Module 1

Lecture 3: Hydrologic losses

Hydrologic losses

- In engineering hydrology, runoff is the main area of interest. So, evaporation and transpiration phases are treated as “losses”.

- If precipitation not available for surface runoff is considered as “loss”, then the following processes are also “losses”:
  - Interception
  - Depression storage
  - Infiltration

- In terms of groundwater, infiltration process is a “gain”.

Interception

❖Interception is the part of the rainfall that is intercepted by the earth's surface and which subsequently evaporates.

❖The interception can take place by vegetal cover or depression storage in puddles and in land formations such as rills and furrows.

❖Interception can amount up to 15-50% of precipitation, which is a significant part of the water balance.

Depression storage

❖ Depression storage is the natural depressions within a catchment area which store runoff. Generally, after the depression storage is filled, runoff starts.

❖ A paved surface will not detain as much water as a recently furrowed field.

❖ The relative importance of depression storage in determining the runoff from a given storm depends on the amount and intensity of precipitation in the storm.

Infiltration

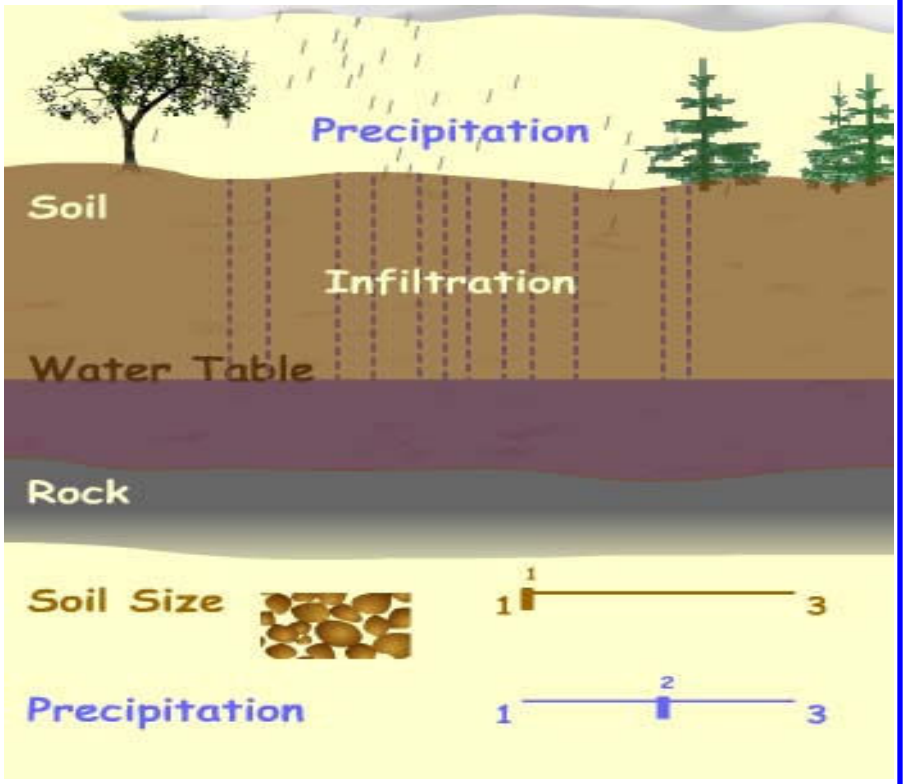
The process by which water on the ground surface enters the soil. The rate of infiltration is affected by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil.

The soil texture and structure, vegetation types and cover, water content of the soli, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity.

Factors affecting infiltration

Infiltration capacity or amount of infiltration depends on :

- Soil type
- Surface of entry
- Fluid characteristics.



http://techalive.mtu.edu/meec/module01/images/Infiltration.jpg

Factors affecting infiltration Contd…

Soil Type : Sand with high porosity will have greater infiltration than clay soil with low porosity.

Surface of Entry : If soil pores are already filled with water, capacity of the soil to infiltrate will greatly reduce. Also, if the surface is covered by leaves or impervious materials like plastic, cement then seepage of water will be blocked.

Fluid Characteristics : Water with high turbidity or suspended solids will face resistance during infiltration as the pores of the soil may be blocked by the dissolved solids. Increase in temperature can influence viscosity of water which will again impact on the movement of water through the surface.

Infiltration rate

Infiltration capacity :

The maximum rate at which, soil at a given time can absorb water.

$$f = f_c \text{ when } i \geq f_c$$

$$f = \text{when } i < f_c$$

where fc = infiltration capacity (cm/hr)

i = intensity of rainfall (cm/hr)

f = rate of infiltration (cm/hr)

Infiltration rate

Contd…

Horton's Formula: This equation assumes an infinite water supply at the surface i.e., it assumes saturation conditions at the soil surface.

For measuring the infiltration capacity the following expression are used:

$$f(t) = f_c + (f_0 - f_c)\, e^{-kt} \quad \text{for} \quad o \leq t \leq t_d$$

where k = decay constant ~ T^{-1}

f_c = final equilibrium infiltration capacity

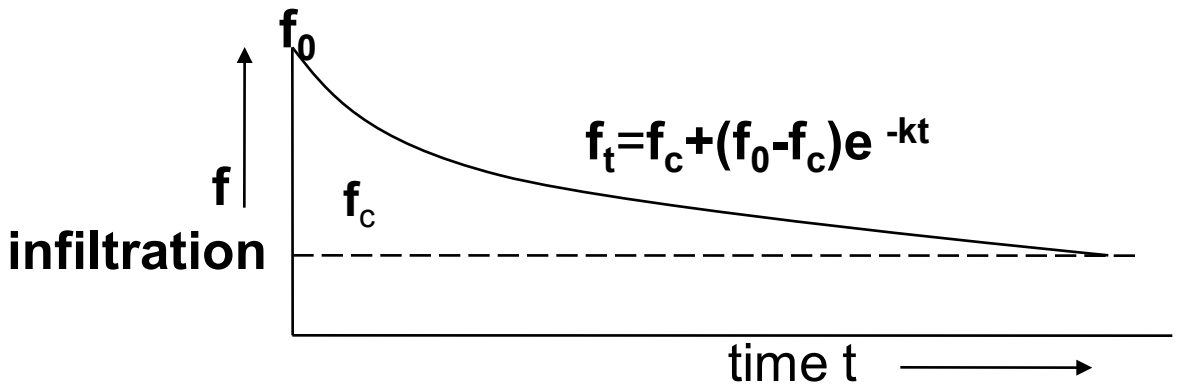
f_0 = initial infiltration capacity when t = 0

f(t) = infiltration capacity at any time t from start of the rainfall

t_d = duration of rainfall

Infiltration rate

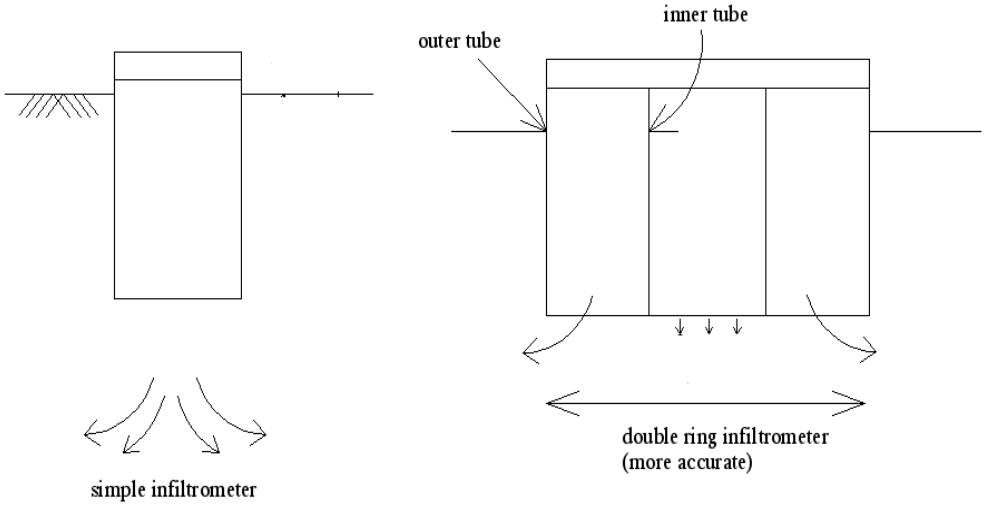
Contd…



Graphical representation of Horton formula

Measurement of infiltration

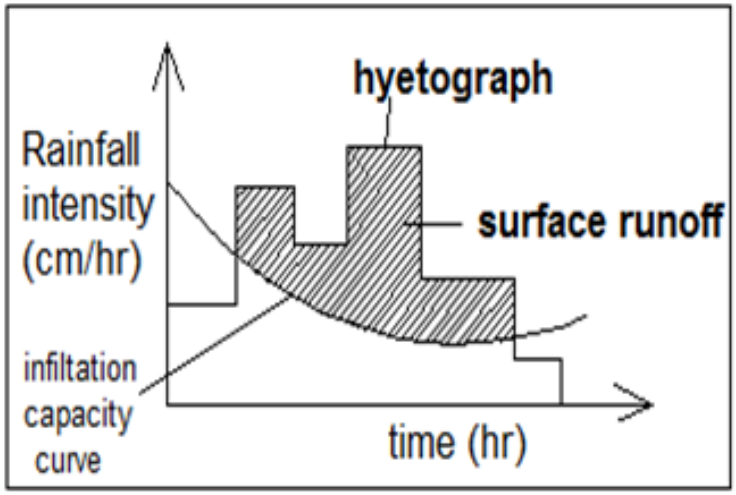
1. Flooding type infiltrometer
2. Rainfall simulator



Measurement of infiltration

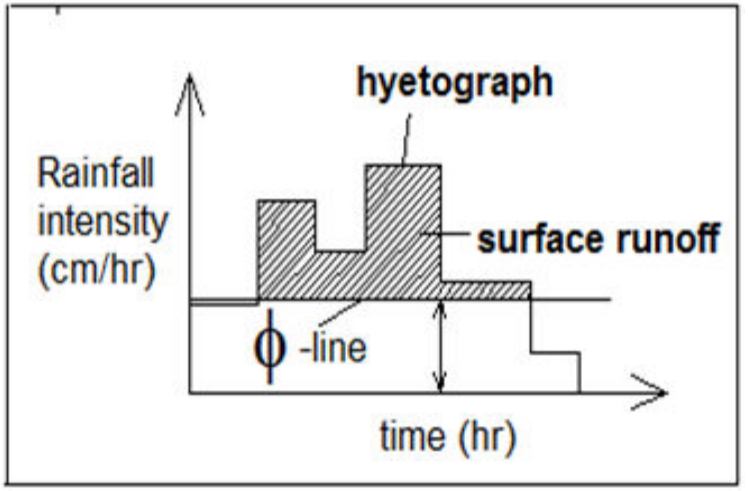
Infiltration indices

The average value of infiltration is called infiltration index.



Two types of infiltration indices

- ϕ - index
- w –index



Measurement of infiltration Contd...

Infiltration indices

- The indices are mathematically expressed as:

$$\phi\text{-index} = (P-R)/t_e$$

$$w\text{-index} = (P-R-I_a)/t_e$$

where P=total storm precipitation (cm)

R=total surface runoff (cm)

I_a=Initial losses (cm)

t**e**= elapsed time period (in hours)

The w-index is more accurate than the ϕ-index because it subtracts initial losses

Example Problem

A 12-hour storm rainfall with the following depths in cm occurred over a basin: 2.0, 2.5, 7.6, 3.8, 10.6, 5.0, 7.0, 10.0, 6.4, 3.8, 1.4 and 1.4. The surface runoff resulting from the above storm is equivalent to 25.5 cm of depth over the basin. Determine the average infiltration index (Φ-index) for the basin.

Total rainfall in 12 hours = 61.5 cm

Total runoff in 12 hours = 25.5 cm

Total infiltration in 12 hours = 36 cm

Average infiltration = 3.0 cm/hr

Average rate of infiltration during the central 8 hours

$8\,\Phi + 2.0 + 2.5 + 1.4 + 1.4 = 36$

Φ **= 3.6cm/hr**

Evaporation

- In this process, water changes from its liquid state to gaseous state.
- Water is transferred from the surface to the atmosphere through evaporation

Evaporation is directly proportional to :

- Vapor pressure (e_w),
- Atmospheric temperature (T),
- Wind speed (W) and
- Heat storage in the water body (A)

Factors affecting evaporation

Vapour pressure: The rate of evaporation is proportional to the difference between the saturation vapour pressure at the water temperature, e_w and the actual vapour pressure in the air ea.

$$E_L = C\,(e_w - e_a)$$

E_L = rate of evaporation (mm/day); C = a constant ; e_w and e_a are in mm of mercury;

The above equation is known as Dalton's law of evaporation. Evaporation takes place till $e_w > e_a$, condensation happen if $e_w < e_a$

Factors affecting evaporation Contd…

Temperature: The rate of evaporation increase if the water temperature is increased. The rate of evaporation also increase with the air temperature.

Heat Storage in water body: Deep bodies can store more heat energy than shallow water bodies. Which causes more evaporation in winter than summer for deep lakes.

Types of Evaporation

- **Soil evaporation:** Evaporation from water stored in the pores of the soil i.e., soil moisture.

- **Canopy evaporation:** Evaporation from tree canopy.

➔ **Total evaporation** from a catchment or an area is the summation of both soil and canopy evaporation.

Measurement of evaporation

The amount of water evaporated from a water surface is estimated by the following methods:

1. Using evaporimeter data
2. Empirical equations
3. Analytical methods

1. **Evaporimeters :** Water containing pans which are exposed to the atmosphere and loss of water by evaporation measured in them in the regular intervals.
   a) Class A Evaporation Pan
   b) ISI Standard pan
   c) Colorado sunken pan
   d) USGS Floating pan

Measurement of evaporation Contd…

1. Evaporimeters

Demerits of Evaporation pan:

1. Pan differs in the heat-storing capacity and heat transfer from the sides and bottom.

   Result: reduces the efficiency (sunken pan and floating pan eliminates this problem)
2. The height of the rim in an evaporation pan affects the wind action over the surface.
3. The heat-transfer characteristics of the pan material is different from that of the reservoir.

Measurement of evaporation Contd…

Pan Coefficient (Cp)

For accurate measurements from evaporation pan a coefficient is introduce, known as pan coefficient (**Cp**). Lake evaporation = **Cp** x pan evaporation

Type of pan	Range of **Cp**	Average value **Cp**
Class A land pan	0.60-0.80	0.70
ISI pan	0.65-1.10	0.80
Colorado sunken pan	0.75-0.86	0.78
USGS Floating pan	0.70-0.82	0.80

Source: Subramanya, 1994

Measurement of evaporation Contd…

2. Empirical equation

Mayer's Formula (1915)

$$E_L = K_m (e_w - e_a) (1 + (u_9/16))$$

where E_L = Lake evaporation in mm/day;

e_w = saturated vapour pressure at the water surface temperature;

e_a = actual vapour pressure of over lying air at a specified height;

u_9 = monthly mean wind velocity in km/hr at about 9 m above the ground;

K_m= coefficient, 0.36 for large deep waters and 0.50 for small shallow waters.

Example Problem

A reservoir with a surface area of 250 ha had the following parameters: water temp. 22.5^{o}C, RH = 40%, wind velocity at 9.0 m above the ground = 20 km/hr. Estimate the volume of the water evaporated from the lake in a week.

Given e_w = 20.44, Km =0.36.

Solution:

e_a = 0.40 x 20.44 = 8.176 mm Hg; U_9 = 20 km/hr;

Substitute the values in Mayer's Equation .

Now, E_L = 9.93 mm/day

For a week it will be **173775 m^3**.

Measurement of evaporation Contd…

3. Analytical method

Water Budget method: This is the simplest analytical method.

$$P + V_{is} + V_{ig} = V_{os} + E_L + ds + T_L$$

P= daily precipitation;

V_{is} = daily surface inflow into the lake;

V_{ig} = daily groundwater flow ;

V_{os}= daily surface outflow from the lake;

V_{og}= daily seepage outflow;

E_L= daily lake evaporation;

ds= increase the lake storage in a day;

T_L= daily transportation loss

Evapotranspiration

Transpiration + Evaporation

This phenomenon describes transport of water into the atmosphere from surfaces, including soil (soil evaporation), and vegetation (transpiration).

Hydrologic Budget equation for Evapotranspiration:

$$P - Rs - Go - Eact = \text{del } S$$

P= precipitation; Rs= Surface runoff; Go= Subsurface outflow; Eact = Actual evapotranspiration; del S = change in the moisture storage.

Highlights in the Module

- **Hydrology** is a science which deals with the movement, distribution, and quality of water on Earth including the hydrologic cycle, water resources and environmental watershed sustainability.

- **Stages of the Hydrologic cycle or Water cycle**
  - Precipitation
  - Infiltration
  - Interception
  - Run-off
  - Evaporation
  - Transpiration
  - Groundwater

Highlights in the Module Contd…

- **Hydrologic Losses :** evaporation, transpiration and interception
- **Measurement of Precipitation**
  - Non-Recording Rain gauges: Symons's gauge
  - Recording Rain gauges: tipping bucket type, weighing bucket type and natural syphon type
- **Presentation of Rainfall Data:** Mass curve, Hyetograph, Point Rainfall and DAD curves
- **Factors affecting Infiltration:** soil characteristics, surface of entry and fluid characteristics
- **Determination of Infiltration rate** can be performed using flooding type infiltrometers and rainfall simulator.

Highlights in the Module

Contd…

- **Factors affecting evaporation :** vapour pressure, wind speed, temperature, atmospheric pressure, presence of soluble salts and heat storage capacity of lake/reservoir
- **Measurement of evaporation:** evaporimeters, empirical equations and analytical methods
- **Weather** refers, generally, to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time.
- **Formation of Precipitation:** frontal, convective, cyclonic and orographic
- **The four different seasons are:** Cold weather, Hot weather, South-West monsoon and Retreating monsoon