Introduction, Hydrology: Part 1
Surface Water Hydrology

- Basic unit: Watershed or drainage basin for surface water

Groundwater divide can differ from surface water divide
• “Political” boundaries can also differ.
The Hydrologic Equation

Law of mass conservation
Inflow = Outflow ± Change of Storage

\[ V_2 = V_1 + I_1 + I_2 + I_3 + I_4 - O_1 - O_2 - O_3 \]

\[ V_2 > V_1 \text{ if } \sum I > \sum O \]
(and vice versa)

Example:
Mono Lake
Mono Lake

- Area = 695 mile²

Input:
- Rainfall, annual average 8 inches
- Stream flow: annual average (150,000 acre-feet; 1 acre-feet = 43,560 ft³)

Output:
- Evaporation: annual 45”
Mono Lake

Lake levels:
• 1856: 6407’ above msl
• 1919: 6428
• 1941: 6410 (water diversion started to Los Angeles ~ 100,000 acre-feet)
• 1981: 6372
• 1984: 6381 (wet period)

Mono Lake

Lake levels (cont.):
• 1989: Dropped again (normal rain; diversions halted because level dropped below 6377)
• 1992: 6373 (even without diversions)
• 1994: 6392
• 2000: 6384
• It will take several years to reach the 1949 level 6392.
Mono Lake

Environmental problems
• Increased salinity: 5.4 – 9.3%
• Reduced brine shrimp
  ○ Commercial
  ○ Food for migratory birds
  ○ Other species
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Difficulties in modeling
- Lack of equations
- Lack of data (cannot be measured; variability; need for calibration, validation; etc.)
- Cost/expertise

**Evaporation**

Atmospheric water vapor

\[ \text{Water molecules} \]

\[ \downarrow \downarrow \]

Liquid water vapor

Every gram of water evaporates absorbs 950 cal. From the surface.
Evaporation

Absolute humidity = \frac{\text{Number of grams of water}}{1 \text{ cubic meter of air}}

Saturation humidity = \text{maximum amount of moisture at a given temp.}

Relative humidity = \frac{\text{Absolute humidity}}{\text{Saturation humidity}}

Evaporation stops at 100% relative humidity
Need estimates for the water budget

(1) Budget
   Ground water ??

(2) Land pan
   NWS has 450 stations use Class A land pan (4’ diameter, 10” deep; made from galvanized metal)
   -water is kept at 7-8” depth
   -keep records of addition/rainfall, wind speed
Errors: Rain splash – birds
  Water warmed faster than open water:
  (a) smaller depth
  (b) heat loss through sides & bottom
→ need land pan coefficient < 1.0
Midwest: 0.58 → 0.78 (average 0.75)
  Dec.  May

(3) Lake evaporation nomograph
Need:  (1) mean daily temp. (°F)
      (2) solar radiation in langleys
(1) langely = one calorie/cm² of surface

(3) wind movement (miles/day)

(4) Mean daily dew point temp. (°F)
          (air temp. at which condensation will begin)
Example

- $T_{air} = 70^\circ F$ and daily radiation 650 langleys /day, 1 langley = 1 calorie/cm$^2$
- Dew point $T_d = 50^\circ F$
- $T_d = 50^\circ F$ and avg wind speed = 40 miles/day
- Intersection of vertical from upper left and horizontal from lower right
- Daily pan evaporation $\sim 0.22$ inches.

Transpiration

- Less than 1% of water is used to manufacture plant tissue
- Transpiration accounts for most losses from land-dominated drainage basins
- Transpiration is a function of density and size of vegetation
  Corn: In May much less (few cms high) than August (7ft high)
Transpiration

- Occurs mostly during the day (95%)
- Only during growing season
  Dryer soil → limited transpiration
  “Soil wilting point” → water will not enter roots

Estimation of Transpiration
Measurement using phytometers (sealed containers filled with soil and plants. Measure humidity in the air)

Evapotranspiration (ET): Total loss

Potential ET = water loss if no water deficiency in soil
Actual ET ≡ under field conditions

Potential ET Estimation
(1) Mean monthly air temp
   Latitude
   Month
Assume that it does not depend on vegetation density or maturity
--> reasonable “annual” estimate.
(2) Same as (1) but add crop factor that changes with season

(3) models that use climatic data
   Vapor pressure
   Sunshine duration
   Net radiation
   Wind speed
   Mean temperature

Some of parameters cannot be measured directly

Measurement of ET
Use Lysimeters (large containers)
- measure initial soil moisture content
- measure precipitation + irrigation water
- measure excess (drainage) water
- measure changes to soil moisture content

⇒ How much of added water is lost to ET?
\[ E_t = S_i + P_t + I - S_f - D \]

- \( S_i \): initial volume of water
- \( S_f \): final volume of water
- \( P \): precipitation
- \( I \): Irrigation
- \( D \): Drainage

Soil moisture changes can be measured by:
1. sampling
2. moisture meters (gages)
3. weighing the entire mass

![Diagram showing potential and actual evapotranspiration over time](image-url)
FIGURE 2.3 Diagram of potential and actual evapotranspiration in an area that has fine soils with ample soil-moisture storage, warm summers, cool winters, and little change in precipitation throughout the year.