured in the laboratory and also on-site in the river. A handheld turbidity meter (left-side picture) measures turbidity of a water sample. The meter is calibrated using standard samples from the meter manufacturer. The picture with the three glass vials shows turbidity standards of 5, 50, and 500 NTUs. Once the meter is calibrated to correctly read these standards, the turbidity of a water sample can be taken.

Dissolved oxygen

You can't tell by looking at water that there is oxygen in it (unless you remember that chemical makeup of a water molecule is hydrogen and oxygen). But, if you look at a closed bottle of a soft drink, you don't see the carbon dioxide dissolved in that - until you shake it up and open the top. The oxygen dissolved in lakes, rivers, and oceans is crucial for the organisms and creatures living in it. As the amount of dissolved oxygen drops below normal levels in water bodies, the water quality is harmed and creatures begin to die off. Indeed, a water body can "die", a process called eutrophication.

Eutrophic conditions, Hartbees River, South Africa
Credit: National Eutrophication Monitoring Programme

Although water molecules contain an oxygen atom, this oxygen is not what is needed by aquatic organisms living in our natural waters. A small amount of oxygen, up to about ten molecules of oxygen per million of water, is actually dissolved in water. This dissolved oxygen is breathed by fish and zooplankton and is needed by them to survive.

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains little. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in our lakes and rivers can cause an oxygen-deficient situation to occur. Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer, when dissolved-oxygen levels are at a seasonal low.

Suspended sediment

Suspended sediment is the amount of soil moving along in a stream. It is highly dependent on the speed of the water flow, as fast-flowing water can pick up and suspend more soil than calm water. During storms, soil is washed from the stream banks into the stream. The amount that washes into a stream depends on the type of land in the river's watershed and the vegetation surrounding the river.

If land is disturbed along a stream and protection measures are not taken, then excess sediment can harm the water quality of a stream. You've probably seen those short, plastic fences that builders put up on the edges of the property they are developing. These silt fences are supposed to trap sediment during a rainstorm and keep it from washing into a stream, as excess sediment can harm the creeks, rivers, lakes, and reservoirs.

Sediment coming into a reservoir is always a concern; once it enters it cannot get out - most of it will settle to the bottom. Reservoirs can "silt in" if too much sediment enters them. The volume of the reservoir is reduced, resulting in less area for boating, fishing, and recreation, as well as reducing the power-generation capability of the power plant in the dam.

Do you want to test your local water quality?

Water test kits are available from World Water Monitoring Day (WWMD). Teachers and water-science enthusiasts: Do you want to be able to perform basic water-quality tests on local waters? WWMD offers inexpensive test kits so you can perform you own tests for temperature, pH, turbidity, and dissolved oxygen.

Water Conservation

http://www.monolake.org/about/waterconservation

WHY CONSERVE?

Water conservation is the most cost-effective and environmentally sound way to reduce our demand. Using less water also puts less pressure on our sewage treatment facilities, and uses less energy for water heating.

SAVING WATER SAVES ENERGY

Saving water also saves energy. 6.5% of the energy used in the state of California is for pumping and treating water—in fact, pumping water south (and uphill) in the State Water Project accounts for 2–3% of all the electricity used in the state. And for your personal energy bill, using less hot water saves on water heating. On the flip side, saving energy and using alternative energy saves water—electricity production from fossil fuels and nuclear energy is responsible for 39% of all freshwater withdrawals in the nation.

WHAT CAN I DO?

There are many effective ways to conserve water in and around your home. Look through this list for ways that will work for you. Indoor savings are based on a family of two adults and one child.

In the Bathroom

1. Make sure your toilet is an ultra-low flush model, which uses only one and a half gallons per flush.

2. If you're taking a shower, don't waste cold water while waiting for hot water to reach the shower head. Catch that water in a container to use on your outside plants or to flush your toilet. Saves 200 to 300 gallons a month.

3. Check toilet for leaks. Put dye tablets or food coloring into the tank. If color appears in the bowl without flushing, there's a leak that should be repaired. Saves 400 gallons a month.

4. Turn off the water while brushing your teeth. Saves three gallons each day.

5. Turn off the water while shaving. Fill the bottom of the sink with a few inches of water to rinse your razor. Saves three gallons each day.

In the Kitchen

1. If you wash dishes by hand—and that's the best way—don't leave the water

running for rinsing. If you have two sinks, fill one with rinse water. If you only have one sink, use a spray device or short blasts instead of letting the water run. Saves 200 to 500 gallons a month.

2. When washing dishes by hand, use the least amount of detergent possible. This minimizes rinse water needed. Saves 50 to 150 gallons a month.

3. Keep a bottle of drinking water in the refrigerator. This beats the wasteful habit of running tap water to cool it for drinking. Saves 200 to 300 gallons a month.

4. Don't defrost frozen foods with running water. Either plan ahead by placing frozen items in the refrigerator overnight or defrost them in the microwave. Saves 50 to 150 gallons a month.

5. Don't let the faucet run while you clean vegetables. Rinse them in a filled sink or pan. Saves 150 to 250 gallons a month.

6. Use the garbage disposal less and the garbage more (even better—compost!). Saves 50 to 150 gallons a month.

Outside

1. Put a layer of mulch around trees and plants. Chunks of bark, peat moss or gravel slows down evaporation. Saves 750 to 1,500 gallons a month.

2. If you have a pool, use a pool cover to cut down on evaporation. It will also keep your pool cleaner and reduce the need to add chemicals. Saves 1,000 gallons a month.

3. Water during the cool parts of the day. Early morning is better than dusk since it helps prevent the growth of fungus. Saves 300 gallons.

4. Don't water the lawn on windy days. There's too much evaporation. Can waste up to 300 gallons in one watering.

5. Cut down watering on cool and overcast days and don't water in the rain. Adjust or deactivate automatic sprinklers. Can save up to 300 gallons each time.

6. Set lawn mower blades one notch higher. Longer grass means less evaporation. Saves 500 to 1,500 gallons each month.

7. Have an evaporative air conditioner? Direct the water drain line to a flower bed, tree base, or lawn.

8. Drive your car onto a lawn to wash it. Rinse water can help water the grass.

9. Tell your children not to play with the garden hose. Saves 10 gallons a minute.

10. If you allow your children to play in the sprinklers, make sure it's only when you're watering the yard—-if it's not too cool at that time of day.

11. Xeriscape—replace your lawn and high-water-using trees and plants with less thirsty ones. But do this only in wet years. Even drought resistant plantings take extra water to get them going. That'll save 750 to 1,500 gallons a month.

12. When taking your car to a car wash—a good idea for saving water—be sure it's one of the many that recycles its wash water.

13. Dispose of hazardous materials properly! One quart of oil can contaminate 250,000 gallons of water, effectively eliminating that much water from our water supply. Contact your city or county for proper waste disposal options. And don't flush prescription medications!

While Shopping
Water is an essential ingredient in most manufacturing operations. Especially for those one billion of us in the high-consumption class, cutting down on our purchases of material things—from clothes and shoes to paper and appliances—**conserves and protects water supplies as effectively as installing a low-flush toilet does.** As with so many natural resources, as long as prices in the marketplace fail to reflect full social and ecological costs, voluntary changes in consumption patterns will play an important role in the quest for sustainability.

- We rarely think about water when we see an automobile, for example, but producing a typical US car requires more than 50 times its weight in water (39,090 gallons)! Choosing a fuel-efficient model will help—it takes 44 gallons of water to refine one gallon of crude oil and 1,700 gallons of water to produce a gallon of ethanol.
- A kilogram (2.2 lbs) of hamburger or steak produced by a typical California beef cattle operation, for instance, uses some 20,500 liters (5,400 gal.) of water.
- Producing one pound of bread requires 500 gallons of water.
- Producing one serving (8 oz.) of chicken requires 330 gallons of water.
- Growing one cotton T-shirt requires 256 gallons of water (source: *The King of California*, by Arax and Wartzman). Manufacture of one pair of organic cotton jeans takes 48 gallons (source: Patagonia, 2011).
- Producing one egg requires over 100 gallons of water.
- Producing one serving (8 fl. oz.) of milk requires 48 gallons of water.
- Producing one serving (2 oz.) of pasta requires 36 gallons of water.
- Producing one serving (4.6 oz.) of oranges requires 14 gallons of water.
- Producing one serving (4.3 oz.) of tomatoes requires 8 gallons of water.
- Producing a typical American Thanksgiving dinner for six people requires over 30,000 gallons of water.