

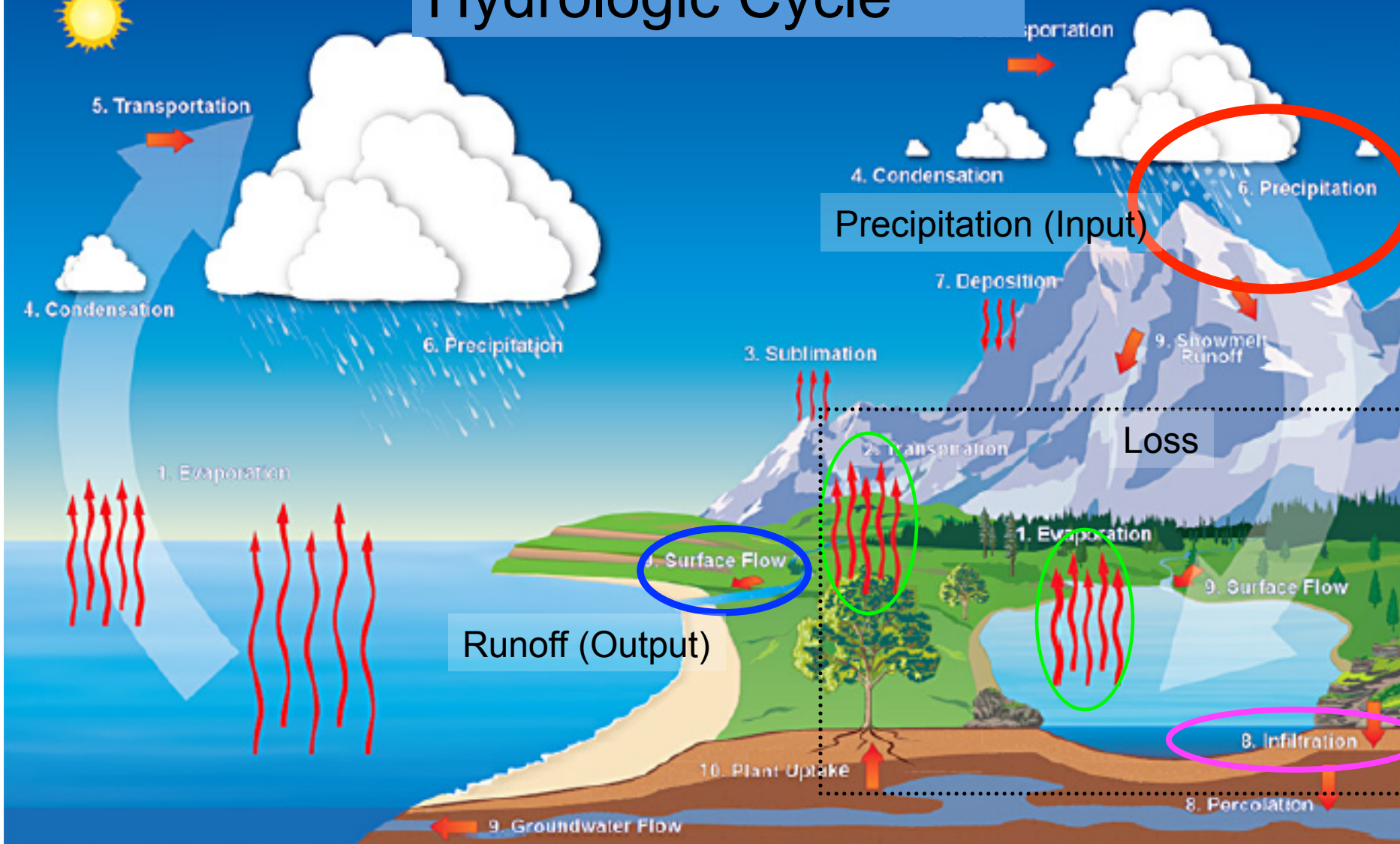
# CE 3354 Engineering Hydrology

Lecture 11: Watershed Loss Processes  
Evapotranspiration

# Outline

- Loss Processes
  - Evapotranspiration

# Hydrologic Cycle



1. Evaporation is the change of state of water (a liquid) to water vapor (a gas). On average, about 17 inches (43 cm) is evaporated into the atmosphere from the oceans each year.
2. Transpiration is the evaporation of liquid water from plants and trees into the atmosphere. Nearly all (99%) of all water that enters the roots transpires into the atmosphere.
3. Sublimation is the process where ice and snow (a solid) changes into water vapor (a gas) without moving through the liquid phase.
4. Condensation is the process where water vapor (a gas) changes back into a liquid. This is when we begin to see clouds.
5. Transportation is the movement of liquid, liquid and gaseous water through the atmosphere. Without this movement, the water evaporated over the ocean would not precipitate over land.
6. Precipitation is water that falls to the earth. Most precipitation falls in rain but includes snow, sleet, drizzle, and hail. On average, about 39 inches (1000 mm) of rain, snow, and sleet fall each year around the world.
7. Deposition is the reverse of sublimation. Water vapor (a gas) changes into ice (a solid) without going through the liquid phase. This is most often seen on clear, cold nights when frost forms on the ground.
8. Infiltration is the movement of water into the ground from the surface. Percolation is movement of water past the soil going deep into the groundwater.
9. Surface flow is the river, lake, and stream transport of water to the ocean. Groundwater flow is the flow of water underground in aquifers. The water may return to the surface in springs or eventually seep into the ocean.
10. Plant uptake is water taken from the groundwater flow and soil moisture. Only 1% of water the plant draws up is used by the plant. The remaining 99% is passed back into the atmosphere.



# Loss Processes - Evapotranspiration

- Process Concepts
- Useful Models:
  - Blaney-Criddle
  - Thornwaithe

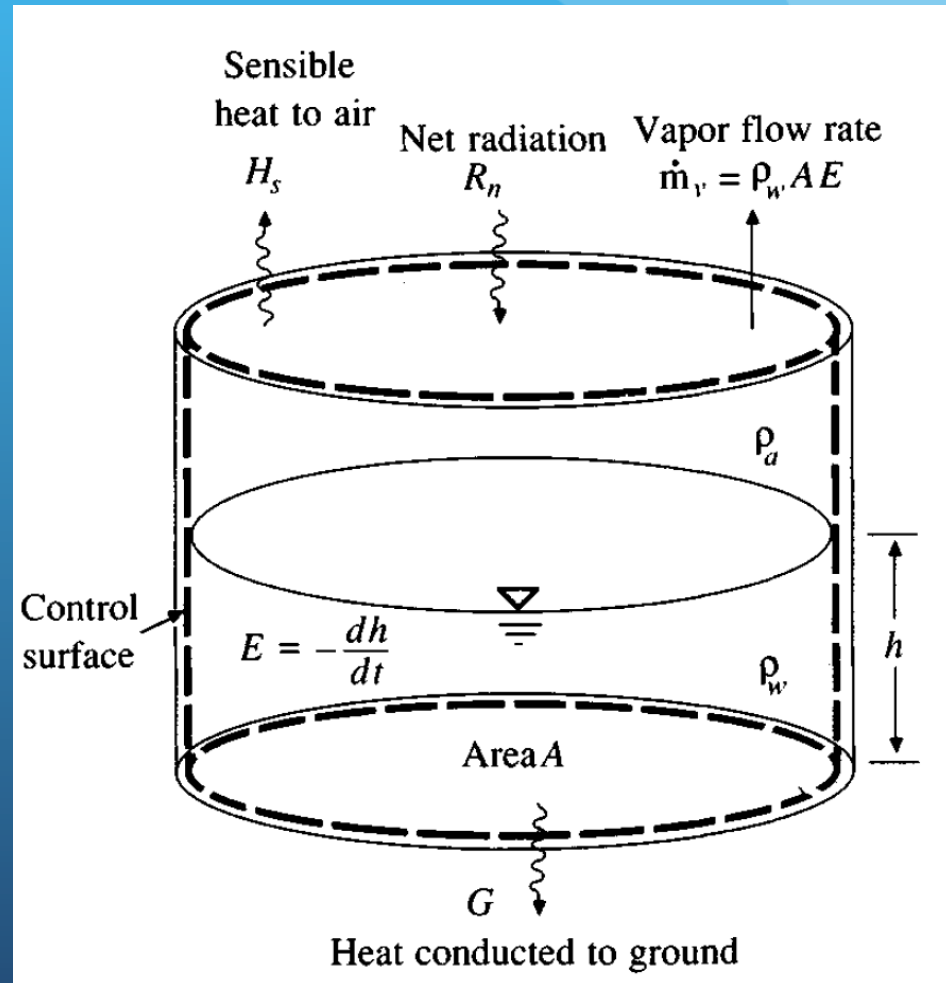
# Loss Processes - Evapotranspiration

- Process Concepts
  - Heat Energy
  - Vapor transport
    - Relative humidity
    - Wind speed

The two main factors influencing evaporation from an open water surface are the supply of energy to provide the latent heat of vaporization and the ability to transport the vapor away from the evaporative surface. Solar radiation is the main source of heat energy. The ability to transport vapor away from the evaporative surface depends on the wind velocity over the surface and the specific humidity gradient in the air above it.

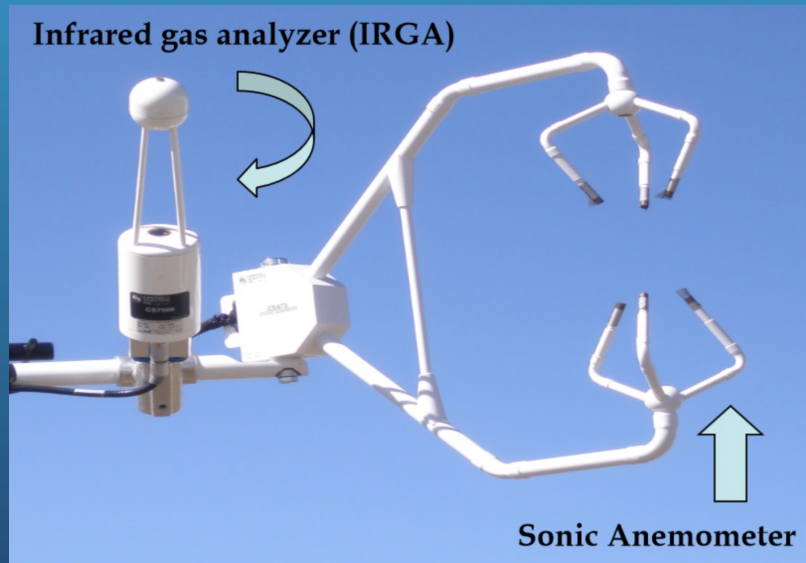
# Loss Processes - Evaporation

- Process Concepts
  - Thermodynamics
  - Fluid Mechanics
    - Energy Method
    - Aerodynamic Method
    - Combined Method
- Data Requirements
  - Extensive
- CMM pp 80-91



# Loss Processes - Evaporation

- Measurement
  - Evaporation Pans
    - Used worldwide
  - Flux Instruments
    - Eddy Covariance Instruments



You Are Here ▶ Weather Instruments ▶ Weather Stations ▶ Fixed Weather Stations ▶ Class A Evaporation Station

## Class A Evaporation Station

**Perfect for Regular Readings of Evaporation Rates**  
Accurately measure the amount of water evaporation on your site with this complete **Class A Evaporation Station**—designed to measure maximum and minimum temperatures of the water and the ...  
[See more details »](#)

Item #: 110375

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Mfr. Model #: 255-500

**Drop Shipped**  
Ships Directly from Manufacturer

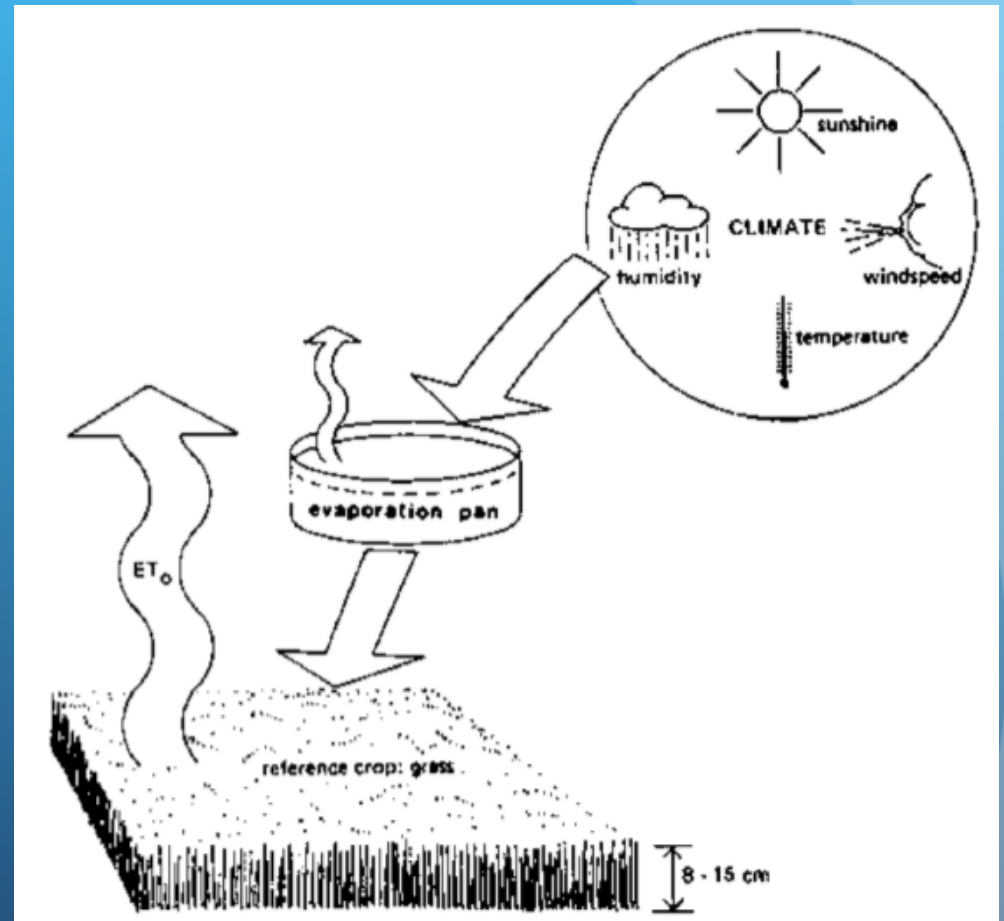
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**DETAILS**

# Evaporation Pans

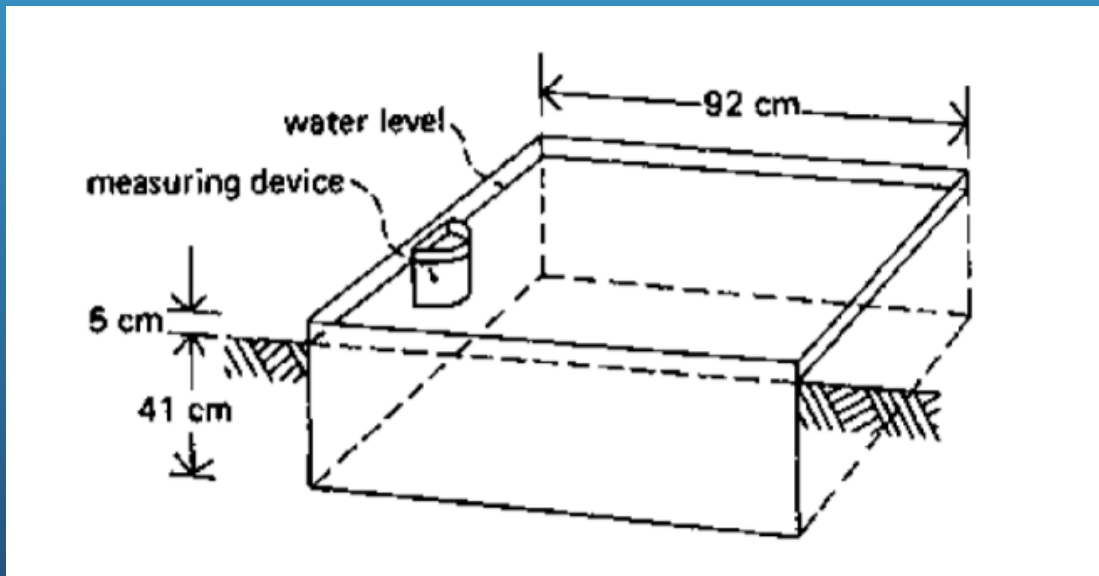
- Used in conjunction with lysimeter instruments to calibrate to crop type.
- Then make measurements with a pan or EC instrument





# Evaporation Pans

- Class A - Circular.
- Colorado Sunken
  - Dug into ground, rectangular

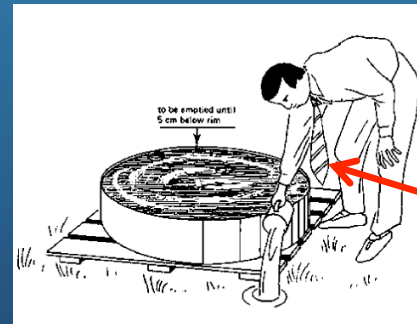


# Evaporation Pan Operation (1 of 2)

- The pan is installed in the field
- The pan is filled with a known quantity of water
- The water is allowed to evaporate during a certain period of time (usually 24 hours).
  - The rainfall, if any, is measured simultaneously
- Every 24 hours, the remaining quantity of water (i.e. water depth) is measured

# Evaporation Pan Operation (2 of 2)

- The amount of evaporation per time unit (the difference between the two measured water depths) is calculated; this is the pan evaporation:  $E_{pan}$  (in mm=24 hours)
- The  $E_{pan}$  is multiplied by a pan coefficient,  $K_{pan}$ , to obtain the  $ET_o$ .
- Reset the pan for next time interval to desired level



Don't forget to dress well for the measurement.  
You are a scientist/  
engineer.  
STEM == TIES

# Pan Constants

- Need to be determined by lysimeter or Eddy Covariance instruments

Table 2: Example of Pan Evaporation measurements and calculations

Item	Value
Pan type	Class A
Water depth in pan on day 1	150 mm
Water depth in pan on day 2	144 mm
Rainfall (during 24 hours)	0 mm
$K_{pan}$	0.75
Formula	$ET_o = K_{pan} \times E_{pan}$
Calculation	$E_{pan} = 150 - 144 = 6mm/day$
Result	$E_o = 0.75 \times 6 = 4.5mm/day$

# Evapotranspiration - Models

- Models are used to estimate ET for practical cases where measurements are not available
  - Blaney-Criddle
  - Turk
  - Thornwaithe
- All similar in that they are correlations to averaged measurements at different locations
- All are just approximations, but are used in practice and when ET matters they may be only tool available

# Blaney-Criddle Model

- Simple formula - Temperature and latitude driven only!
  - Estimates daily rate for a particular month

$$ET_o = p (0.46 T_{mean} + 8)$$

- Temperature is an average from daily values for a month

$$T_{max} = \frac{\sum T_{max \text{ daily}}}{\text{days}}$$

$$T_{min} = \frac{\sum T_{min \text{ daily}}}{\text{days}}$$

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$



# Next Time

- Loss Processes
  - Evapotranspiration