Basic Hydrologic Concepts

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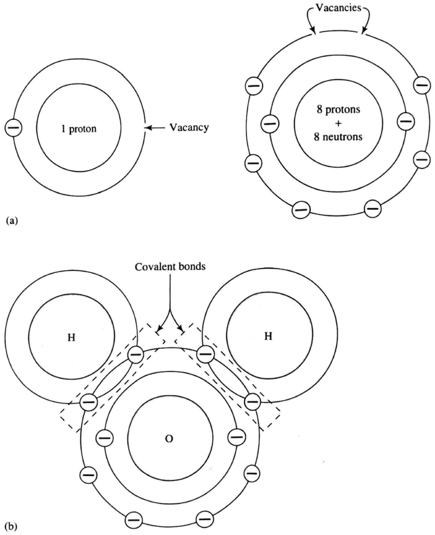
Water Molecule

The molecular formula of water is H_2O, with two hydrogen atoms and one oxygen atom. The outer shell of hydrogen has 1 electron but can accommodate 2 and the outer shell of oxygen has 6 electrons but can accommodate 8.

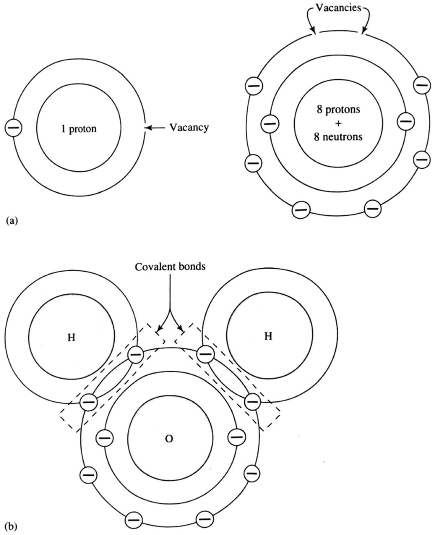
This mutual sharing of electrons is a **covalent bond**.



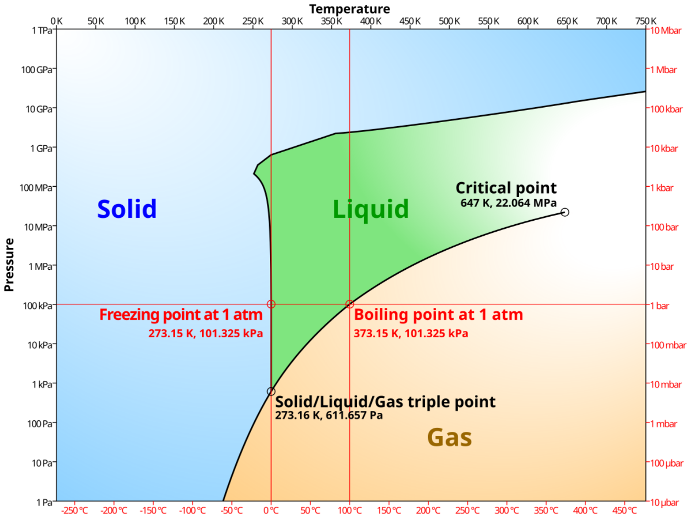
Features of Water Molecule

- Covalent bonds are very strong (much energy needed to break them)
- Molecular structure is asymmetric, with hydrogen atoms at 105° angle.
- This asymmetry leads to the molecule having a positively and negatively charged end (i.e., a **polar** molecule).
- Attractive force between polar water molecules is called a **hydrogen bond**.

These features explain much of the unusual properties of water.



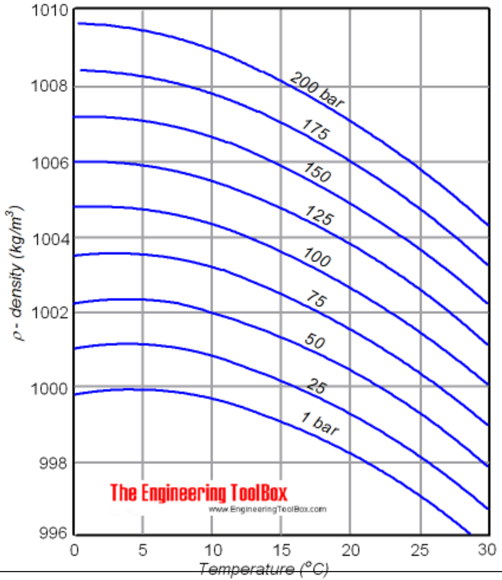
Phase Diagram



Density

$$\rho = \frac{m}{V}$$

where ρ is density, m is mass (in units M), and V is volume (in units L^3).



Units!

Science uses international system of units (SI), but practitioners in hydrology often still use imperial units.

1. Time, T, with SI units of seconds (s)
2. Mass, M, with SI units of grams (g) and imperial units of pounds (lb).
3. Length, L, with SI units of meters (m) and imperial units of feet (ft).
4. Force, F, with SI units of Newtons (N) and imperial units of pounds (lb).
5. Pressure, p, with SI units of Pascals (pa) and imperial units of pounds per square inch (psi).
6. Energy, E, with SI units of Joules (J)
7. Angle, θ, with SI units of radians (rad) or degrees ($^\circ$)

What the heck is an acre-foot (AF)?

Quantities

1. Volume (L^3)
2. Mass concentration (M/V), such as concentration of contaminant in water.
3. Rate (L/T), such as velocity.
4. Flux (V/T), such as streamflow.

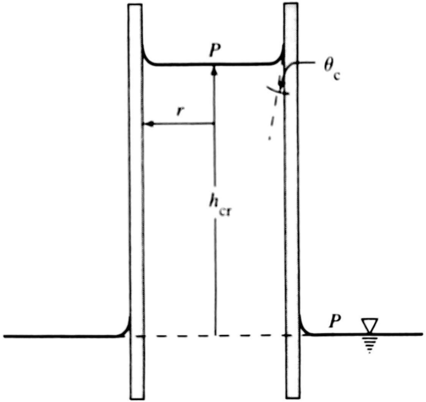
Surface Tension

Hydrogen bonds produce a net inward force to molecules at the surface of water called surface tension (σ) having units of force (F) divided by distance over which it acts (L^{-1})

σ is equal to 0.0756 Nm^{-1} at $0^{\circ}C$ but decreases with increasing temperature or in presence of dissolved surfactants.

Capillary Rise

The polarity of water also leads to an attraction of molecules to surfaces, leading to water being drawn upward where flow scale is less than a few millimeters (i.e., pores).



$$F_u = \sigma \cdot \cos(\theta_c) \cdot 2 \cdot \pi \cdot r$$

$$F_d = \gamma \cdot \pi \cdot r^2 \cdot h_{cr}$$

Where, σ is surface tension, θ_c is contact

angle, r is radius of cylinder, γ is weight density of water, and h_{cr} is height to which water will rise.

Solving for Capillary Rise

Since Newton's 3rd Law of Motion states that for every action force, there is an equal and opposite reaction force, we can combine the equations of upward and downward force to solve for capillary rise (h_{cr}).

We know (or can estimate) σ and γ, and we can measure θ_c and r, we can solve for the expected capillary rise in a cylinder.

Physical Laws

The following are basic laws of classical physics that apply to hydrology:

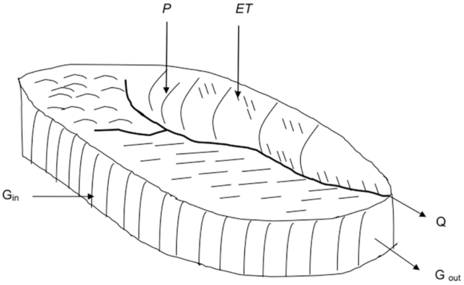
- Conservation of Mass, mass is neither created nor destroyed.
- Newton's Laws of Motion
    1. Conservation of Momentum, momentum of an object remains constant unless acted upon by a net force.
    2. The acceleration of an object is proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object. (Force = mass * acceleration).
    3. For every net force on an object, there is an equal and opposite force.
- Laws of Thermodynamics
    1. Conservation of Energy, energy is neither created nor destroyed.
    2. Heat always flows spontaneously from hotter to colder regions of matter (Entropy)
- Fick's First Law of Diffusion, a substance moves from higher to lower concentrations at a rate that is proportional to the concentration gradient.

Conservation Equations

Amount In - Amount Out = Change in Storage

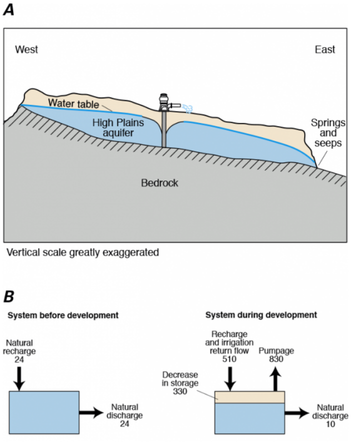
for a defined control volume, a defined period of time, and a conservative substance.

Control Volume



Where:

P	=	Precipitation
ET	=	Evapotranspiration
Q	=	Stream outflow
G_{in}	=	Ground water in
G_{out}	=	Ground water out

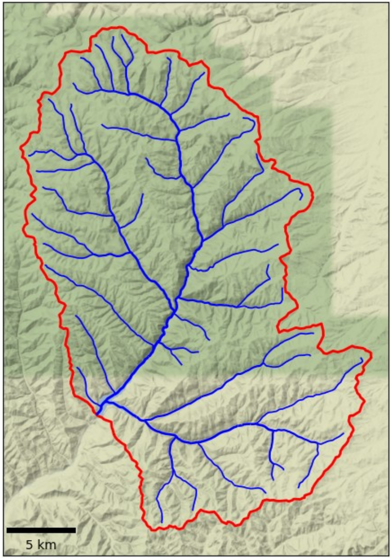


Does not have to be physically contiguous (i.e., glaciers)

Watershed Delineation

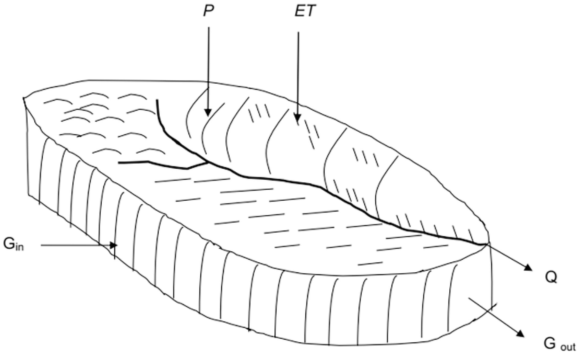
Watershed is most common control volume, defined as area that appears (on basis of topography) to contribute all water that passes through a given cross-section of a stream.

Nowadays, it is trivial to delineate a watershed based on an arbitrary point along a stream using a Digital Elevation Model (DEM) and openly available GIS tools. We will do this in our homework.



Regional Water Balance

$$P + G_{in} - (Q + ET + G_{out}) = \Delta S$$



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Challenges to Estimating Regional Water Balance

EPS 522 Term Project

Hydrologic Analysis of a Watershed

1. Pick an existing (or delineate your own) watershed.
2. Assemble all available data and quantify the regional water balance.
3. Identify the primary water resource management concern(s) (e.g., climate change, land use change, contamination, drought, etc.).
4. Estimate, quantify, and/or model changes to water balance due to historic and/or future changes (including management interventions if desired).

Deliverables: technical memorandum and presentation to the class.