Water Resources and Pollution

"When the well is dry, we learn the worth of water."
- Benjamin Franklin

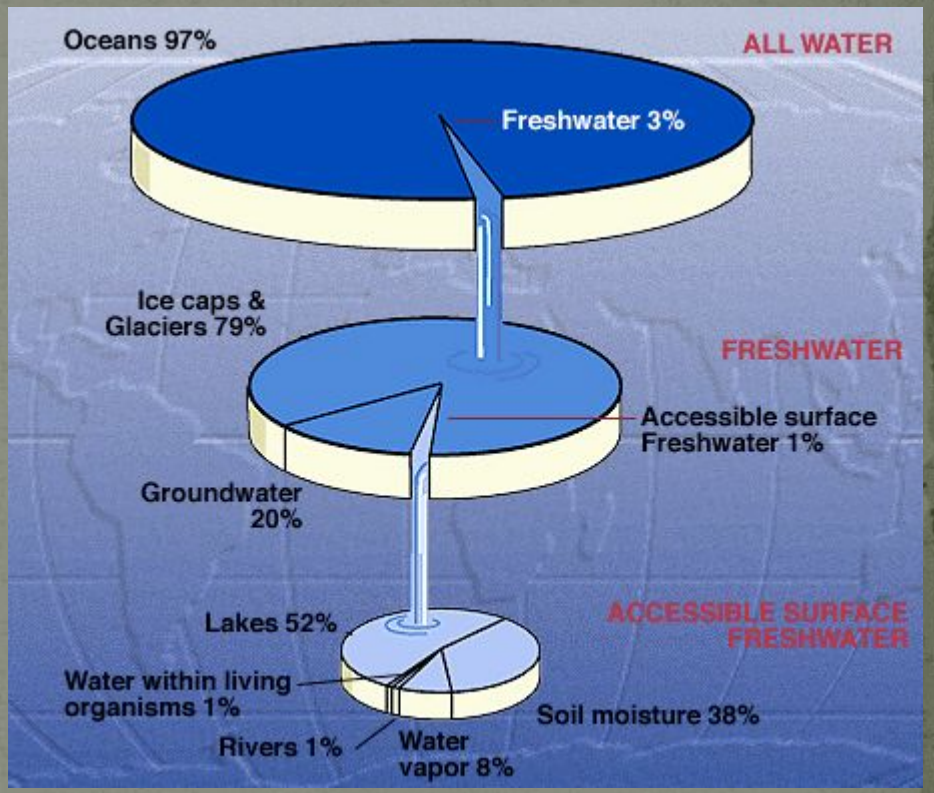
Hydrologic Cycle

- The hydrologic cycle describes the mechanisms by which water moves throughout the Earth.
  - Heat from the sun causes water to evaporate from rivers, lakes, oceans, or the soil.
  - Plant roots extract water from the soil and release some of it into the atmosphere through their leaves, a process called transpiration.

Barron Gorge National Park, Cairns, Australia.

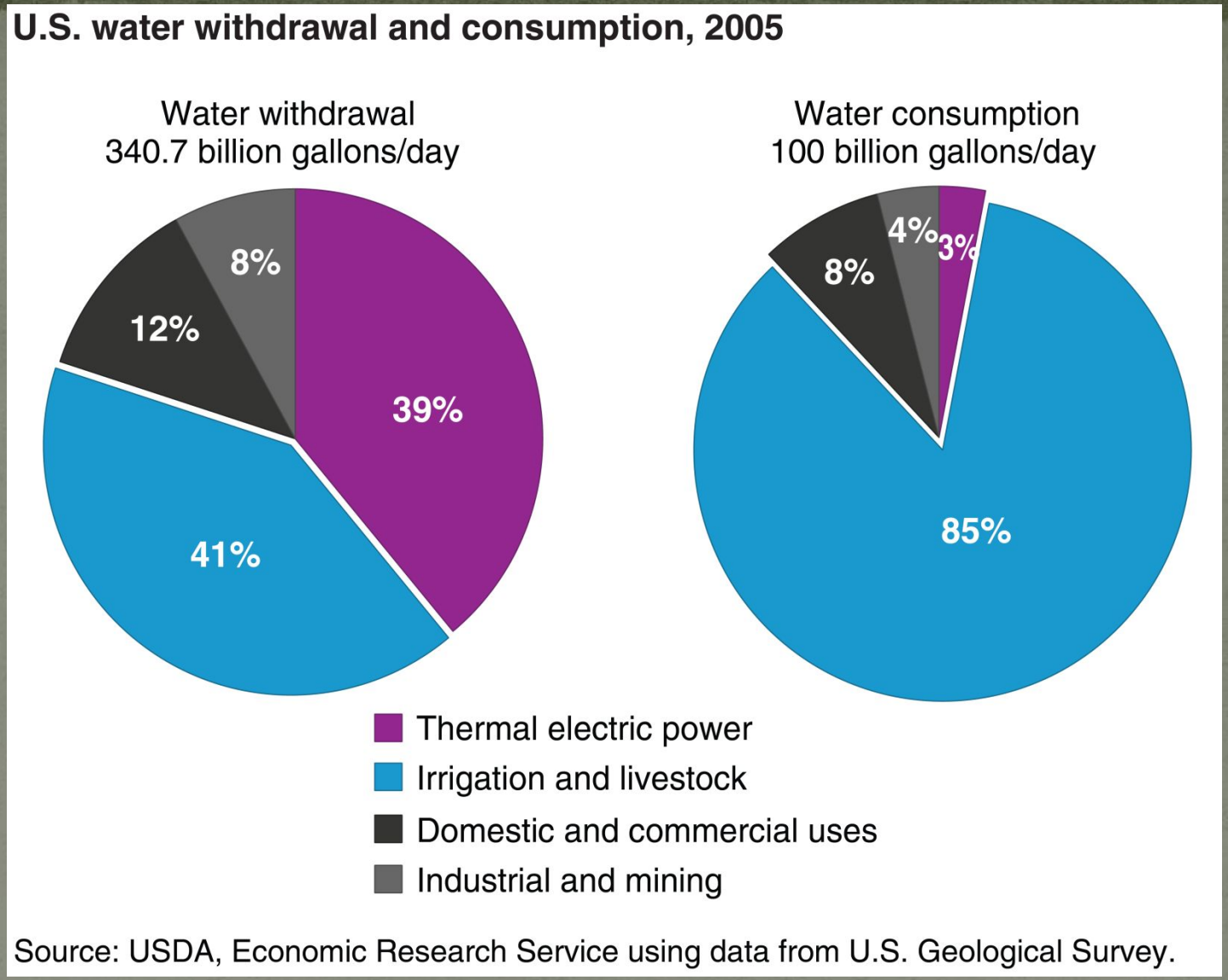
- As the evaporated water moves up into the atmosphere, it loses heat and condenses into clouds.
- The water then returns to the Earth as precipitation; rain, snow, or ice.
  - Some of that water will form runoff, moving towards lower elevations and collecting into another body of surface water.
  - The rest of the water soaks into the soil, a process called infiltration.

- At any given time, only about 3% of the world's water supply is freshwater. The rest is in the oceans.
- The majority of freshwater is frozen within land ice (glaciers).
- Another 20% is underground.
- Only 1% of freshwater is available at the surface.



Water Usage

- Water use is measured in two ways:
  - Water withdrawal measures the total amount diverted or withdrawn from a source.
    - Example: Coolant water withdrawn by a power plant, then returned to the river.
  - Water consumption measures water permanently removed from a source.
    - Example: Water is sprayed on crops for irrigation, then evaporates or transpires into the atmosphere.



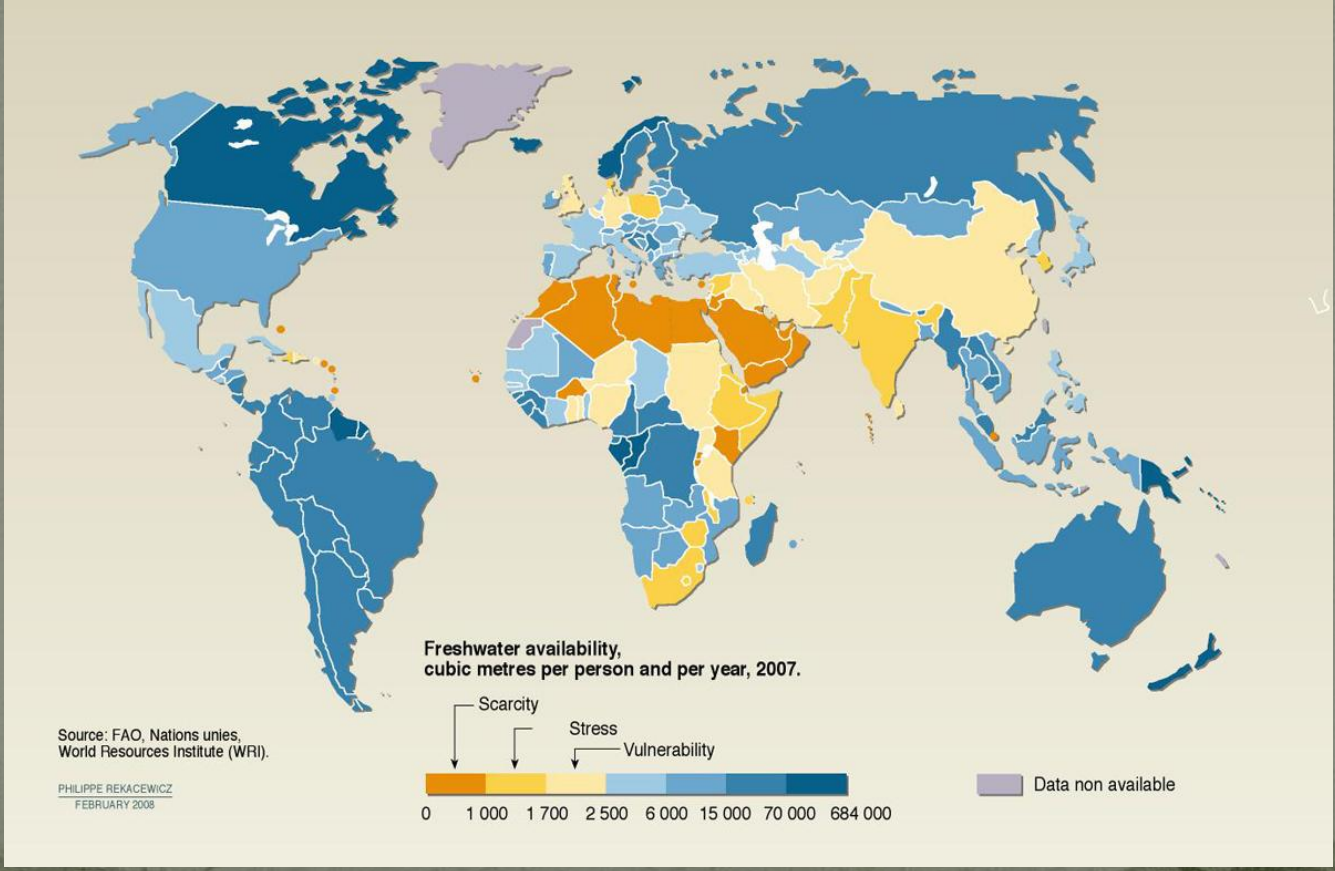
- Agriculture makes up the majority of both water withdrawal and consumption.

The Salton Sea

- The Salton Sink is a waterless depression in southeastern California, part of the Sonoran desert.
- At one point, the sink was actually the bottom of a huge freshwater lake.

Salton Sink, showing the water line of Lake Cahuilla.

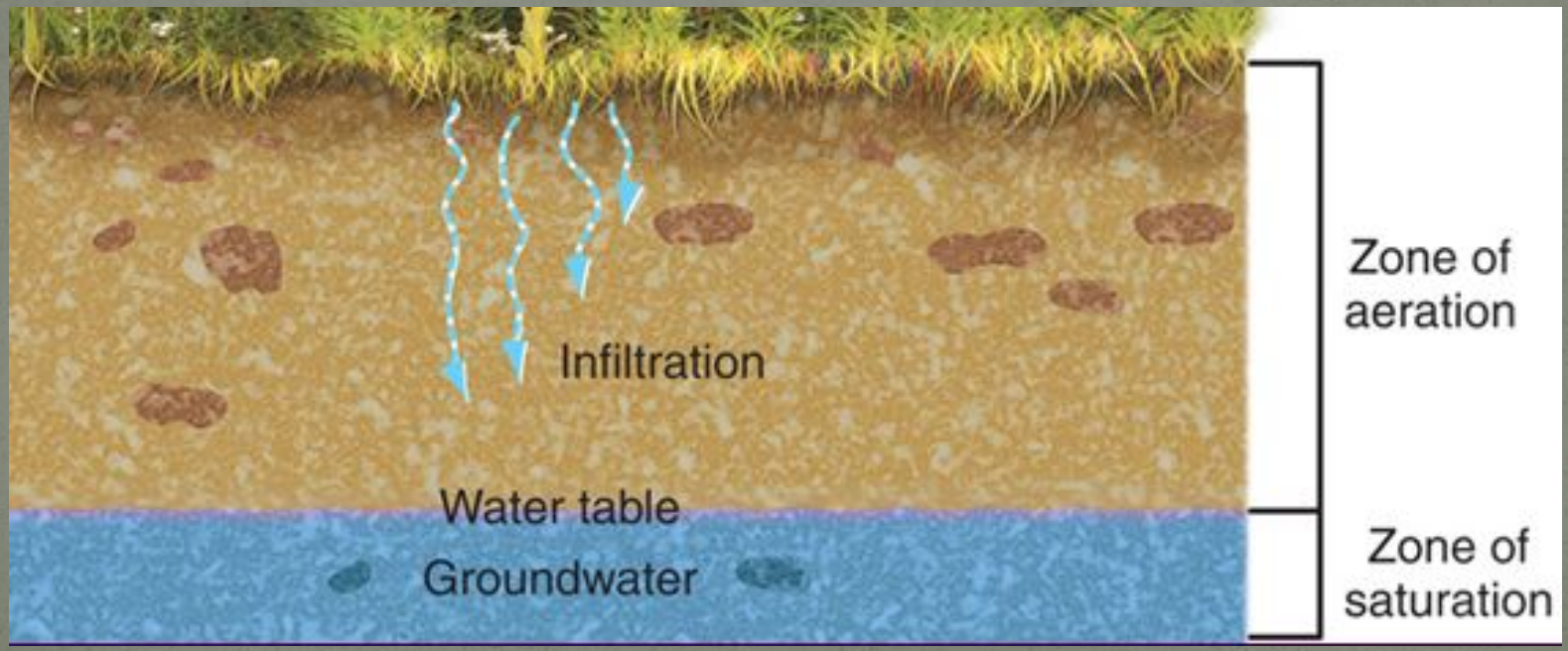
- The Salton Sink was an area experiencing water scarcity, meaning there was not enough access to freshwater to drink or grow food.
  - Countries experiencing water scarcity tend to be in highly populated and dry regions.



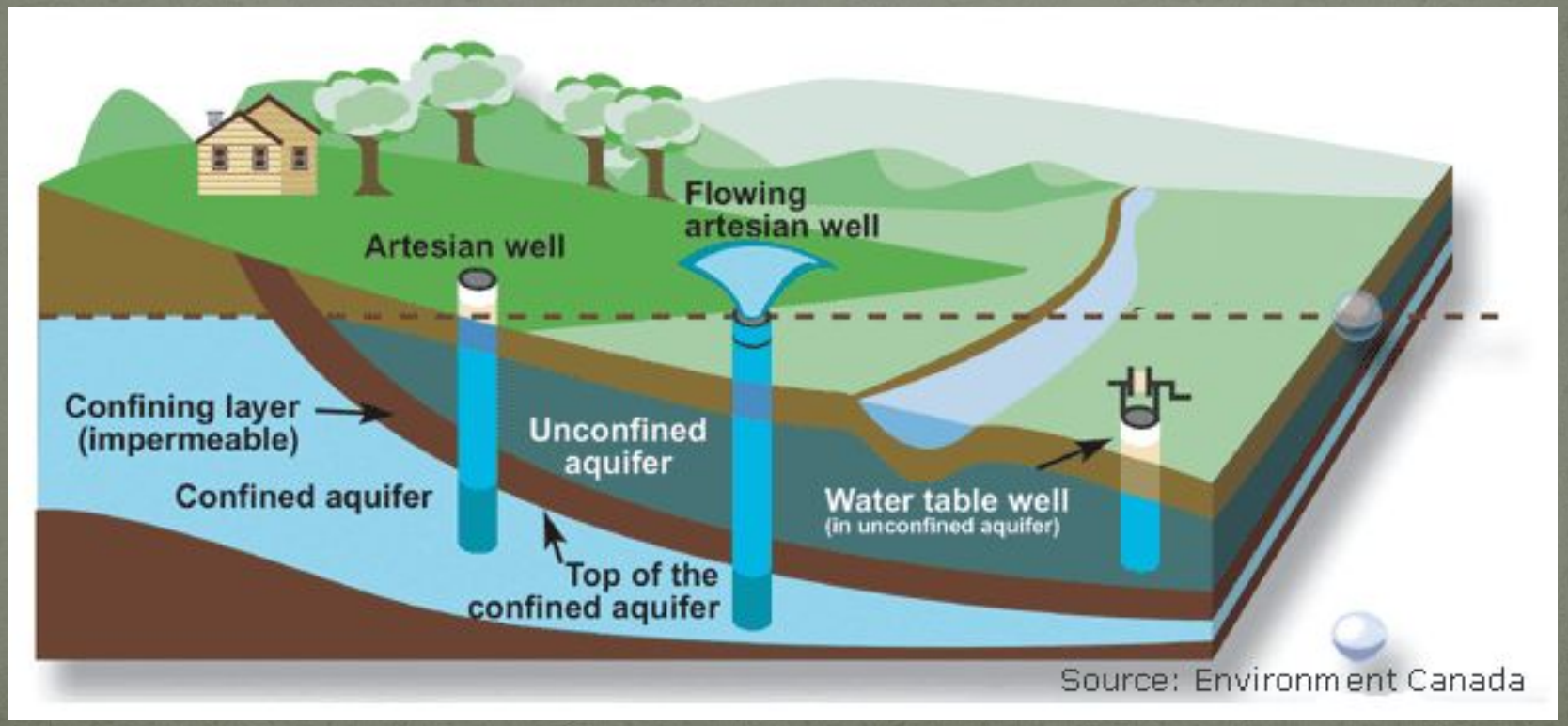
- In 1900, a development company began constructing irrigation canals to divert water from the Colorado River into the Salton Sink.
  - The land became fertile, and crops were planted.
- In 1905, heavy rainfall and snowmelt caused the river to swell and breach the dikes of the canals.
  - Two new rivers were carved out, causing the entire volume of the Colorado river to empty into the sink, creating the Salton Sea.

Accessing Groundwater

- Groundwater is located in a region of soil called the zone of saturation, where all of the spaces between soil particles are filled with water.
  - The top of this region is called the water table.



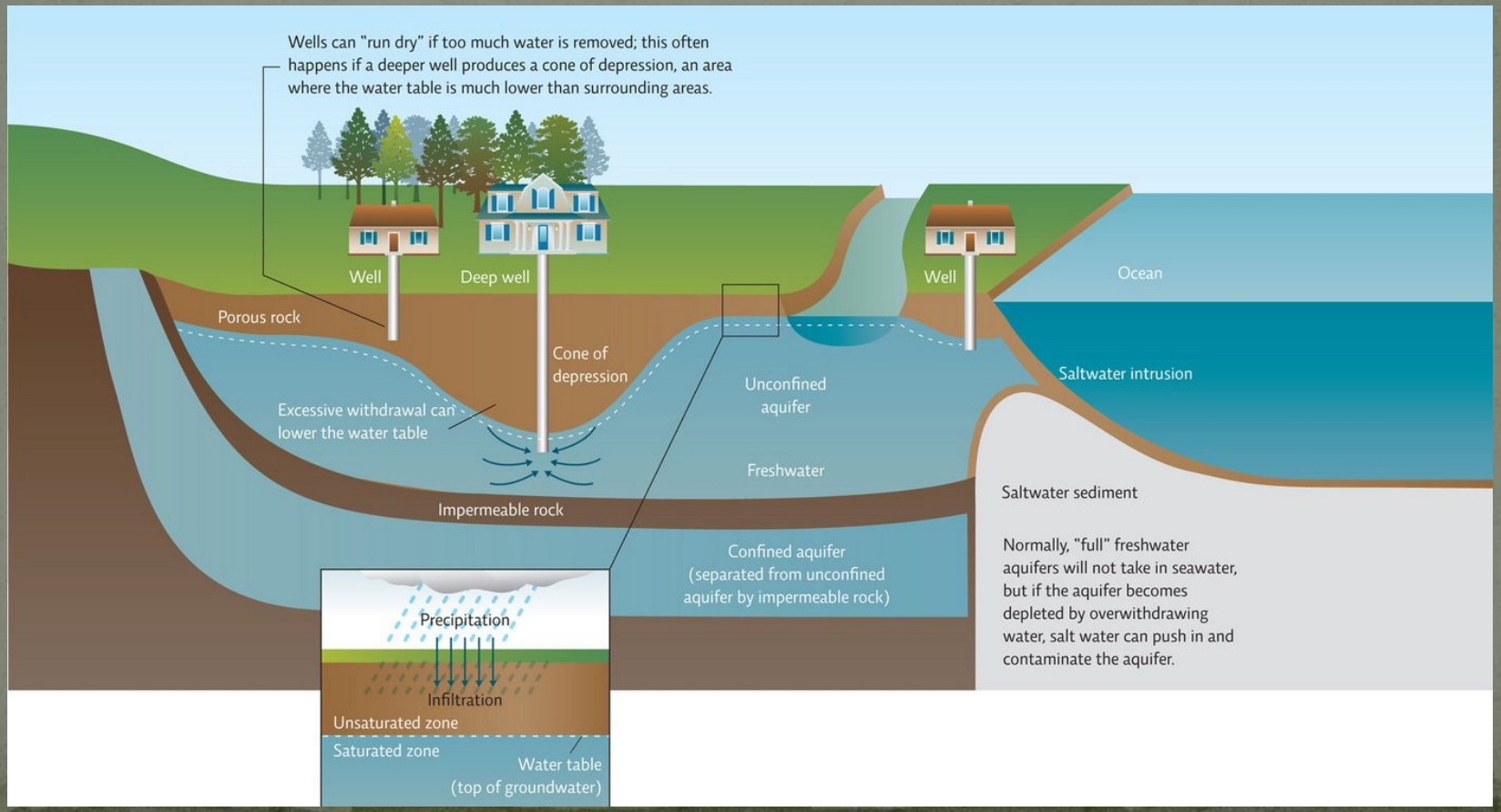
- Aquifers are underground regions of soil or porous rock that are saturated with water.
  - If the aquifer is physically separated from the groundwater, it is called a confined aquifer.
- Regions where the water can infiltrate the soil and reach the aquifer are called recharge zones.



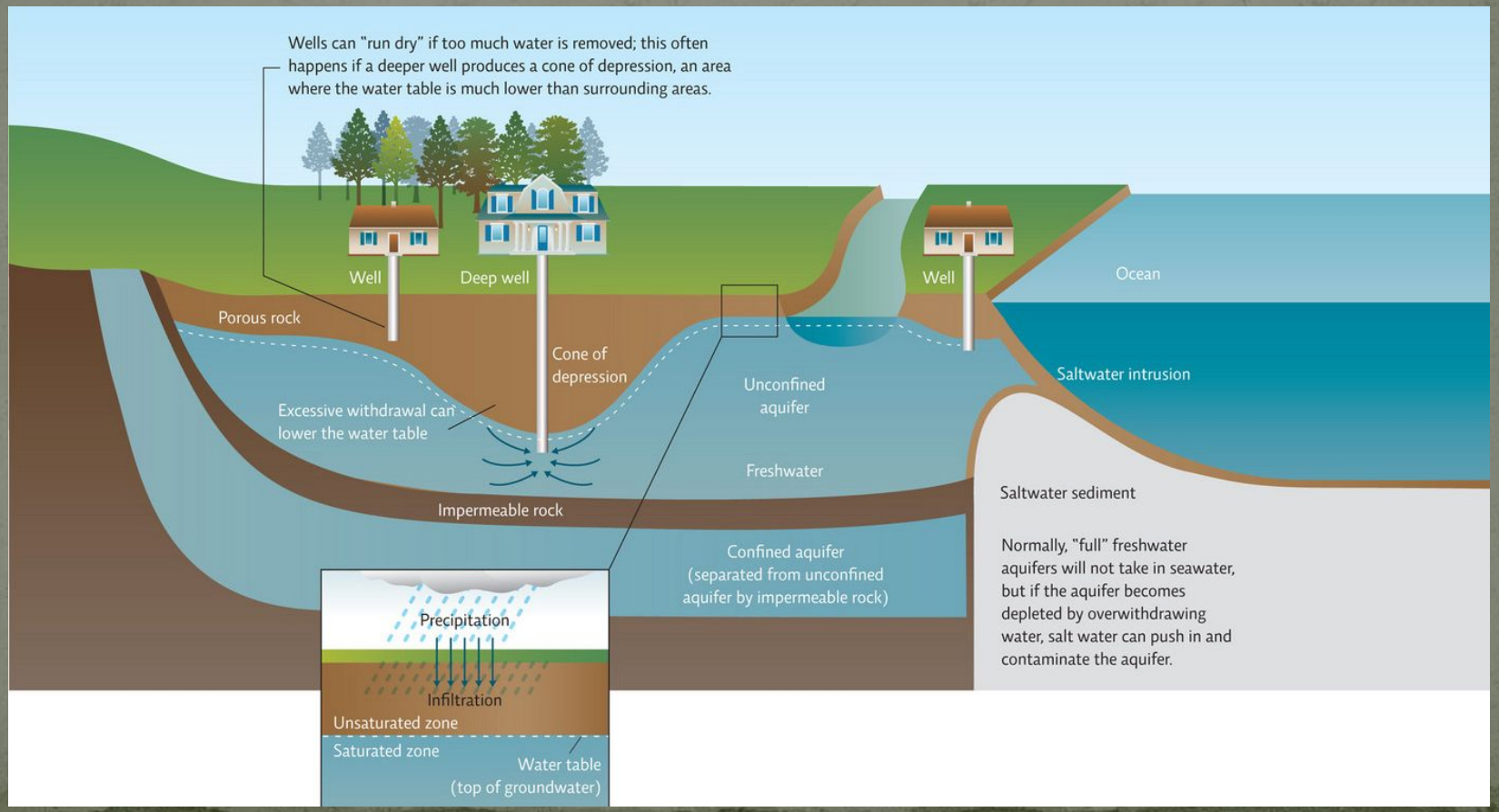
- Most of the United States crop production takes place in the Great Plains, in areas far away from lakes or major rivers.
- Water for irrigation here is mostly taken from the Ogallala aquifer.

Overconsumption

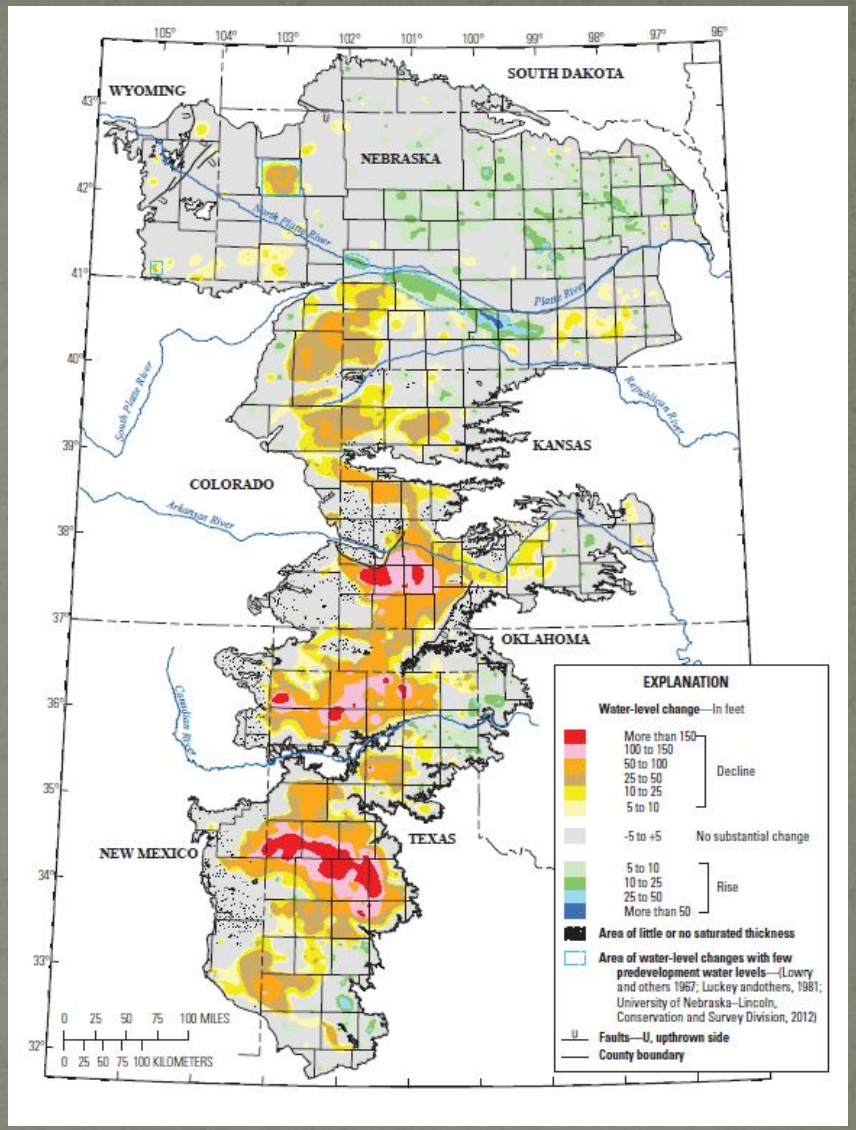
- Excessive water withdrawal can cause a lowering of the water table, called a cone of depression.
  - This may cause nearby, shallower wells to run dry.



- Wells located near the ocean can experience saltwater intrusion as the ocean water mixes with the groundwater.



- Only about one inch of precipitation reaches the Ogallala annually, far less than what is actually withdrawn.



Water Purification

- Countries without access to groundwater or surface water may resort to desalination, or the removal of salt from saltwater.
  - Desalinated water is much more expensive due to the high energy costs of operating the plants.

Tampa Bay desalination plant (power plant in background).

Drinking Water

- Municipal tap water is regulated by the Environmental Protection Agency (EPA).
  - Standards are established within the Safe Drinking Water Act, passed in 1974.
- Bottled water is regulated by the Food and Drug Administration (FDA), instead of the EPA.
  - Much less strict testing standards.
  - The FDA has set several different types or classifications of bottled water.

- Artesian water – From a confined aquifer.
  - Fiji
- Distilled – Water has been boiled and recollected. Contains no minerals.
  - Glaceau
- Purified water – Water (probably tap) that has been filtered by deionization or reverse osmosis.
  - Aquafina, Dasani
- Spring – From an underground formation that naturally flows to the surface.
  - Evian

Aquafina labels used to say "P.W.S." instead of public water supply, giving the impression that it was spring water.

Domestic Water Conservation

- Estimates suggest many societies could save as much as **half** of current domestic water usage without great sacrifice or serious change in lifestyle.
  - What are the biggest domestic uses of water?

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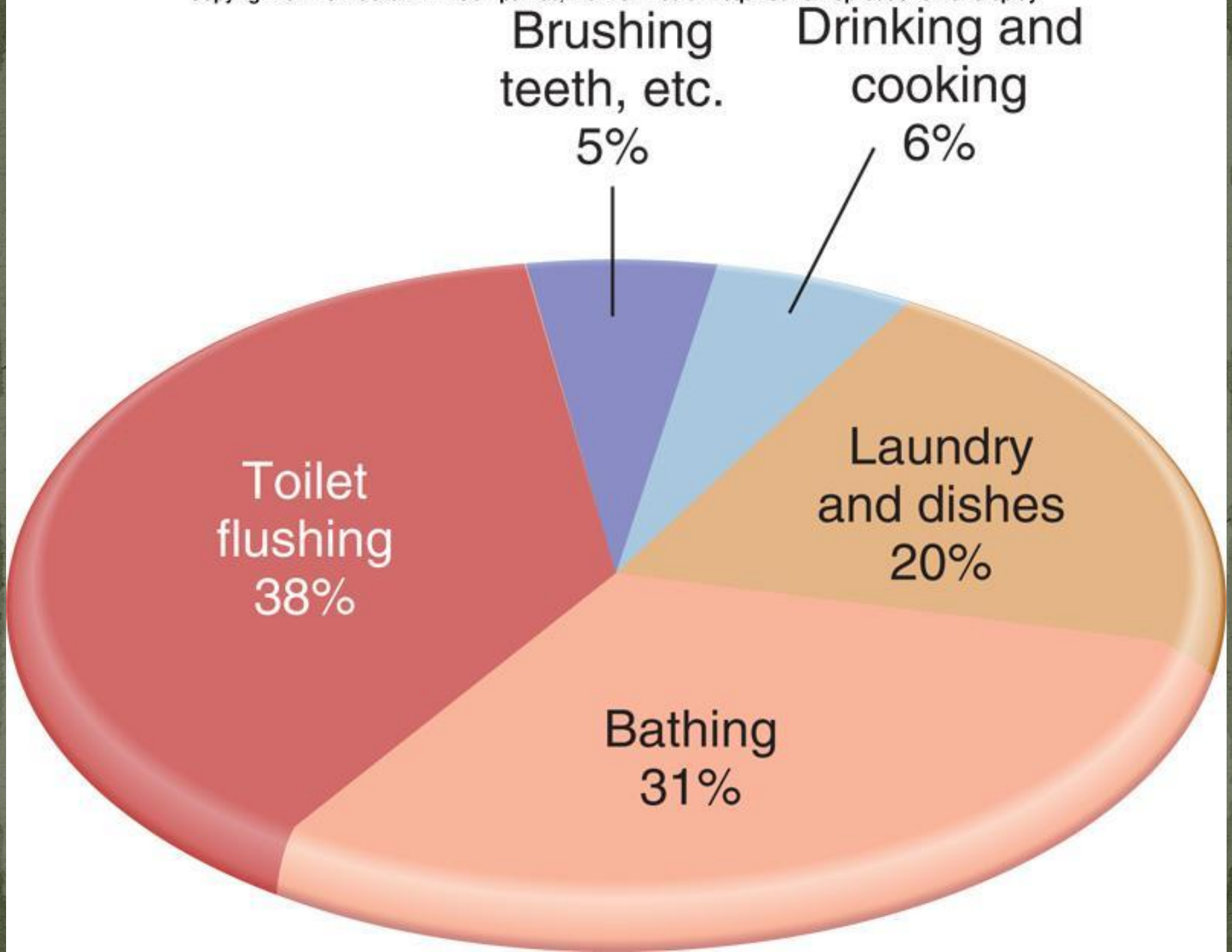


Water Conservation

- Dual-flush toilet: Two buttons; half-flush for liquid waste, full-flush for solid.

- High Efficiency washing machine: Half the water use of top-loaders.

Water Conservation

- Typical shower head: 2.5 gallons/minute.

- Water-saver shower head: 1.5 gallons/minute.

Water Pollution

- Water pollution is the addition of any substance that degrades, or lowers the quality of the water for living organisms.

- The Salton Sea has seen a large amount of nutrient pollution from excess fertilizer that has runoff from nearby farms.
- Excess nutrient pollution causes eutrophication and an overgrowth of algae.

- Algae blooms caused by eutrophication block sunlight from reaching underwater plants.
  - As the plants die, the dissolved oxygen (DO) levels of the water decline.
  - A decline in dissolved oxygen causes the suffocation of large organisms, like fish.

A boat moving through a 2011 algae bloom in Lake Erie. Photo by Peter Essick, National Geographic.

Types of Water Pollution

- Fertilizer runoff is an example of nonpoint source pollution, because it does not come from a single discharge location.
- Raw sewage discharged from a large pipe would be an example of point source pollution.

Discharge from the Arcata Wastewater Treatment Plant, California

- Nonpoint sources of pollution can enter a body of water from anywhere across its watershed – the area of land over which all rain and other water sources drain into it.

The Mississippi River watershed.
Source: nature-education.org

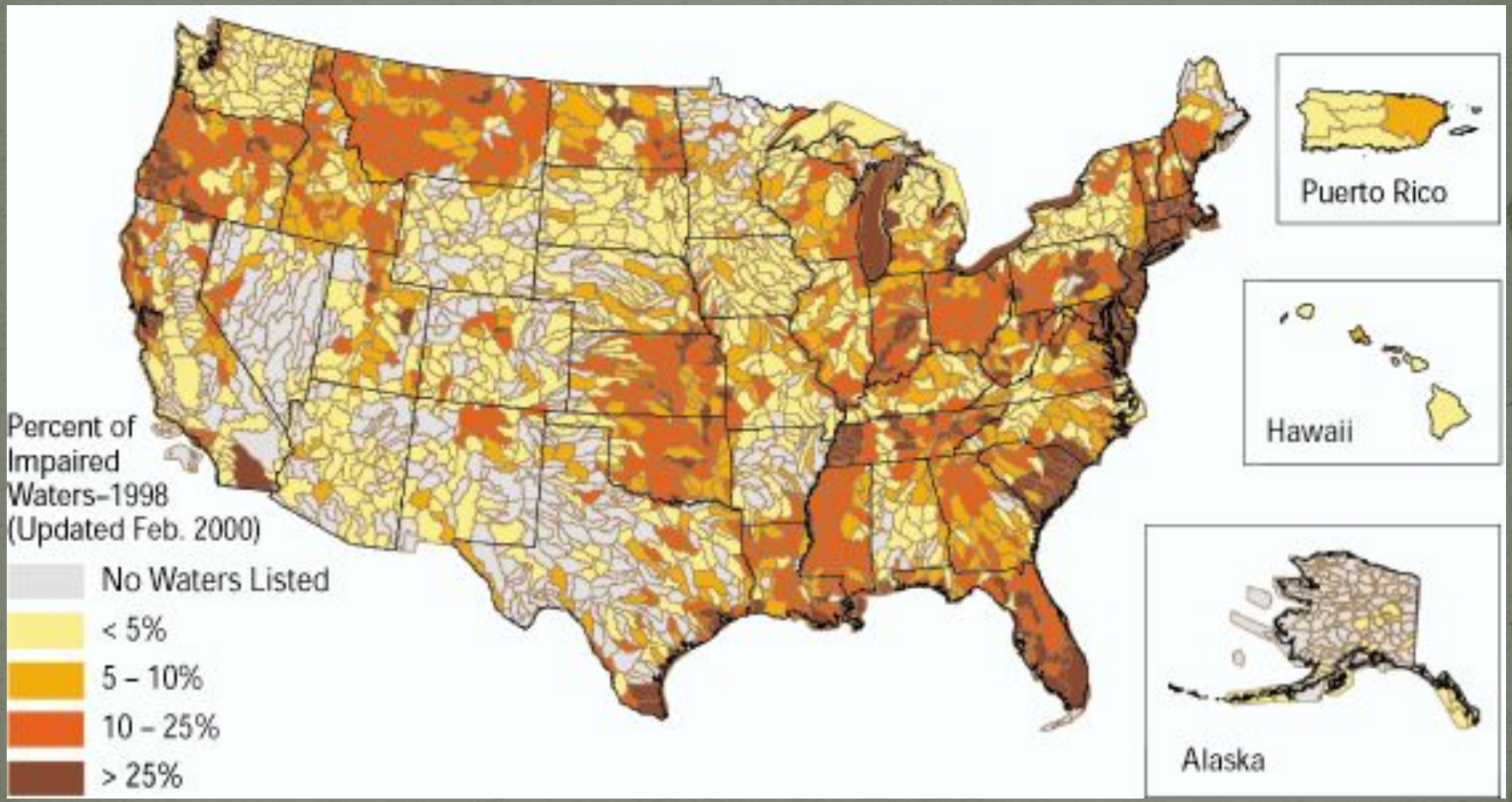
Clean Water Act

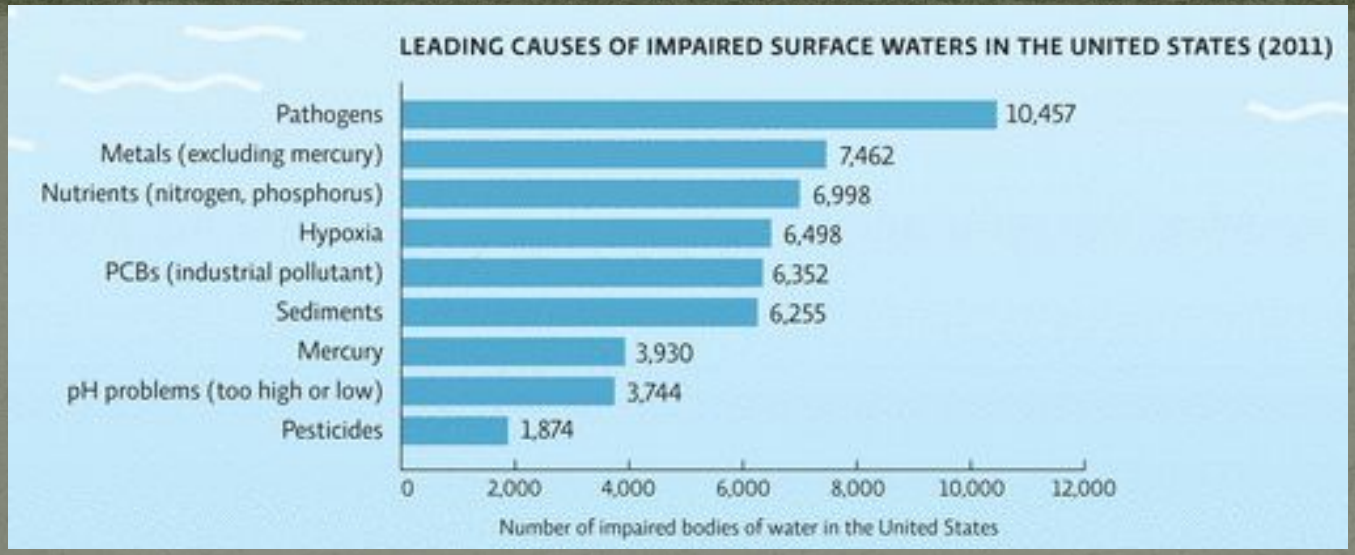
- Beginning with the industrial revolution and continuing into the 1960s, water pollution was seen as a necessary consequence of growth and industry.
- In 1969, the Cuyahoga River in Ohio caught fire, due to a buildup of oil on its surface.
  - Articles in Time Magazine and National Geographic spurred a movement that gave birth the first water pollution laws.

Cuyahoga River fire, 1952.

- By 1972, about two-thirds of U.S. lakes, rivers, and coastal waters were unsafe for swimming and fishing.
- The Clean Water Act, passed in 1977, is a law that set the allowable limits for various pollutants in surface waters.
  - Any point source may not discharge pollution into surface waters without a permit.
  - States are required to develop lists of impaired waters that are too polluted or degraded to meet water quality standards.

- A large number of surface waters in the United States are still considered impaired.





- Leading causes of impaired waters include:
  - Pathogens; bacteria and parasites that cause disease.
  - Metals
  - Nutrient pollution from fertilizer runoff.
  - Oxygen-depleting pollution, such as raw sewage.
  - PCBs, synthetic chemicals found to be mutagenic and banned in 1979.
  - Sediment pollution from soil erosion.
  - Acid pollution, which lowers the pH of water.
  - Pesticide runoff.

Chinook Salmon

All Waters
Less than 32"
1 meal/month
- or -
Larger than 32"
6 meals/year
Contaminant - PCBs

Coho Salmon

All Waters
All Sizes
1 meal/month
Contaminant - PCBs

Rainbow Trout

All Waters
Less than 22"
1 meal/week
-or-
Larger than 22"
1 meal/month
Contaminant - PCBs

Brown Trout

All Waters
Less than 22"
1 meal/month
- or -
Larger than 22"
6 meals/year
Contaminant - PCBs

Channel Catfish

All Waters
All Sizes
Do Not Eat
Contaminant - PCBs

Lake Trout

All Waters
Less than 23"
1 meal/month
- or -
23" to 27"
6 meals/year
- or -
Larger than 27"
Do Not Eat
Contaminant - PCBs

Yellow Perch

All Waters
All Sizes
1 meal/week
Contaminant - PCBs

Carp

All Waters
All Sizes
Do Not Eat
Contaminant - PCBs

- This guide to Lake Michigan fish shows the persistence of PCB pollution and its bioaccumulation in the food chain.

Ocean Pollution

- The majority of pollution in the ocean falls into two categories:
  - Oil
  - Petroleum-based plastics

- The biggest sources of oil in the ocean include:
  - Natural seeps from oil deposits at the ocean floor.
  - Runoff from land, including leaking cars and improper disposal of used motor oil.
    - This is the largest source.
  - Discharge from ships.
  - Spills from offshore drilling.
  - Spills from oil tanker accidents.
- Oil penetrates the fur and feathers of animals, destroying the natural insulation.
  - Oil also directly damages the tissues of fish and other aquatic organisms.

Oil Spills

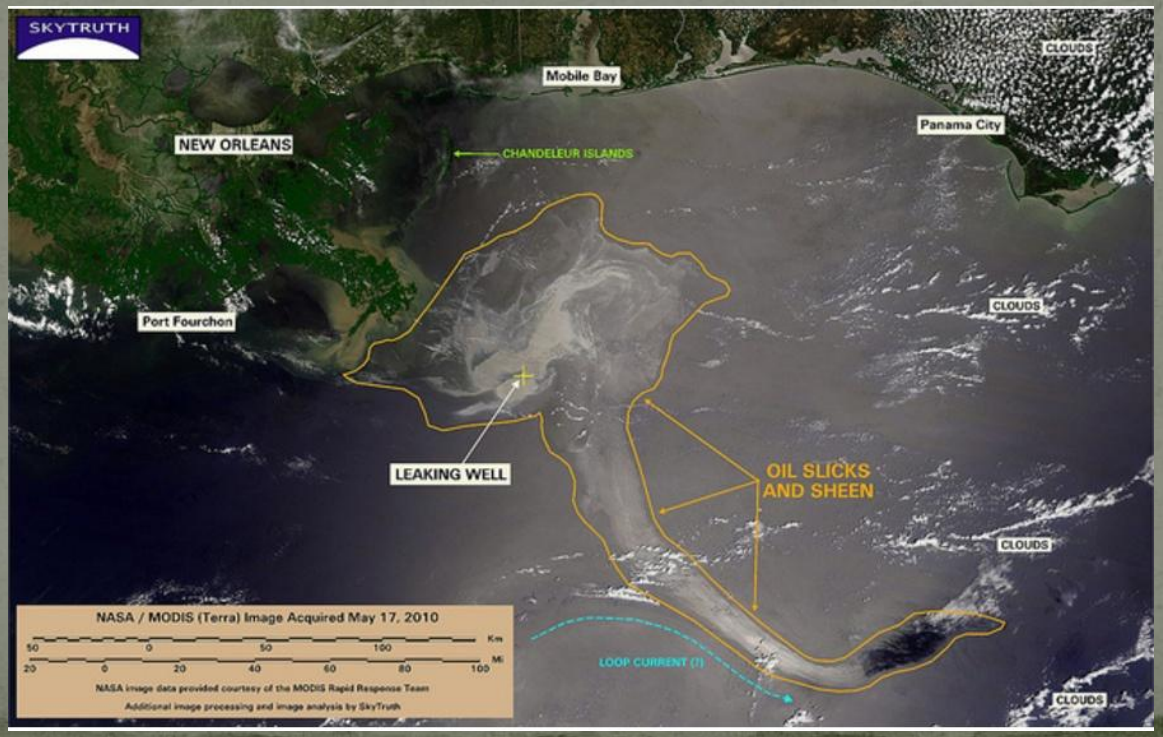
- Although oil spills from rigs and tanker ships are not the biggest source of oil in the ocean, they have the most severe effects in the immediate area.
- One of the worst spills to ever affect North America was the Exxon Valdez in 1989.

- When the Exxon Valdez ran aground in Alaska, a high volume of oil was spilled.
- The damage was worsened by a series of other factors:
  - The remoteness of the spill's location.
  - A delayed cleanup response due to a lack of preparation by the oil companies.

- Following the Exxon Valdez spill, the Oil Pollution Act of 1990 made the following changes:
  - Operators of oil tankers are responsible for all cleanup costs.
  - Increased the maximum liability for losses by businesses and private individuals.
  - Phased out single-hulled tankers in favor of double-hulled tankers.
    - Reduces losses in an oil spill by 4-6 times.

Deepwater Horizon

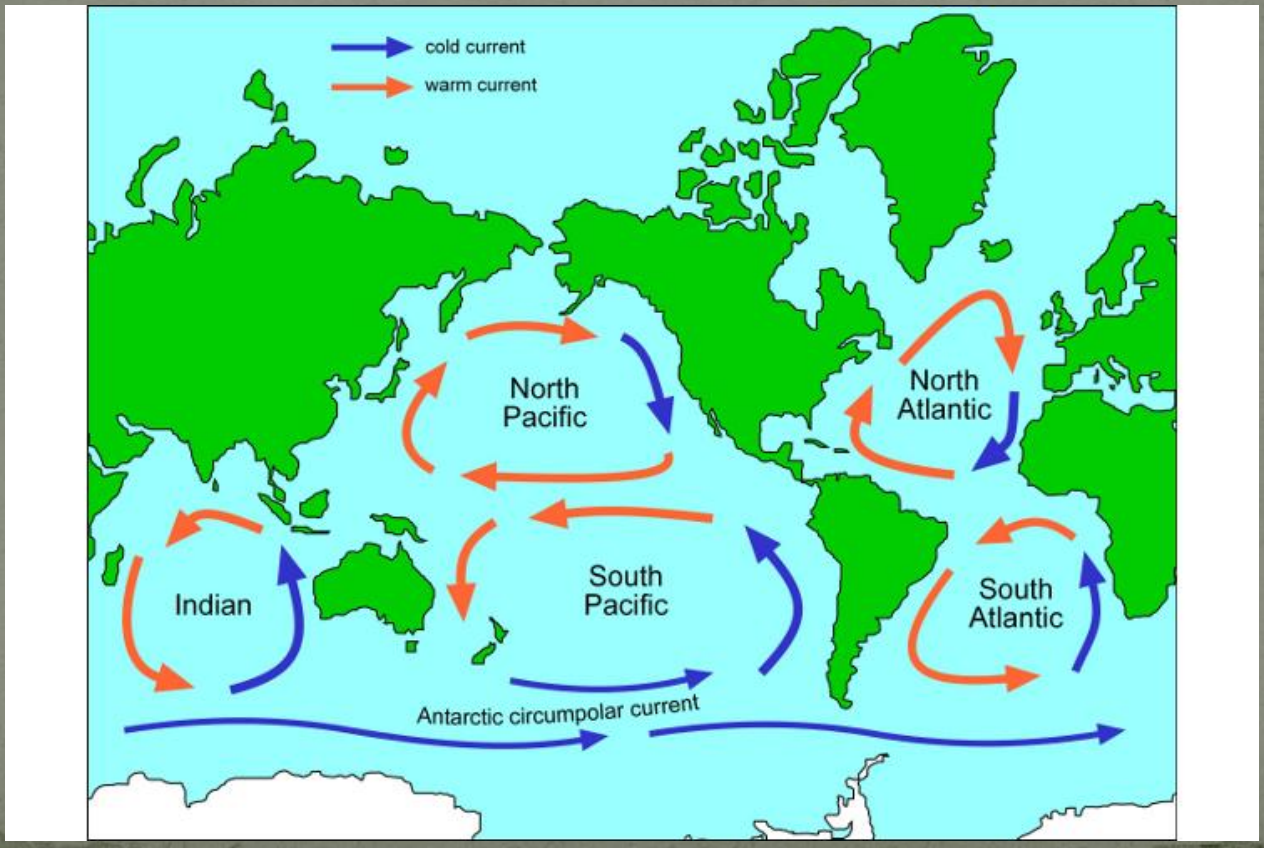
- The worst oil spill by volume occurred in 2010 when an oil rig in the Gulf of Mexico experienced a blowout.
  - The drilled well at the bottom of the sea gushed nearly 5 million barrels of oil into the sea over a period of four months.



Plastic

- A study by the Environmental Investigation Agency revealed that whales in the ocean were ingesting large amounts of plastic and fishing gear.
- A gray whale stranded near Seattle was found to have the following in its stomach:
  - Sweatpants
  - Duct tape
  - Surgical gloves
  - Golf ball
  - More than 20 plastic bags

- Plastic is non-degradable, meaning that it does not fully decompose in the environment.
- Exposure to sunlight will cause it to break apart into smaller pieces, which accumulate in systems of rotating ocean currents called gyres.



- The largest collection of plastic pollution in the ocean is the Great Pacific Trash Vortex, located in the South Pacific gyre.
  - Most of the plastic is small and suspended below the surface.
  - The mass of plastic pieces sampled from this area is 6 times greater than the plankton biomass.

A sample of the plastic and fishing gear caught by filmmakers of the *Garbage Island* documentary.

Wastewater Treatment

- Human sewage is a waste product that is unavoidable, but it can be treated to minimize environmental impacts.
- Screening removes any trash or large objects that may have entered the sewage stream.

Inlet Screen, Sewage Treatment Plant, Bateau Bay, Australia.

Wastewater Treatment

- Primary treatment holds the sewage in a large containment vessel.
  - Heavy solids that sink to the bottom are removed as sludge.
  - May also be aerated to remove as much of the smell as possible.
- The sludge that is leftover from these treatments is decomposed with bacteria or composted.

- Secondary treatment adds bacteria to decompose the dissolved organic matter.
  - The bacteria must then be killed once the process is complete. This is usually done with chlorine.
- Tertiary treatment is any additional treatment, such as the removal of nitrates and phosphates.

Sewer Overflow

- Sewage treatment plants have a limited amount of water that can be processed at any given time.
- If a flood, snow melt, or other excess water event occurs, raw sewage may be dumped directly into the nearby water body.

Sewage overflow plume in Milwaukee Harbor