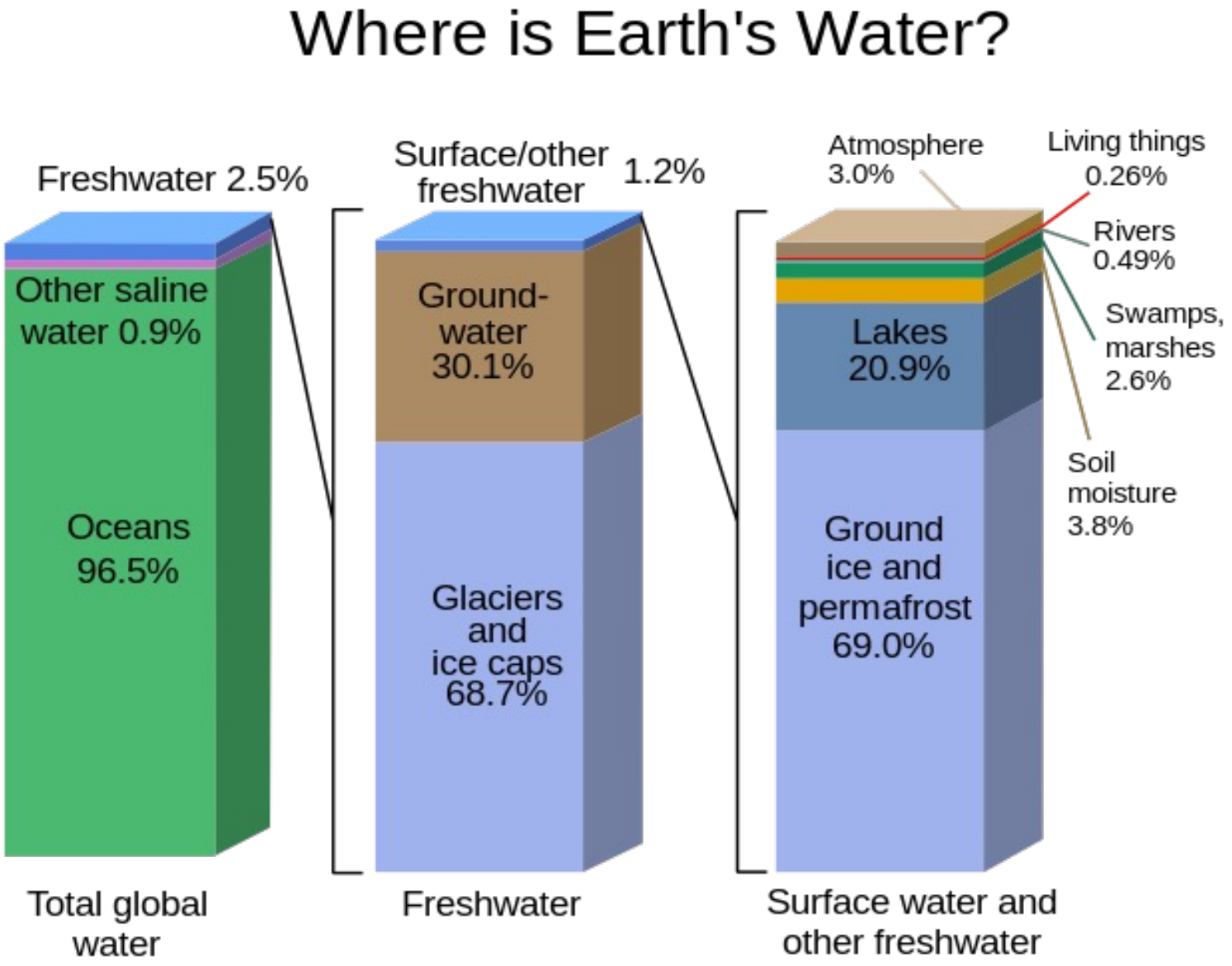
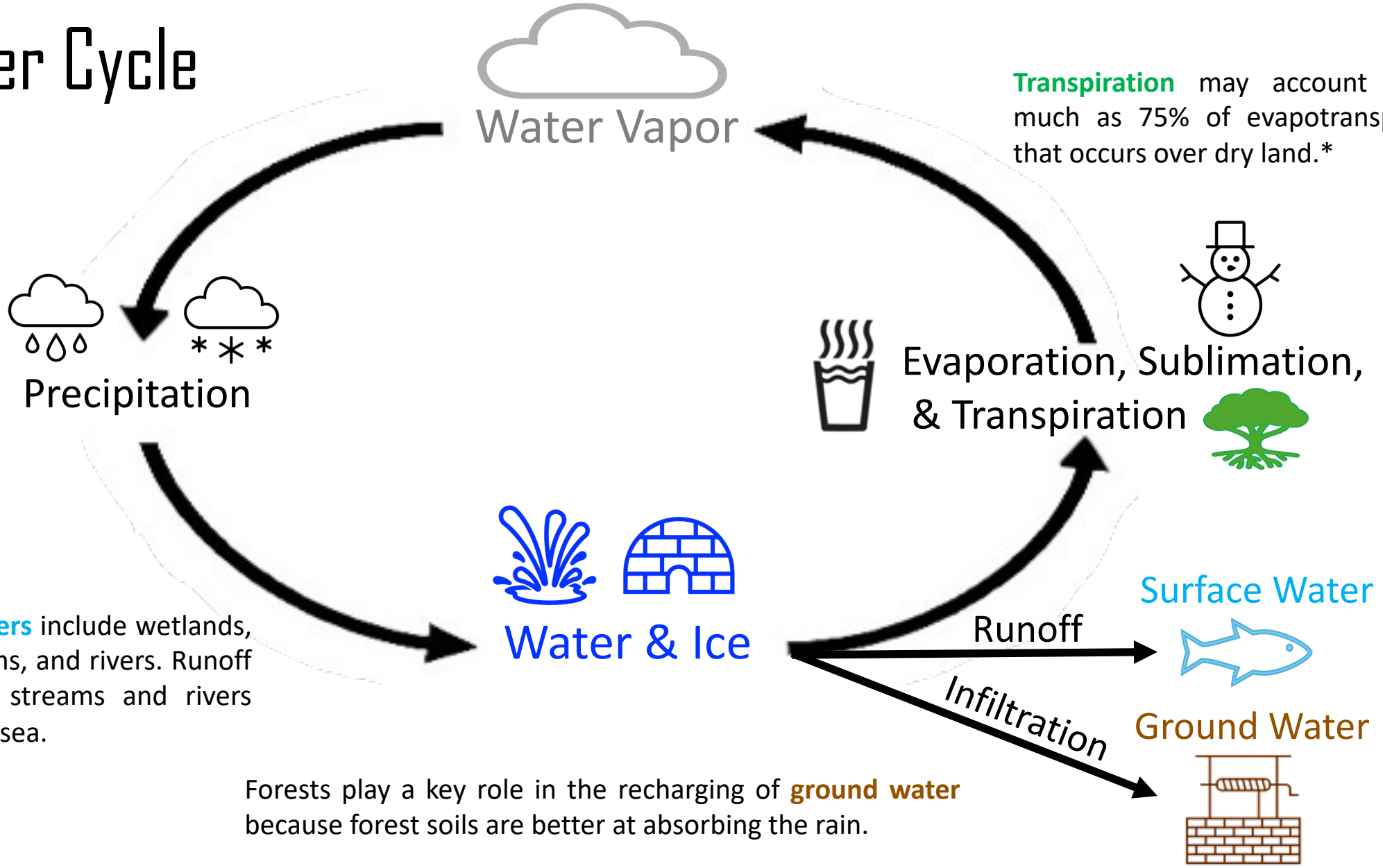
Freshwater Resources



Only 2.5% of the world's water is freshwater, and more than half of the world's freshwater is in glaciers and ice caps.

Water Cycle



Transpiration may account for as much as 75% of evapotranspiration that occurs over dry land.*

Surface waters include wetlands, lakes, streams, and rivers. Runoff that enters streams and rivers flows to the sea.

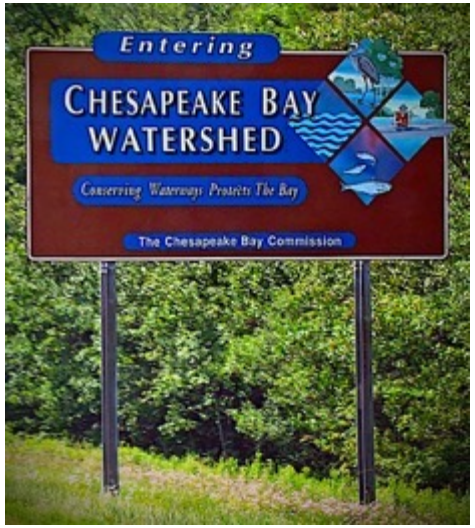
Forests play a key role in the recharging of **ground water** because forest soils are better at absorbing the rain.

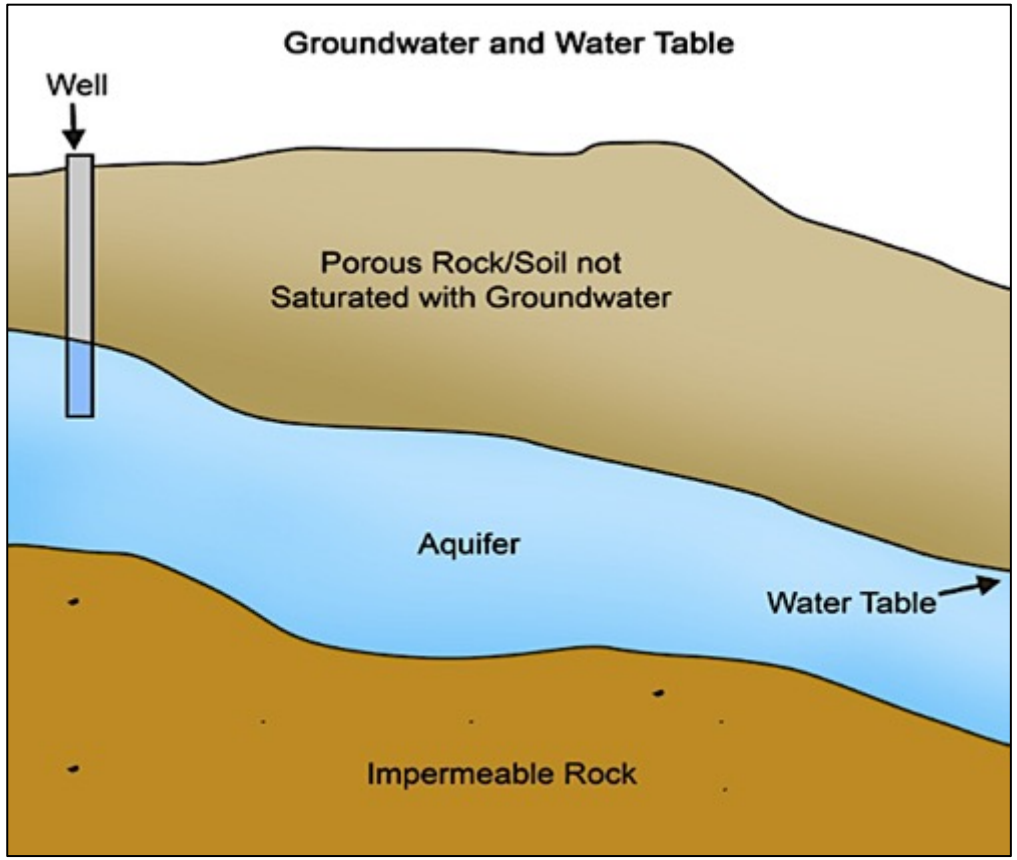
*Information from CID Bio-Science: https://cid-inc.com/blog/transpiration-in-plants-its-importance-and-applications/

Watersheds provide all the water for rivers and estuaries via discharges from **tributaries and runoff** from surrounding regions.

Unsurprisingly, the Mississippi watershed is the largest in the US.

The Chesapeake watershed is much smaller, but it still manages to include portions of five different states.

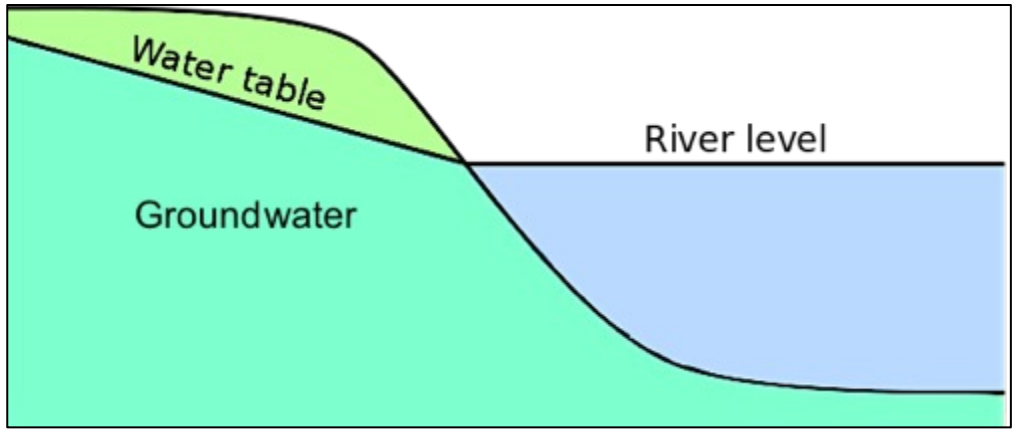




The water table follows the overall contour of the land, and the underlying groundwater is separated by impermeable rock into distinct "bodies" of groundwater called **aquifers**.

In dry weather, the water from rivers comes entirely from **groundwater discharge** to the surface.

Even though some of the water from rivers seeps back into the groundwater, much of it flows into estuaries that take this water to the ocean.



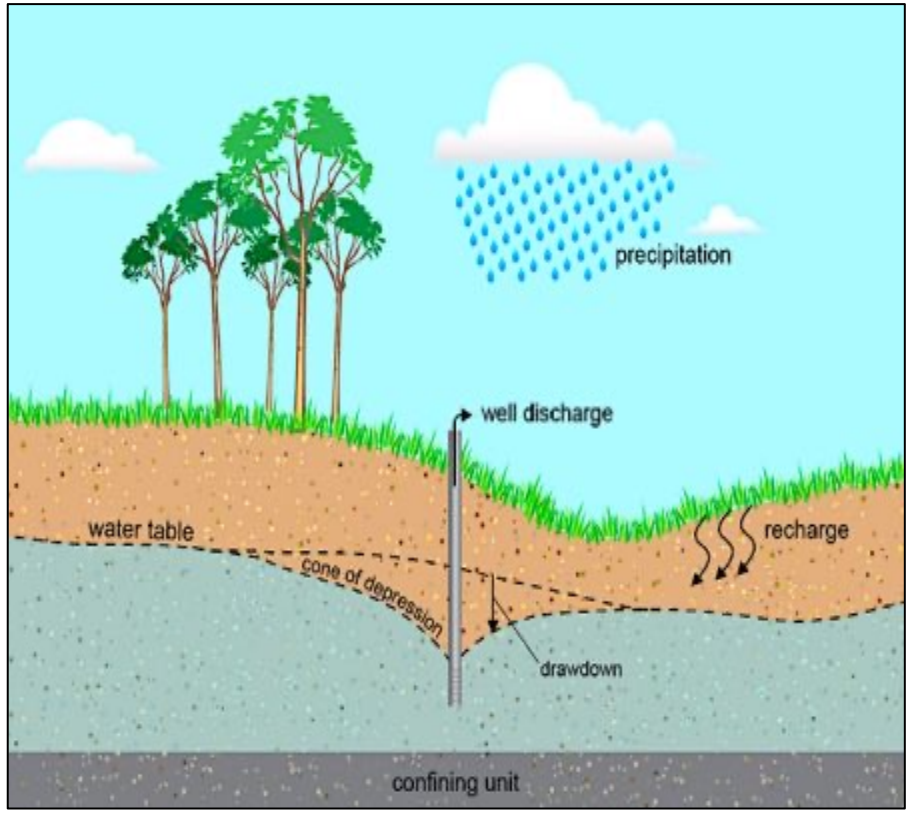
Securing Access to Freshwater

Forests play a key role in the **recharge of aquifers** because their soils are very permeable.

Seepage from **standing waters like lakes and wetlands** also contribute significantly to the groundwater.

Rain gardens like this one in New York City are designed to compensate for the vast expanses of **pavement and sidewalk that increase runoff** and the expense of infiltration.

Rain gardens also mitigate urban flooding by **reducing the burden on stormwater drainage systems**.



Aquifers are the main source of water for urban and agricultural needs, and withdrawals of groundwater can significantly **lower the water** table when the **withdrawal rate exceeds the rate of recharge**.

Adding insult to injury, **changes to the Earth's surface** such as deforestation and addition of pavement increase runoff at the expense of the infiltration that recharges aquifers.

In the short run, this causes **flooding and erosion**.

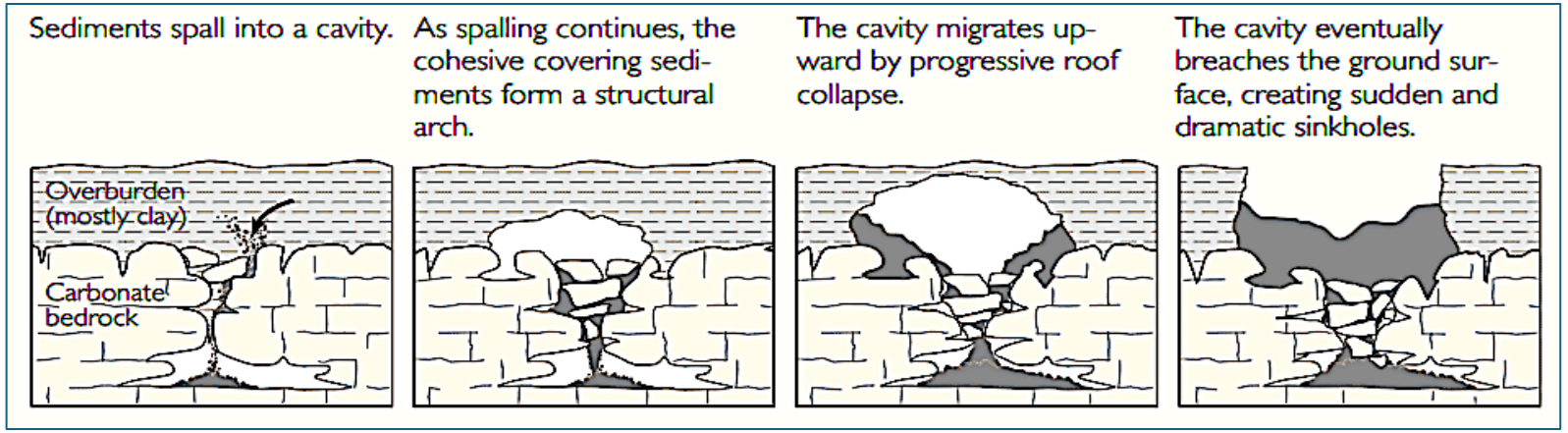
In the long run, the **decline in ground water recharge** combined with **transpiration losses** from a lack of trees result in a **lower water table**.




Excessive withdrawals from aquifers do not only strain water sources: Loss of underground water pressure can result in **land subsidence**, where the land sinks to fill the gap.

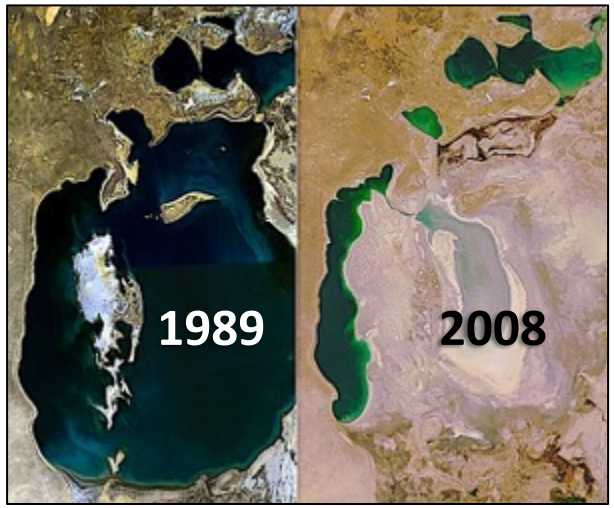
In the case of **sinkholes**, land subsidence can be an abrupt and life-threatening event.

In many instances subsidence is gradual, as in the case of historic buildings like the "leaning" Basílica of Guadalupe in Mexico.



Excessive **withdrawals of surface waters** can also generate serious problems: The **Aral Sea** in Central Asia was a large inland saline lake that once supported fishing communities in what is now Kazakhstan and Uzbekistan. In the 1960's the Soviet government started to **divert water from rivers** feeding the lake to irrigate **cotton farms** in the surrounding desert.

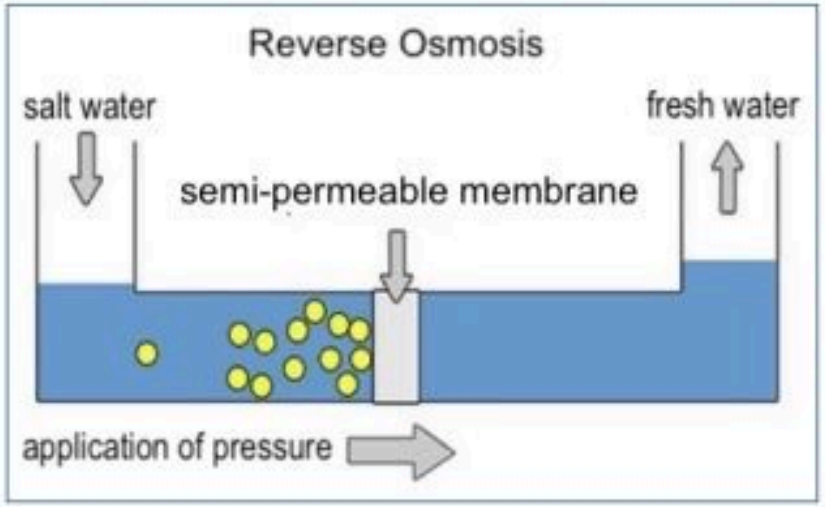
Deprived of its water sources, the Aral Sea **diminished to a less than a quarter** of its original size and **salinity levels rose over tenfold**. Not only was the **fishery destroyed, miscarriages** and **chronic diseases** became widespread as desert winds picked up **toxic salts** from the exposed seabed. The UN characterized this incident as "the most staggering disaster of the 20th century."*



* Information from: https://www.un.org/en/chronicle/article/dry-tears-aral

The strain on water resources will only get worse with expected increases in population and standards of living. Strategies for increasing access to water may include:

Augmentation Strategy	Pros	Cons
Building **dams** to create **reservoirs**.	Reduces the amount of water reaching the ocean.	Dams disrupt the natural river flow and reproduction of migratory fish.
Building **aqueducts** to transport water to places in need.	Less strain on local aquifers.	Aqueducts are less conducive to biodiversity because they lack shorelines.
The **desalinization** of seawater.	Seawater is abundant.	The process is energy-intensive.

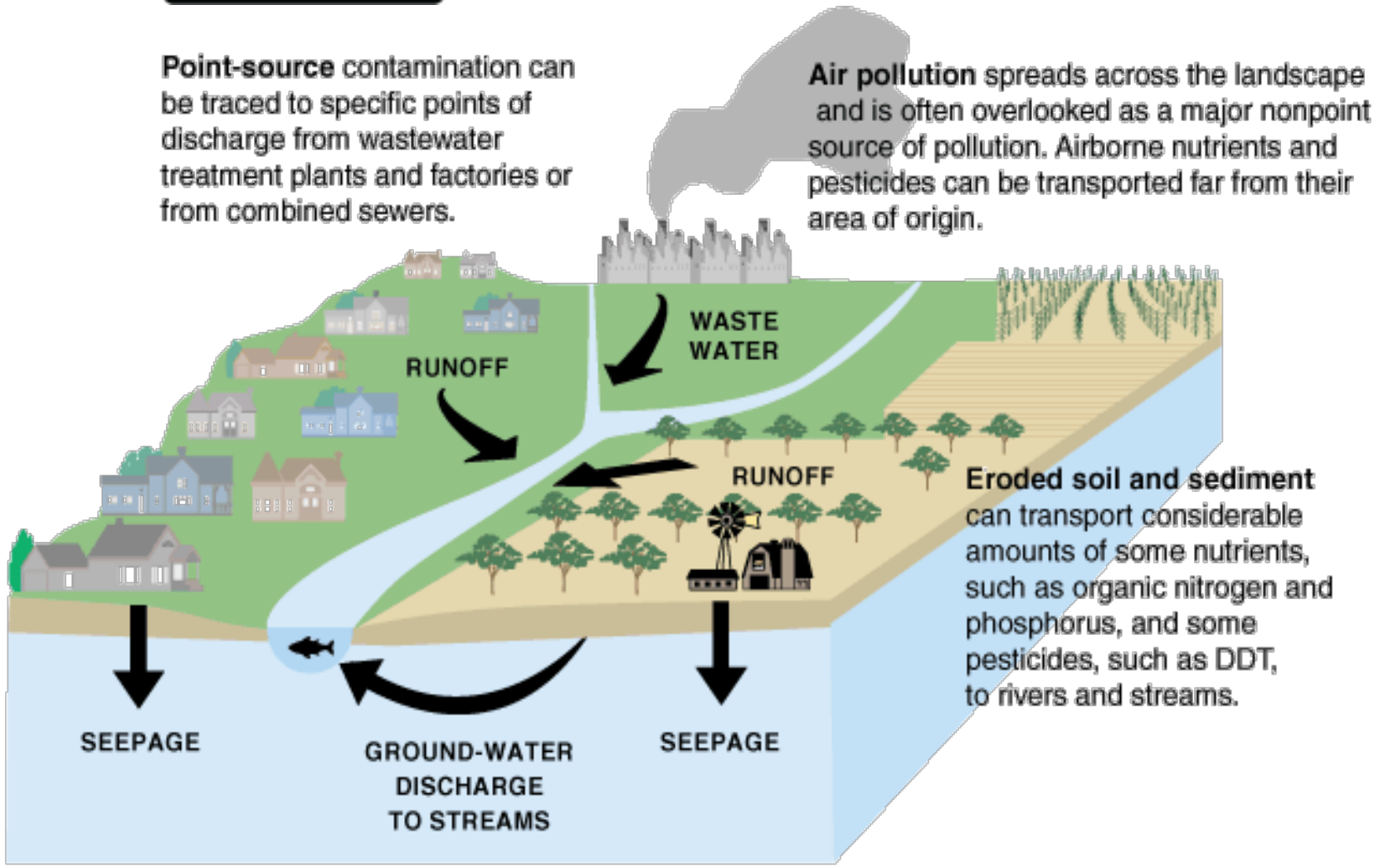


Strategies for augmenting water supplies are problematic because they all cause varying degrees of harm to the environment. Conservation is always a guaranteed long-term solution. Here are some strategies for saving water:

Conservation Strategy	Pros	Cons
The **recycling of greywater** from showers or laundry to flush toilets.	Conserves water and reduces the burden on sewage systems.	Requires dual plumbing to separate out grey water.
Use of **rain barrels** to harvest rain.	Conserves water and reduces burden on stormwater drains.	This water is usually not potable.
Use of **drip irrigation** in agriculture.	Conserves water and prevents soil salinization from excess water.	Installation is expensive.
Xeriscaping as an alternative to lawns.	Minimizes need for irrigation.	Personal preferences.

Water Pollution

Point sources of water pollution are traceable concentrated sources like factories, feedlots, and sewage treatment plants.



Nonpoint sources are not traceable because they are spread out. Most of them enter the water in the form of run-off that drains into the surface waters.

The most prevalent form of water pollution worldwide is **nutrient pollution**.

A point source of **urban nutrient pollution** is discharge from **sewage treatment plants** that have not undergone tertiary treatment for removal of nutrients.

A nonpoint source of urban nutrient pollution is **runoff from urban streets** that wash atmospheric deposits, organic matter, and pet wastes into storm drains that empty into rivers.

A point source of **rural nutrient pollution** is discharge from **factory farms**. Chicken farms on the Eastern Shore of Maryland are the leading source of nutrient pollution in the Chesapeake Bay.

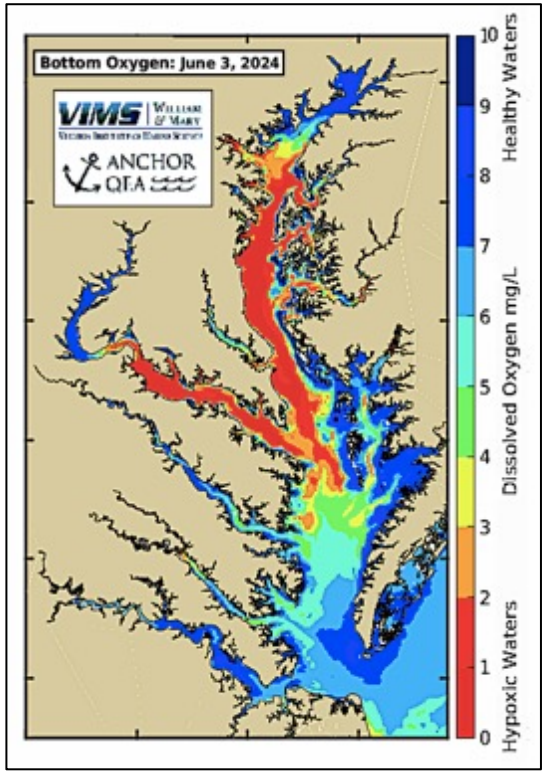
A major nonpoint source of rural nutrient pollution is **fertilizer runoff from farms**.

*Information from The Environmental Integrity Project: https://htv-prod-media.s3.amazonaws.com/files/md-cafo-enforcement-report-embargoed-for-10-28-21-1635354222.pdf

Oligotrophic bodies of water are clear and amenable to species that require high dissolved oxygen levels like **trout**.

Nutrient pollution results in **hypereutrophic** bodies of water with **high biological oxygen demand** (BOD) as the result of **too much algae**. **Carp** are more likely to prevail under these murky conditions.

Algae make oxygen during daylight hours, but under warm conditions most of this oxygen does not remain in the water. Adding insult to injury, warm conditions increase BOD. Together, these conditions create the perfect storm for catastrophic oxygen deficits that are responsible for the seasonal "**dead zones**" that occur the Chesapeake Bay during the summer.



Map downloaded from the Virginia Institute of Marine Science: https://www.vims.edu/research/products/cbefs/cbay/

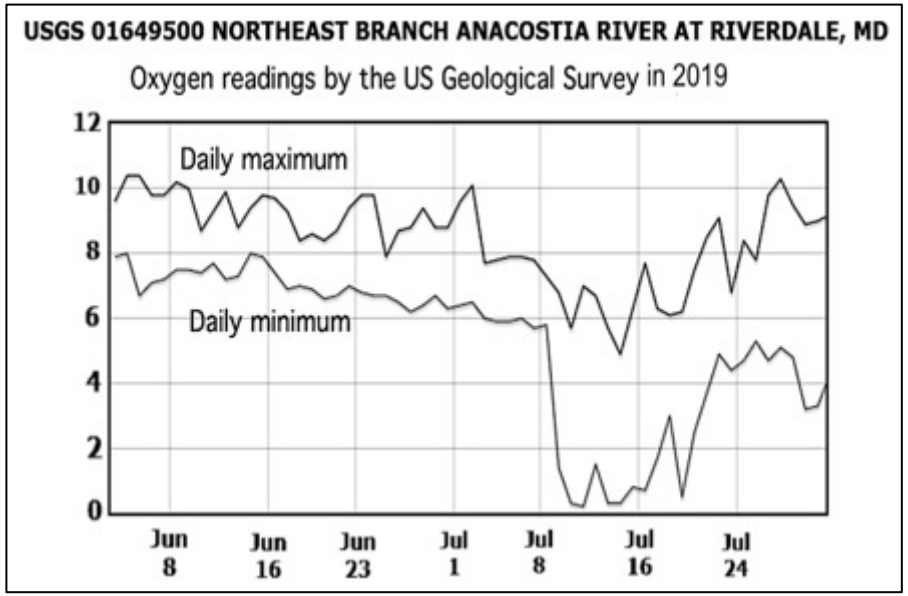
Cost-effective ways to mitigate nutrient pollution include:

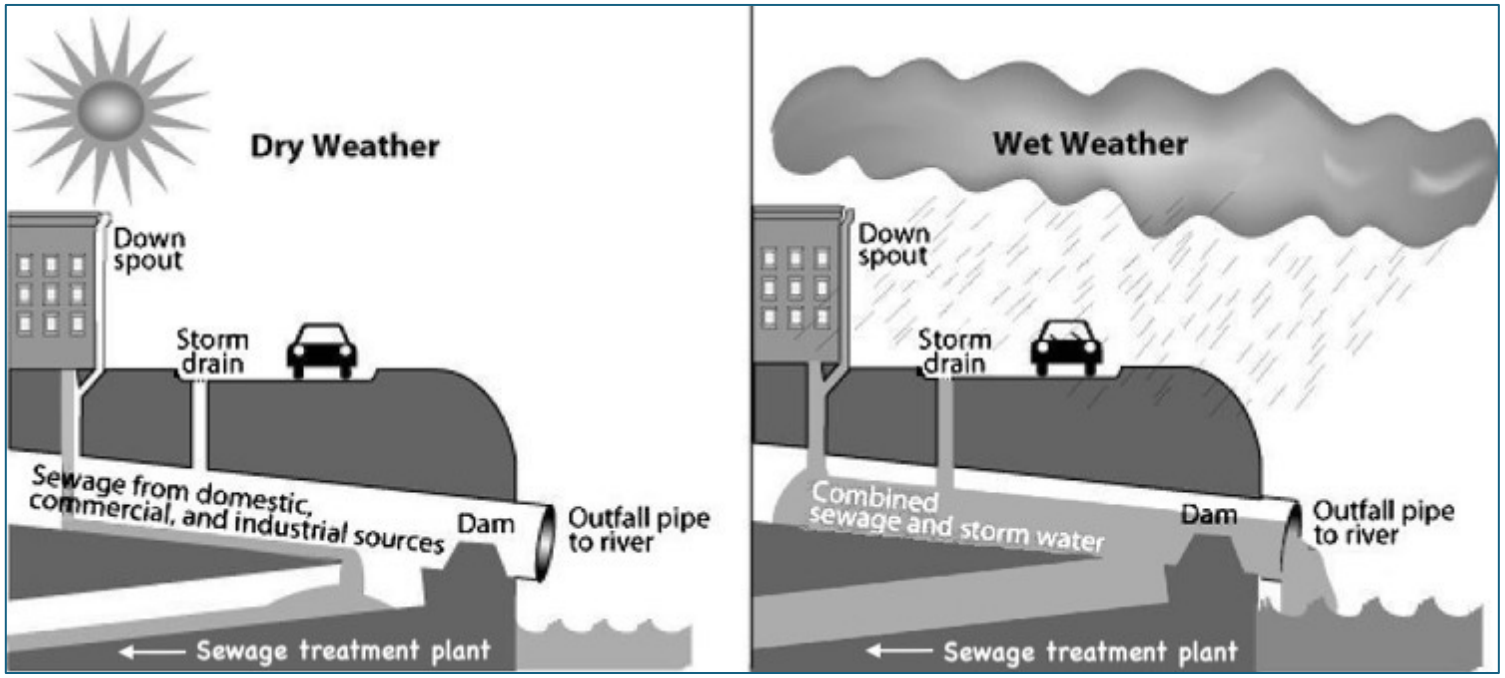
- **Forest buffers** that **intercept runoff** from surrounding farms and provide **habitat for pollinators**.
- **Reconstructed wetlands** that **filter pollutants** before they reach rivers and aquifers.

Oxygen demanding wastes like **raw sewage** dramatically increase BOD and generate localized dead zones of anaerobic bacteria. This is a serious problem in less affluent countries with outdated infrastructure.

In more developed nations, raw sewage overflows into rivers when storm drainage is overwhelmed.

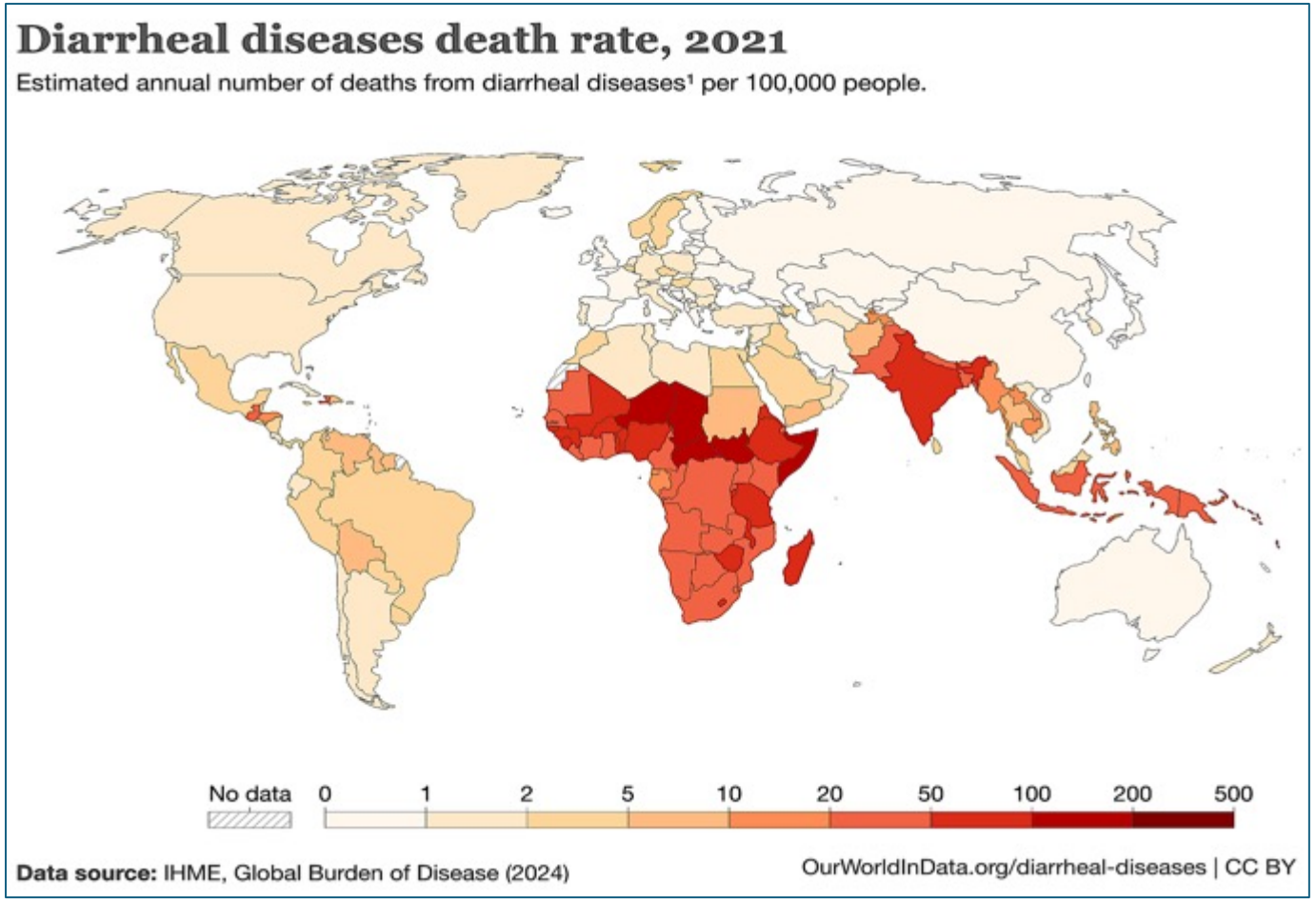
This graph from the US Geological Survey shows a major **low oxygen event** occurring in in the middle of July of 2019.





Water can also be polluted with **water-borne pathogens** that cause diseases such as typhoid, cholera, giardia, dysentery, hepatitis A, and salmonella. These diseases are common in nations with **inadequate sewage treatment**.

Diarrheal diseases are a leading cause of childhood death in South Asia and sub-Saharan Africa.

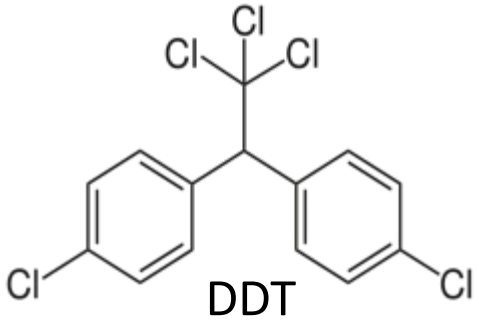


Chemical pollutants are harmful substances found at concentrations higher than the natural background rate. These chemical agents can be either organic or inorganic.

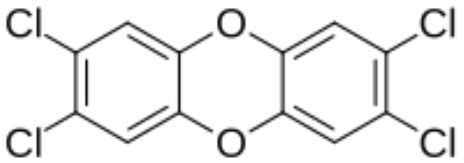
- **Inorganic chemical pollutants** include many toxic heavy metals like arsenic, cadmium, and mercury. The movie “Erin Brockovich” is based on the true story about a legal clerk whose persistence played a key role in winning a $333 million settlement against a utility company that had been dumping chromium-6 into a California town’s water supply.
- **Persistent organic pollutants** (POPs) include a long list of petrochemicals associated with agriculture and industry. Unlike inorganic pollutants, POPs can be broken down into less harmful substances through high-temperature incineration.


A crop duster plane sprays pesticides over crops.


A military helicopter sprays agent orange over Vietnam.



DDT

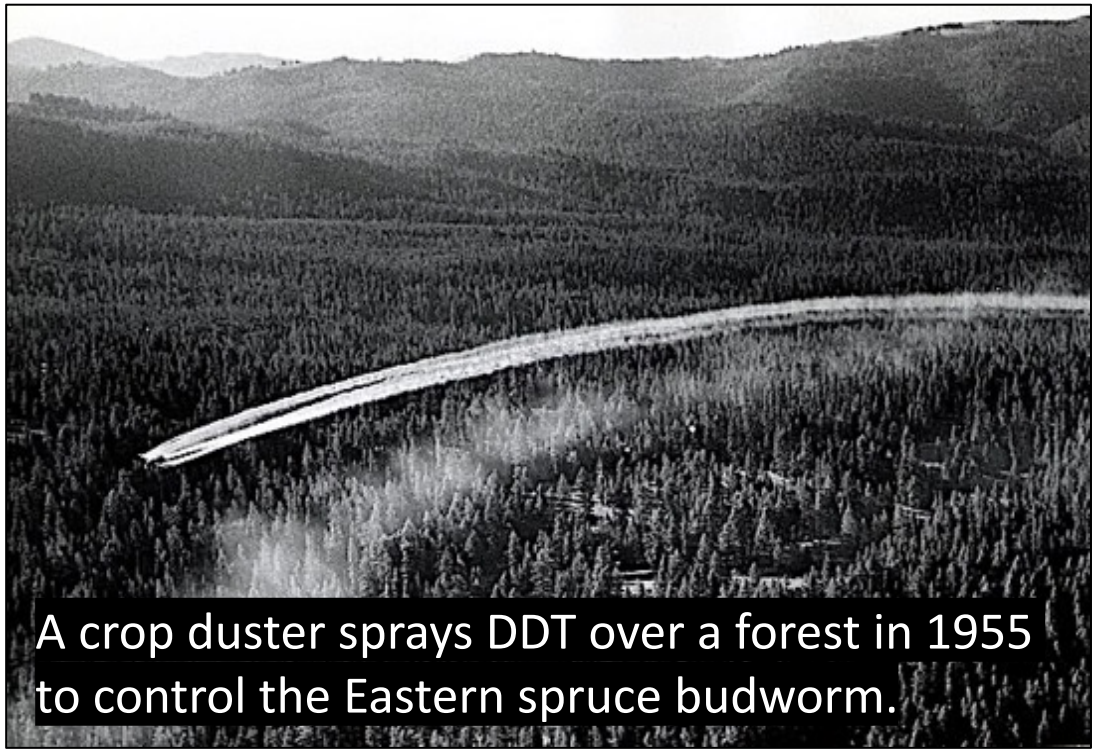


Dioxin

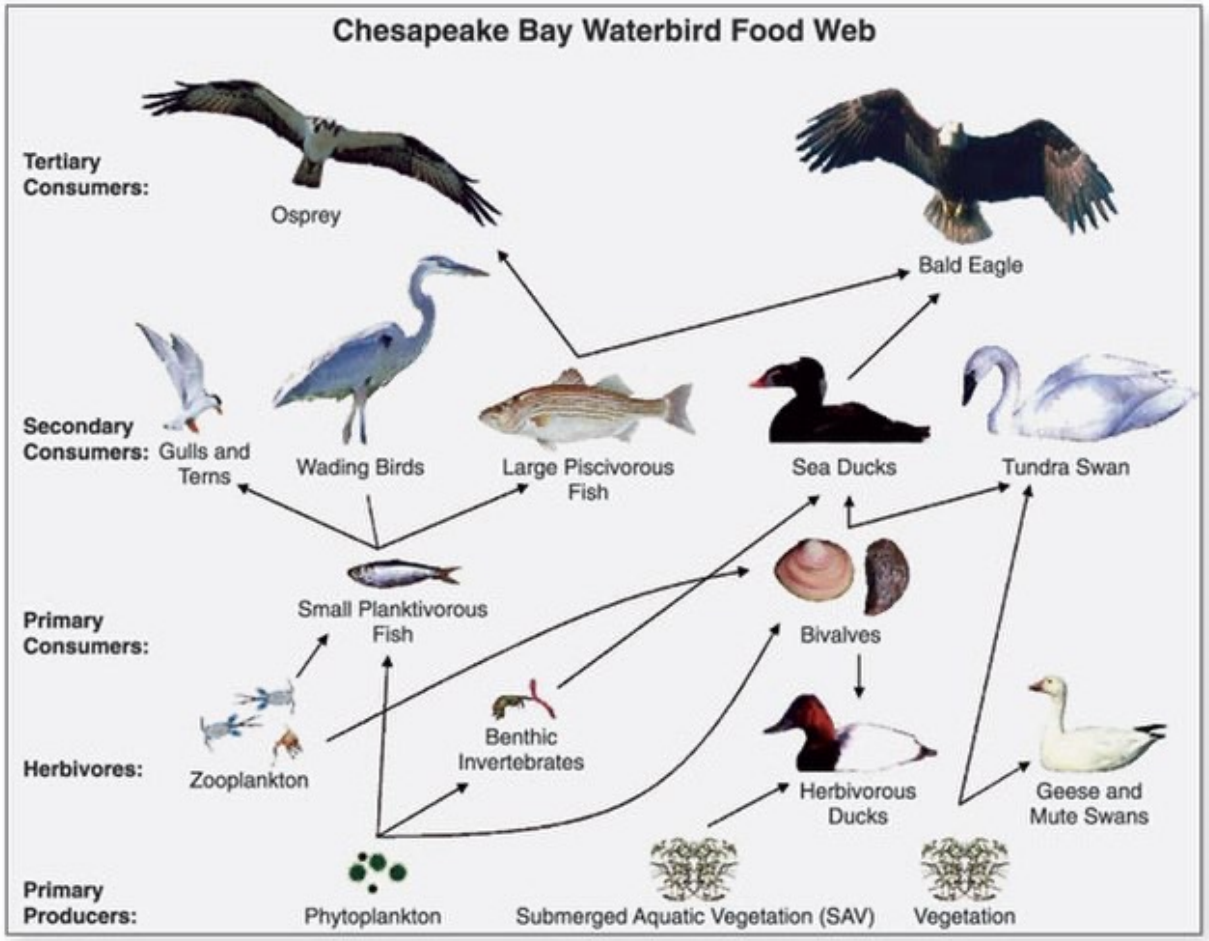
Like mercury, **DDT concentrations are magnified** up the **trophic pyramid**.

This is why the extensive use of DDT in the 1950's devasted populations **eagles and ospreys** after DDT poisoning resulted in **fragile egg shells** that were prone to break.

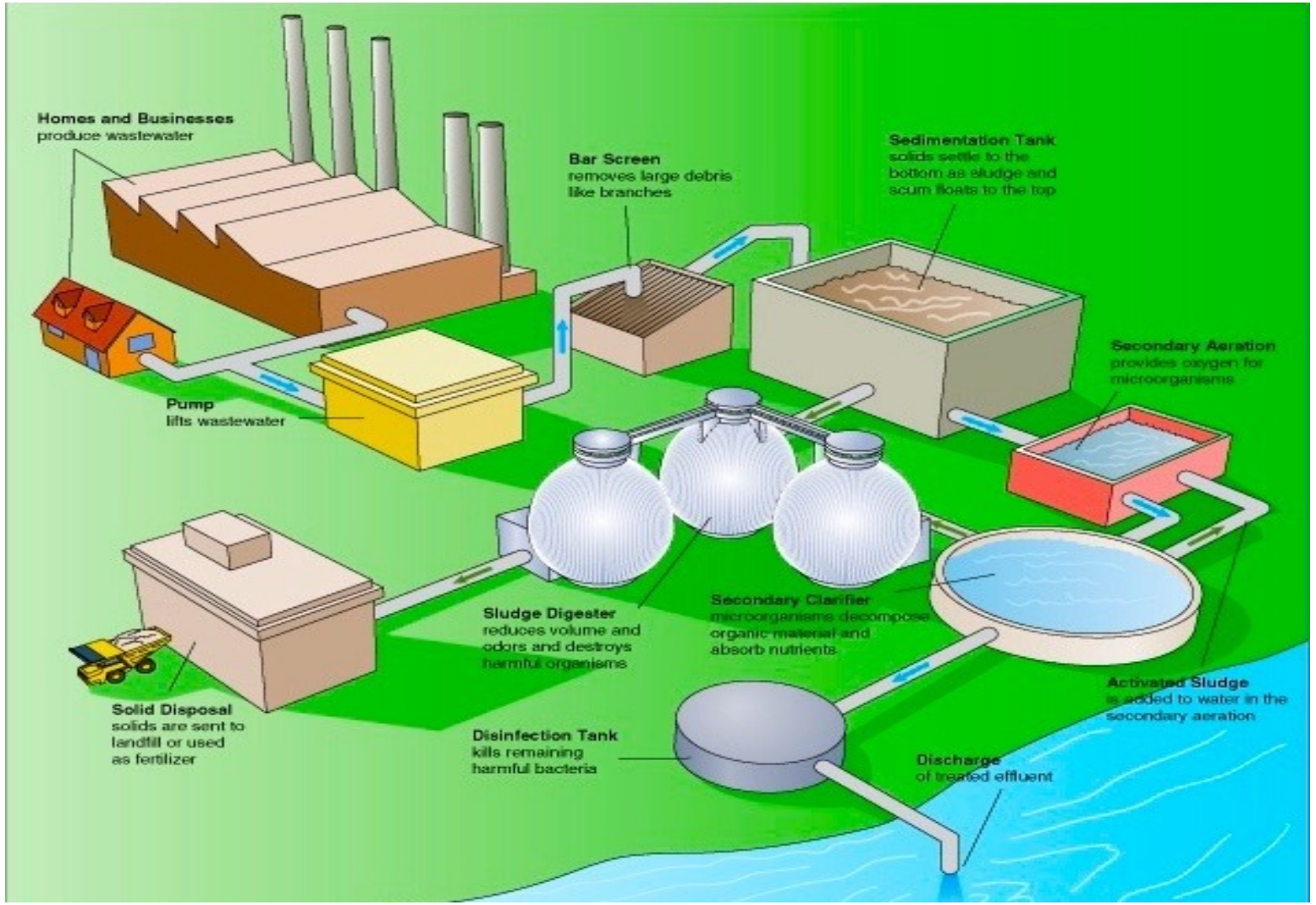
Both species made a remarkable comeback after **DDT was banned** in the US in 1972.



A crop duster sprays DDT over a forest in 1955 to control the Eastern spruce budworm.

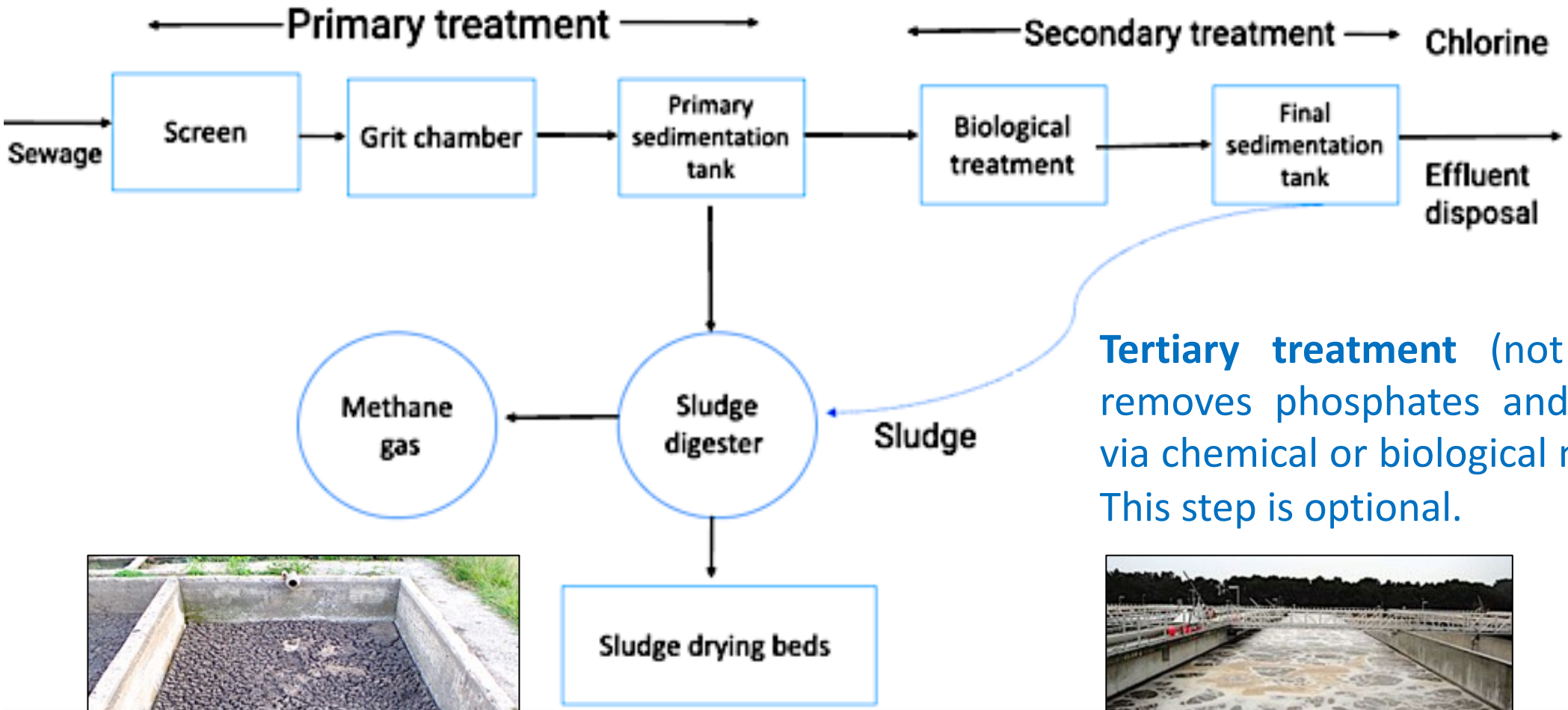


Sewage Treatment



Primary treatment is removes solids through screening and **sedimentation.**

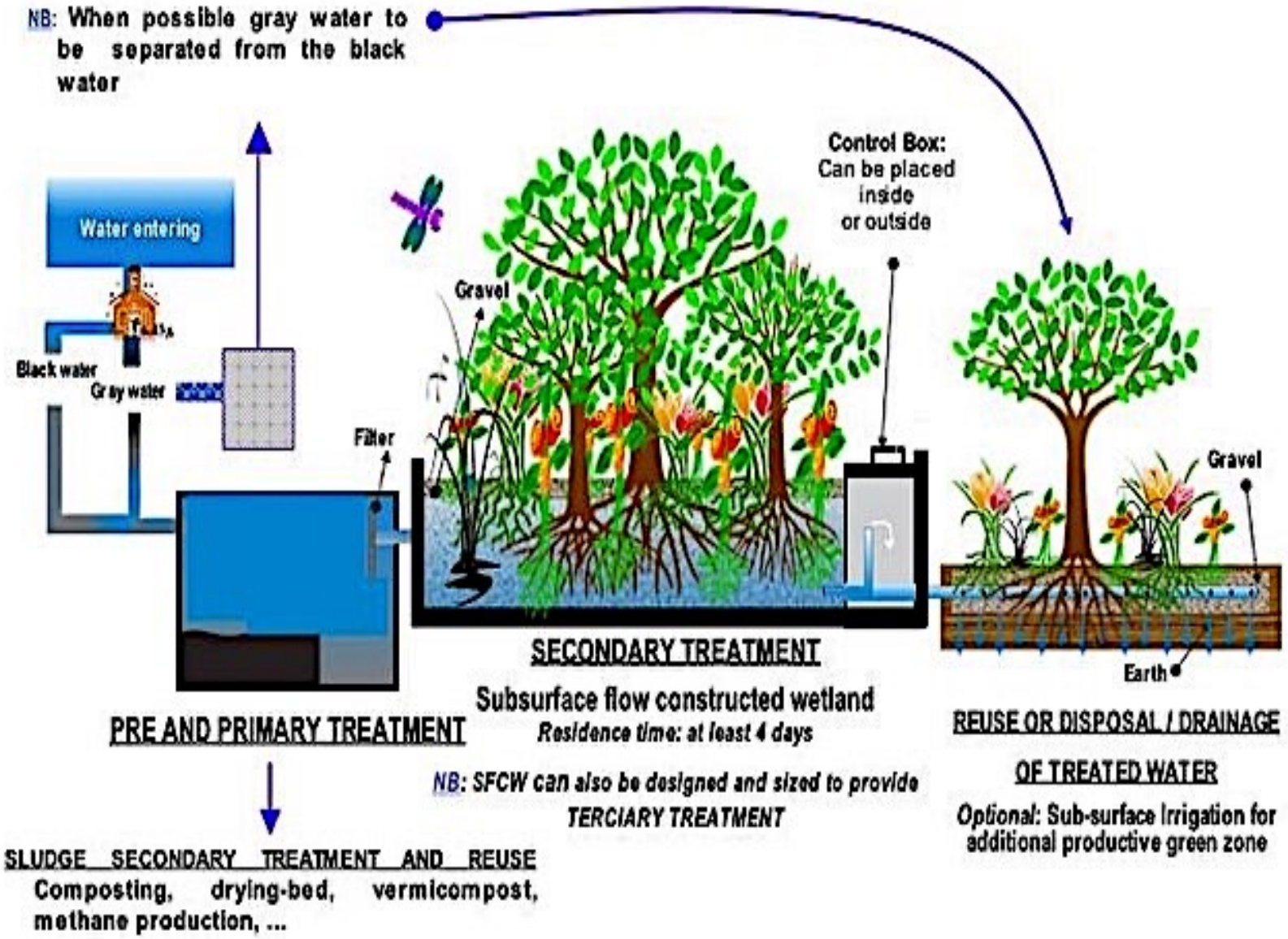
Secondary treatment involves the use of **microorganisms** that facilitate the **biological breakdown of the remaining organic matter.**



Tertiary treatment (not shown) removes phosphates and nitrates via chemical or biological methods. This step is optional.

Dried Sludge

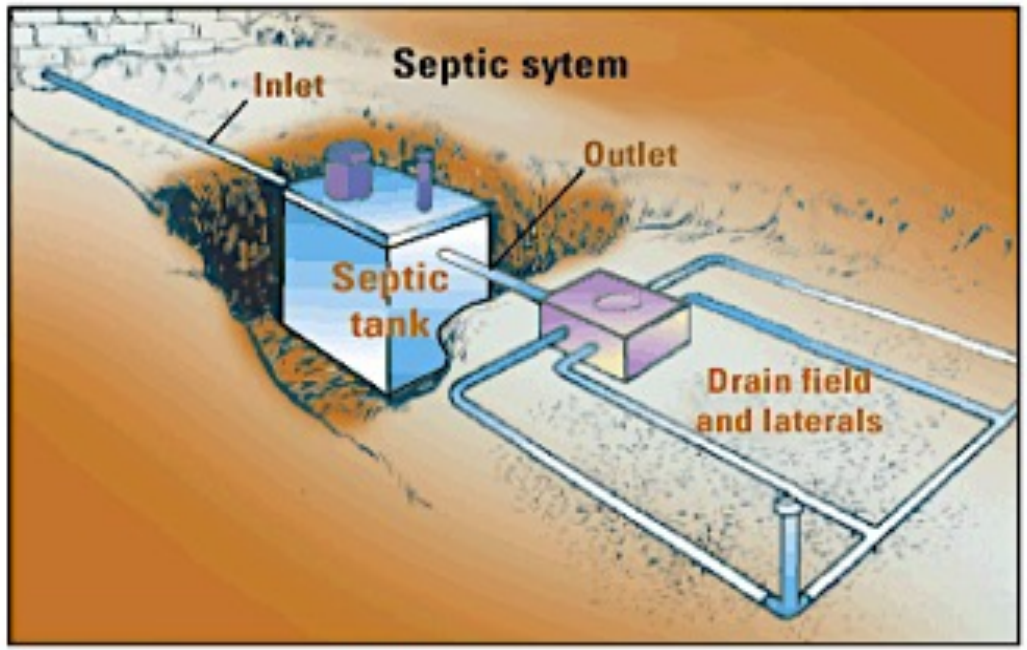
Aeration Tank

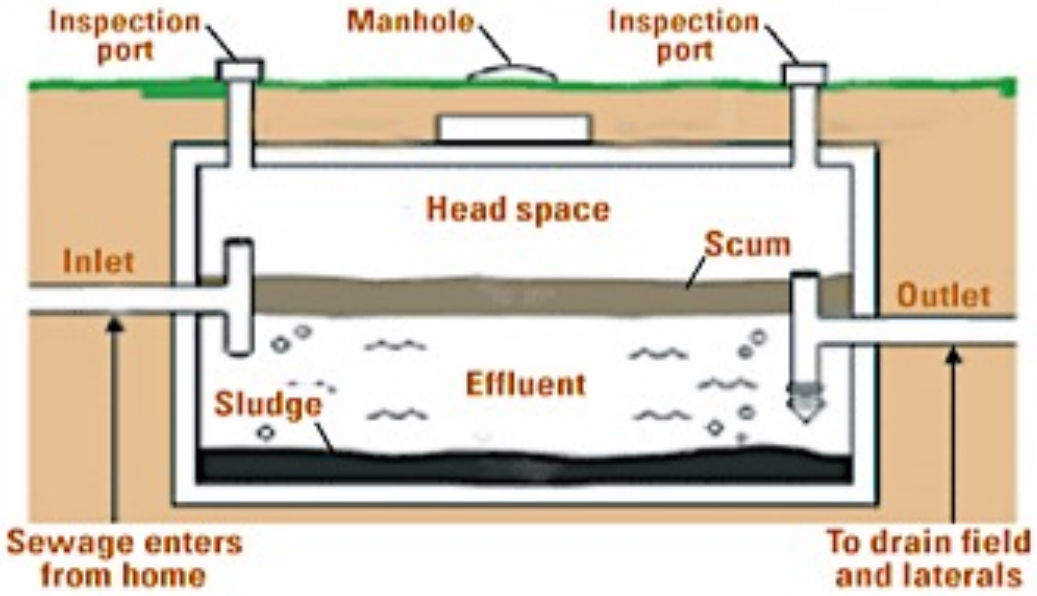


An alternate method of secondary treatment is the use of **constructed wetlands.**

The example below is from Bangkok, Thailand.

Septic tanks are used in locations where connecting to a centralized sewage system is impractical.





Acknowledgement:

Unless otherwise indicated, all images in this presentation were downloaded from **Wikimedia Commons**: https://commons.wikimedia.org/wiki/Main_Page