CVEN3501 – Water Resources Engineering

Water and Energy Cycles

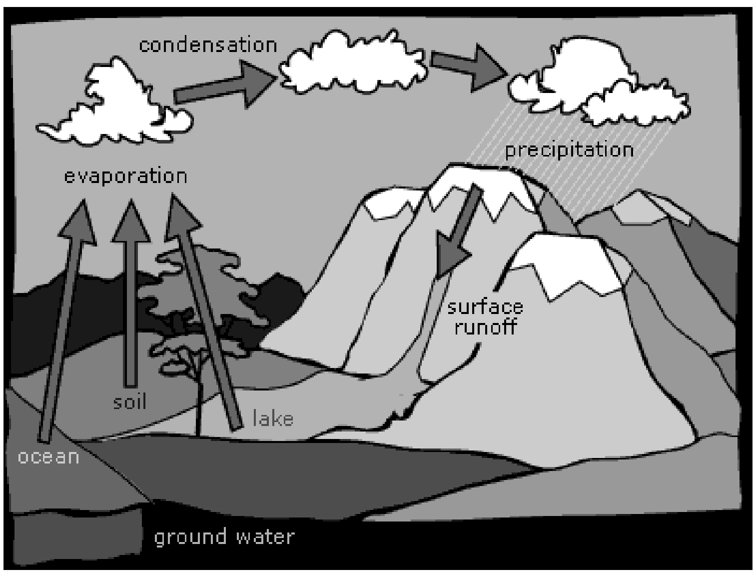
Development of water resources encompasses the control and utilisation of water and the disposal of wastewater in a manner that minimises the environmental and ecological impact.

What is the hydrological cycle?

It is a conceptual model that describes the storage and movement of water in the Earth system, essentially between reservoirs. It is the distribution, spatial and temporal variation of water in the terrestrial, oceanic and atmospheric compartments of the global system.

Describe the hydrological cycle

Water can be stored in any one of the following: atmosphere, oceans, lakes, rivers, soils, glaciers, snowfields and groundwater. The water then moves from one reservoir to another via: evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transpiration, melting or groundwater flow. The oceans supply most of the evaporated water found in the atmosphere. Of this, at least 80% of the water is returned to the ocean basins by precipitation, the remaining 20% is transported over landmass.



Evaporation: transferring water from land to atmosphere – continuously occurring

Precipitation: transferring water from atmosphere to land – continuously occurring

Climate change affects these amounts

Condensation: the conversation of a vapour or gas to a liquid – water which collects as droplets on a cold surface when humid air is in contact with it

Sublimation: the process of snow and ice changing into water vapour in the air without first melting into water

Deposition: where water vapour changes directly into ice – such as snowflakes and frost

Runoff: surface runoff is water from rain, snowmelt or other sources that flows over the land surface. Runoff that occurs on surfaces before reaching a channel is also called overland flow.

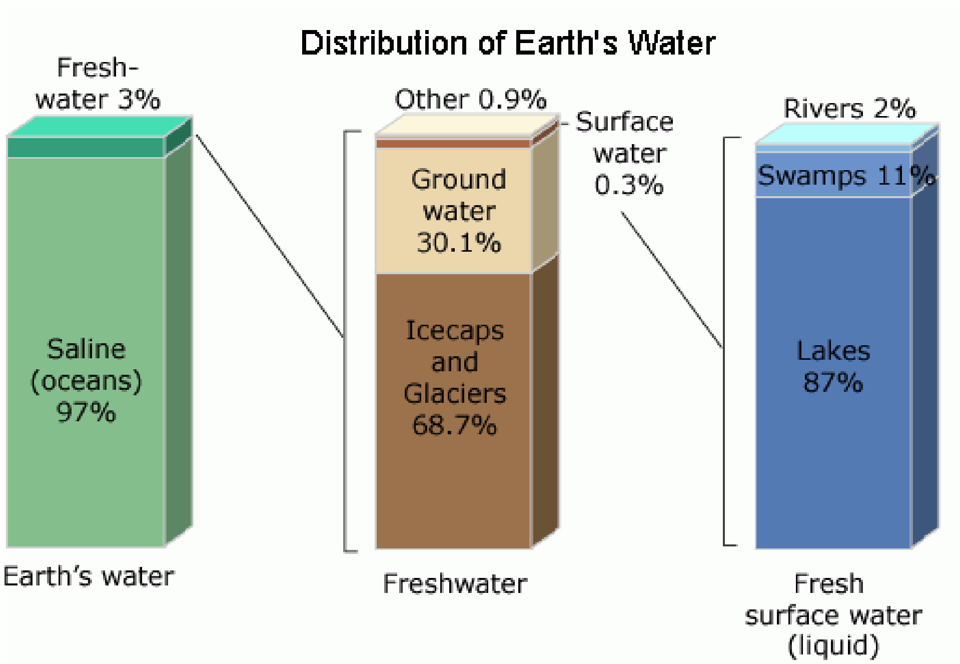
Infiltration: the process by which precipitation or water soaks into subsurface soils and moves into rocks through cracks and pore spaces. The bulk of rainwater and melted snow end up infiltrated.

Transpiration: 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. It is essentially the evaporation of water from plant leaves.

Groundwater: some part of the precipitation that lands on the ground surface infiltrates into the subsurface. That part that continues downward through the soil until it reaches rock material that is saturated is groundwater recharge.

Describe the hydrosphere

More than 70% of the Earth is covered by water. Water has its maximum density in liquid form and conducts heat and has a high specific heat. Water is neither lost nor obtained from outside the planet, due to mass conservation it is continuously recycled.



Warmer climates can store more moisture, this leads to major storms and floods in urban centres.

$$W_{in}\Delta t = \Delta storage = W_{out}\Delta t$$

What powers the global evaporation process?

Solar radiation powers the global evaporation process. 86% of the Earth's evaporation occurs over the oceans; 14% occurs over land.

$$\Delta V/\Delta t = ET_{ocean} + ET_{land} - P$$

The change in atmospheric volume over time equals: evaporation of the ocean + evaporation of land – precipitation

What is the residence times?

The amount of time that water stays in a storage component can be calculated by dividing the total volume (m^3) by the flux rate ($m^3.s^{-1}$). Water is renewed in rivers once every 16 days. Water in the atmosphere is completely replaced every 8 days. Slower rates occur in large lakes, glaciers, ocean bodies and groundwater. Replacement can take hundreds to thousands of years.

Describe Australia's hydrology

Australia's rainfall is the lowest out of all the continents. It has low precipitation combined with high evaporation which leads to low flows and seasonal river systems. Low and seasonal flows contribute to problems of salinity, algal blooms and water shortages.

How is Australia influenced by ENSO?

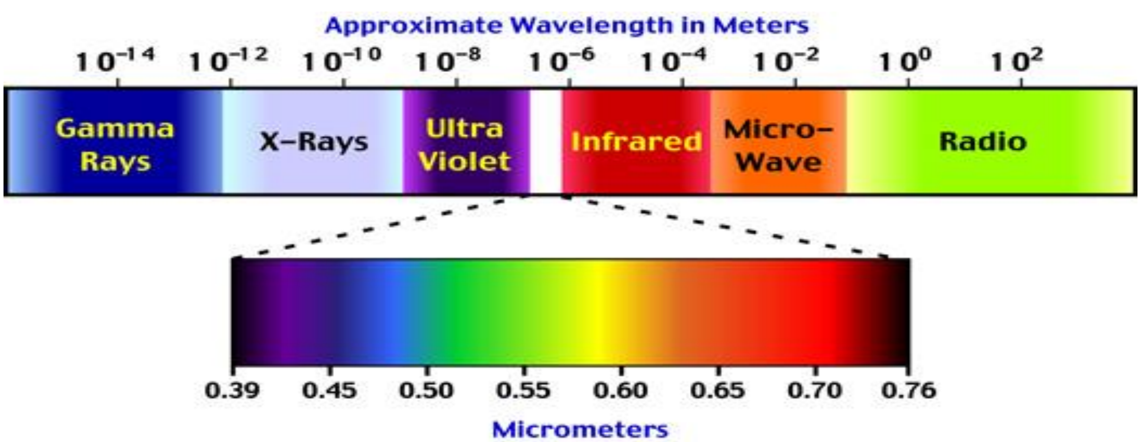
Australia's climate has a high year to year rainfall variability. This is influenced by the El Nino – Southern Oscillation (ENSO). Australia is one of the most affected, experiencing major droughts interspersed with extensive wets. Frequencies of tropical cyclones, heat waves, bushfires and frosts are also linked to ENSO.

What is the main driver of the hydrological cycle?

The sun – energy

Radiation: the emission of energy from a material object in the form of electromagnetic waves and photons. It is the only means of energy transfer than can occur in a vacuum.

All objects above absolute zero (-273.15 degrees) radiate energy (radiation) to the environment. Energy is emitted as electromagnetic (EM) waves that travel at the speed of light. There are many different types of radiation, each identified by its wavelength or frequency. Wavelength is inversely proportional to frequency.



The peak of the sun's energy output is in the visible light range. Visible light has a wavelength between 0.4-0.71 micrometres.

What did Stefan-Boltzmann state?

That the amount of electromagnetic radiation that a body emits per unit surface area per unit time is directly related to its temperature.

For a perfect emitter (i.e. a black body) the relationship holds that:

$$E = \sigma T^4$$

σ = Stephan-Boltzmann constant: $5.67 \times 10^{-8}\ W.m^{-2}K^{-4}$

The relationship says that a small increase in temperature results in a large amount of radiation being emitted.

What is Wein's law?

That there is an inverse relationship between the wavelength of the peak emission of a blackbody and its temperature. The hotter something is, the shorter the wavelength it emits. It can be shown that for a body at temperature T, the wavelength at which the radiation peaks (λ_m): $\lambda_m T = 2877$ µm K (n.b units)

What are the units of energy?

- **1 Joule: basic unit of energy (1 Joule work done to move 1 Newton by 1 metre)**
- **Power: energy per time → 1 Watt = 1 Joule/second**
- **Flux: power per area → W/m^2 – flux depends on distance and angle of the plane of interception (not total area)**

The global radiation balance

$$S = S_o \left(\frac{r_o}{D} \right)^2$$

Energy leaving the sun = 65 x 10^6 $W.m^{-2}$

R_{sun} = 700 x 10^6 m

R_{earth} = 6.4 x 10^6 m

Distance (earth to the sun) D_{SE} = 150 x 10^9 m

What is the solar constant?

At the top of the atmosphere, incoming energy is approximately equal to 1400 $W.m^{-2}$.

The total solar radiation intercepted by the Earth is the solar constant multiplied by the cross section area of the Earth (circle). If we divide by the surface area of the Earth (sphere), we can find the solar radiation received, on average, by a square meter at the Earth's surface.

$$S_e = S.\pi r^2 / 4\pi r^2$$
$$= 1400/4$$
$$\sim 350 \text{ W.m}^{-2}$$

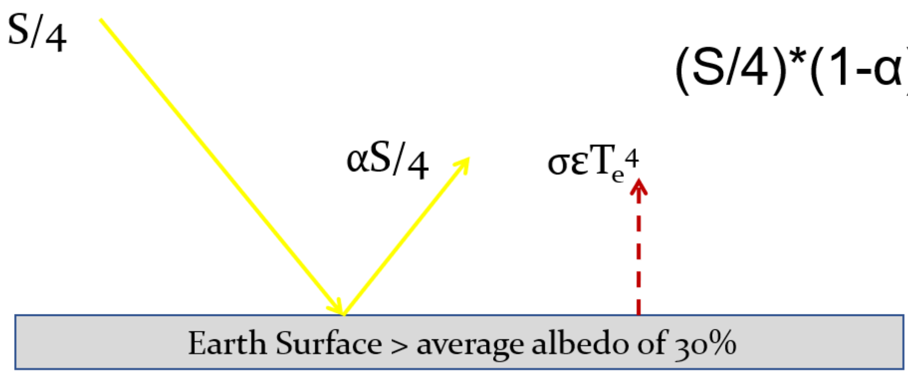
What is incoming and outgoing solar radiation?

- **Incoming solar radiation is shortwave**

- Outgoing is the **reflected solar radiation** + the **longwave** radiation emitted by the surface

Energy absorbed by Earth = Energy emitted by Earth

$$(S/4)*(1-\alpha) = \sigma\varepsilon T_e^4$$



This is the general case assuming that there is no atmosphere – perfect transmission of radiation