

Welcome to Applied Hydrology (EHG 311)

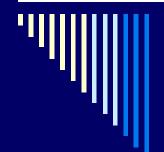
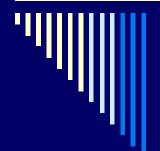


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- 7- Water Budget



1- HYDROLOIC CYCLE

• 1.1 Hydrologic Cycle Elements

Evaporation

Transpiration

Condensation

Precipitation

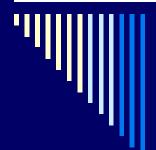
Runoff

Infiltration

Percolation

o 1-2 Air masses Types Affecting Saudi

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2- PRECIPITATION

- - Definition
- Causes of precipitation
- o Types
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- Orogarphic Precipitation
- Cyclonic Precipitation
- Precipitation Measurements
- Types of Raingauges
- Average Rainfall Depth Estimation
- Arithmetic Mean Method
- Isohyetal Method
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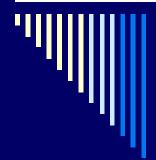


- - Precipitation Data Processing
- Estimation of Missing Data
- Normal Ratio Method
- Optimum Number of Rainguages



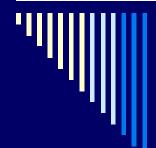
3- EVAPORATION

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- Factor Affecting Evaporation Process
- Evaporation Measurements
- Field measurements
- Empirical Equations



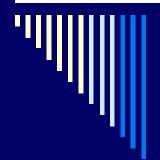
4-INFILTRATION

- Definitions
- Factor Affecting Infiltration Capacity
- Infiltration Measurements
- - Field measurements
- Operational methods
- SCS Curve Number method



5- SURFACE RUNOFF

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- Meteorological characteristics
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- Streamflow measurements
- Stage measurement
- Velocity measurement
 - Current meter
- Discharge measurement
 - Velocity-Area Method
 - Dye Method
- Slope-Area Method



6- UNIT HYDROGRAPHS

- Definitions
- Hydrograph Components
- Hydrograph development
- Floods Prediction
- Synthetic Unit Hydrograph
- Rational Method
- SCS Method
- Snyder's Method



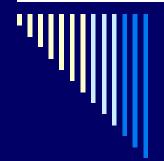
7-WATER BUDGET



1.1 Hydrologic Cycle Elements

Evaporation:

As water is heated by the sun, it's surface molecules become sufficiently energized to break free of the attractive force binding them together, and then *evaporate* and rise as invisible vapour in the atmosphere.



Transpiration:

Water vapour is also emitted from plant leaves by a process called transpiration. Every day an actively growing plant transpires 5 to 10 times as much water as it can hold at once.



Condensation:

As water vapour rises, it cools and eventually condenses, usually on tiny particles of dust in the air. When it condenses it becomes a liquid again or turns directly into a solid (ice, hail or snow). These water particles then collect and form clouds.



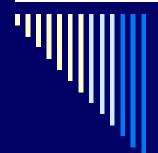
Precipitation:

Precipitation in the form of rain, snow and hail comes from clouds. Clouds move around the world, propelled by air currents. For instance, when they rise over mountain ranges, they cool, becoming so saturated with water that water begins to fall as rain, snow or hail, depending on the temperature of the surrounding air.



Runoff:

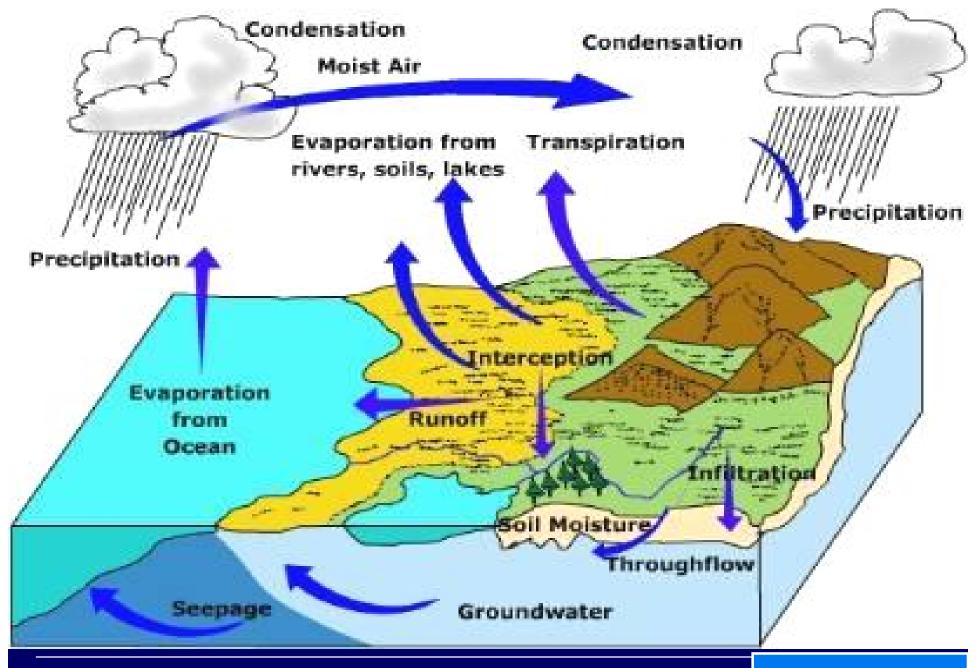
Excessive rain or snowmelt can produce overland flow to creeks and ditches. Runoff is visible flow of water in rivers, creeks and lakes as the water stored in the basin drains out.



Percolation:

Some of the precipitation and snow melt moves downward, percolates or infiltrates through cracks, joints and pores in soil and rocks until it reaches the water table where it becomes groundwater.

All the hydrological elements are shown in (Fig. 1)





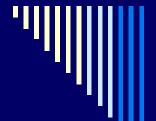
1-2 Air masses Types Affecting Saudi Arabia Climate

Four major types of air masses determine the SA's weather. They can bring anything from scorching heat to bone-chilling cold depending on the type of air mass. The SA's most violent weather usually occurs in winter when continental polar air clashes with maritime tropical air. These are:



- o Continental polar Air Masses CPA):
- o Maritime polar Air Masses (MPA):
- Maritime tropical Air Masses (MTA):
- o Continental Tropical Air Masses (CTA):
- o (See Fig. 2)

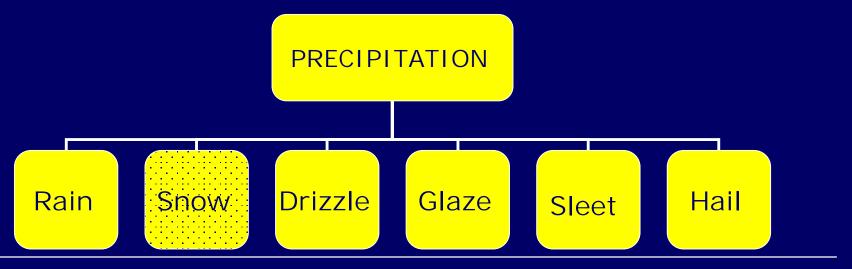




2-PRECIPITATION

2-1 Causes of precipitation

• Precipitation in liquid form. It consists of drops of water falling from clouds. Some of the common forms of precipitation are:





2-2 Precipitation Types

- Convective precipitation
- Orographic precipitation
- Cyclonic precipitation



- 2-3 Measurement of Rainfall
- 2-4 Rain Gauges Types
- The following types of raingauges can be used for the measurement of rainfall:
 - Non- recording gauge: As shown in (Fig. 3)
 - Recording gauge: An example Tipping Bucket type (Fig. 4)



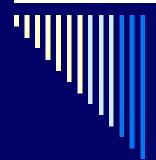






2-5 Precipitation Data Processing

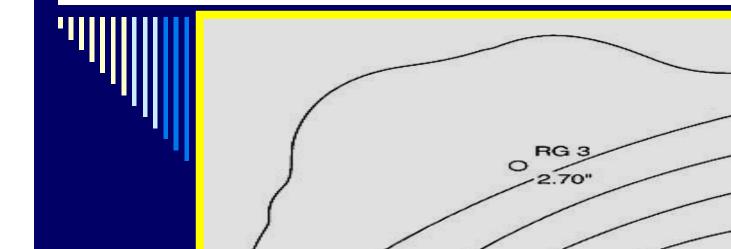
- o Estimation of Missing Rainfall Data
 - Normal Ratio Method
- o Optimum Number of raingauges



2-6 Rainfall Estimation Average

- 1- Arithmetic Mean
- 2- Isohyetal method (Fig. 5)
- 3- Theissen polygon method (Fig. 6)

$$P = \sum AiPi / \sum Ai$$

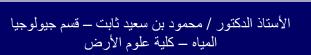


RG 2 3.75"

5.0

6.50"

3.0



Average Precip. = 4.73"

7.0

RG 1

3.0

6.0

7.0

8.0

7.00"

RG 4

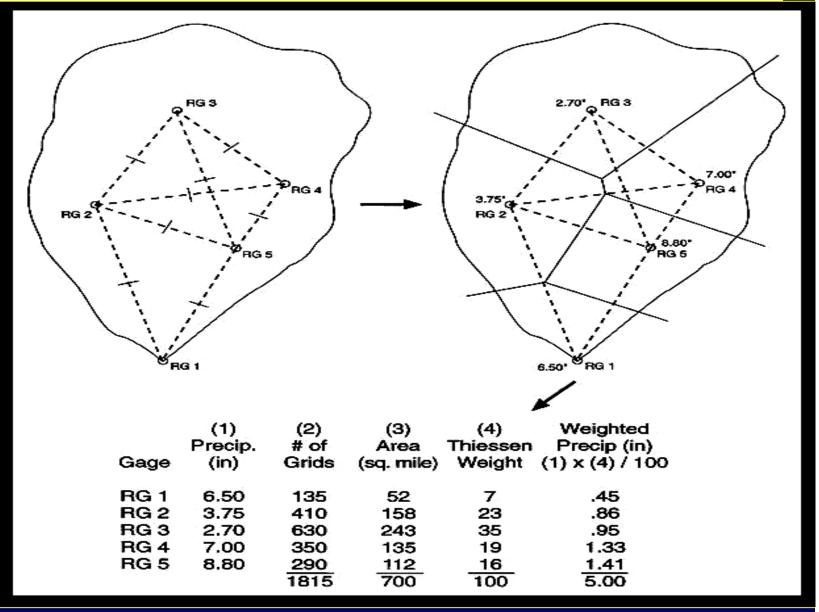
8.80" RG 5

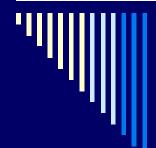
8.0

4.0

5.0







3-EVAPORATION

o 3-1 Definitions:

• As shown above that the water is heated by the sun, it's surface molecules become sufficiently energized to break free of the attractive force binding them together, and then evaporate and rise as invisible vapour in the atmosphere.



3-2 Factor affecting evaporation process

- Solar radiation
- Atmospheric humidity
- Wind
- Size and depth of water body
- Water quality

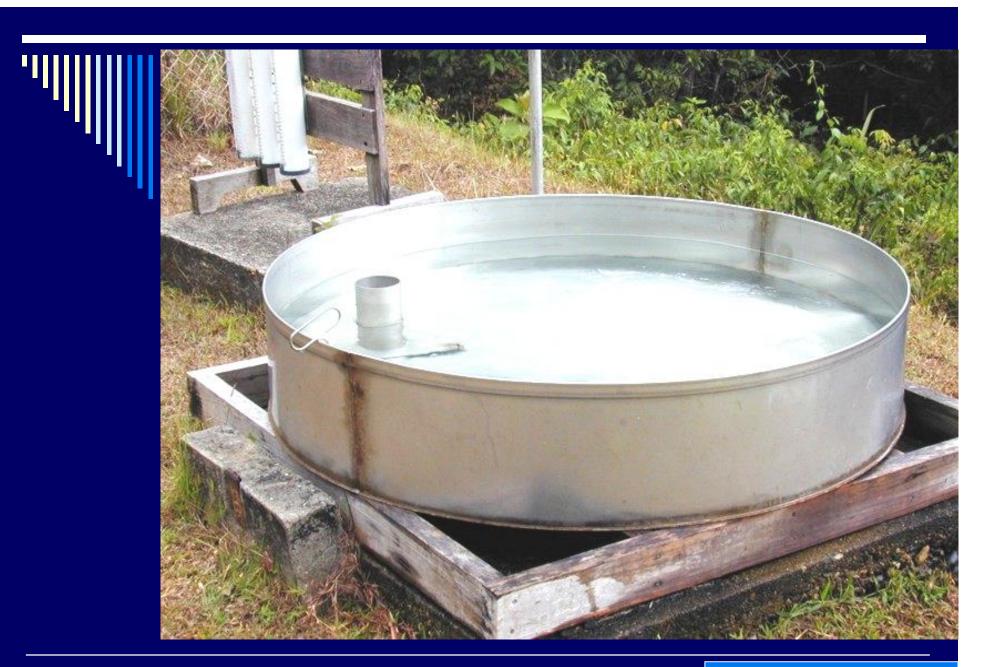


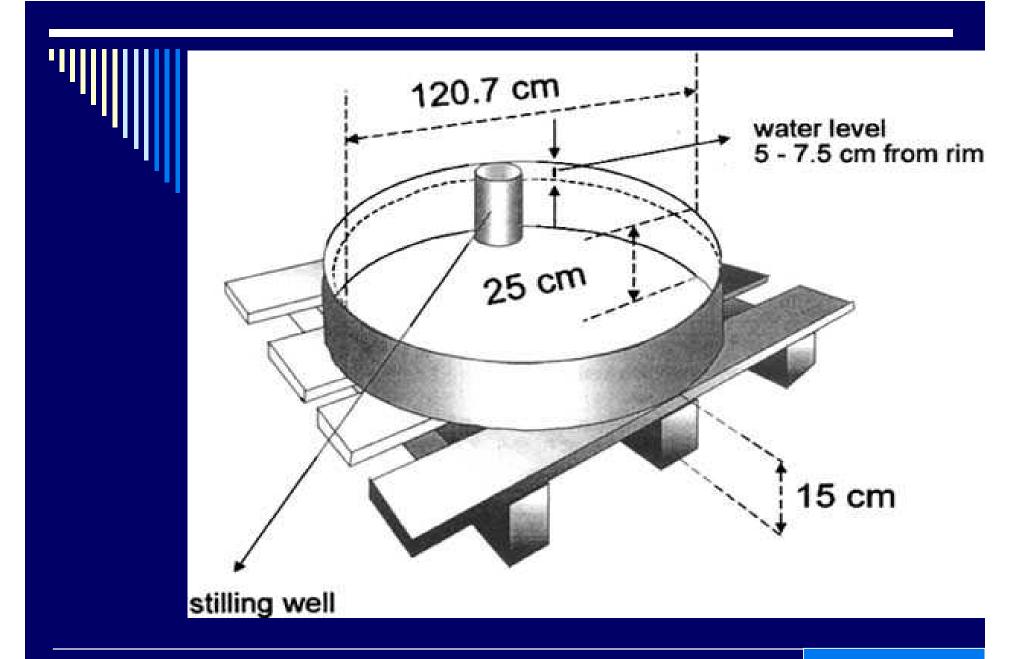
3-3 Evaporation Measurements

- o Class A Pan and Class A Pan Coefficient
- o Lake Evaporation monograph
- o Potential Evapotranspiration (ETP)
- o Actual Evapotranspiration (ETA)

3-3-1 Field Measurement

• Pan evaporation (Figs. 7 & 8)



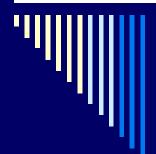




• The pan evaporation is related to the reference evapotranspiration by an empirically derived pan coefficient:

where

ETo reference evapotranspiration [mm/day],
 Kp pan coefficient [-],
 Epan pan evaporation [mm/day].



3-3-2 Empirical Equations

o 1-Penman Formula

o In 1944, Penman combined the energy budget and aerodynamic approaches. Penman's derivation eliminates the need for measuring water surface temperature; only the air temperature is required. The resulting equation is as follows:

$$E = (\Delta / \Delta + \gamma) Er + (\gamma / \Delta + \gamma) Ea$$
 where
$$Er = Rn/lv\rho w$$

$$Ea = K(u)(es-e)$$



0

Rn is net radiation (typical units are W/m²), ly is latent heat of vaporization (J/kg), pw is density of water (kg/m³), K(u) is a mass transfer coefficient, es is saturated vapor pressure at air temperature, and e is the actual vapor pressure. The Penman equation is a weighted average of the rates of evaporation due to net radiation (Er) and turbulent mass transfer (Ea). Provided that model assumptions are met and adequate input data are available, various forms of the Penman equation yield the most accurate estimates of evaporation from saturated surfaces.



2-Thornthwaite Formula

• Potential evapotranspiration can be calculated using the Thornthwaite water balance method using the following formula.

 $E = 1.6 (10T/I)^a$



Where:

E= monthly potential evapotranspiration (cm).

T= mean monthly temperature (C).

I= a heat index for a given area which is the sum of 12 monthly index values i. i is derived from mean monthly temperatures using the following formula:

$(T/5)^{1.514}$

- a= an empirically derived exponent which is a function of I,
- $a = 6.75*10^{-7} I^3 7.71*10^{-5} I^2 + 1.79*10^{-2} I + 0.49$

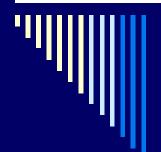


o 3- Turc Formula

Actual evaporation can be calculated using the Turc method using the following formula:

$$ET = P/[0.9 + (P/L)^2]^{0.5}$$

- o where
- o P = the mean annual precipitation (mm)
- $L = 300 + 25T + 0.05 T^3$ (mm)
- o T = the mean air temperature (oC)



4-INFILTRATION

Definitions:

- o Infiltration:
- Percolation: Infiltration capacity fp:
- O Infiltration rate f: Cumulative Infiltration F:
- Field Capacity
- Moisture Content q: Soil Moisture deficit D:
- o Porosity:
- Capillary Potential: Hydraulic Conductivity K:
- Saturated Conductivity Ks:
- Unsaturated Conductivity K(q:



o 4-2Factors Affecting Infiltration Capacity

- **o** 4-3 Infiltration Measurement
 - n 1- Field Measurement
 - Use infiltrometer device as shown in(Fig. 9)







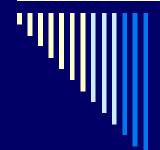


2-Operational Methods

i - phi- Index (Ø): Average Infiltration rate for a storm, averaged over many storms. Computed by taking the (total rain in cm(P) - total runoff volume(Q) (in cm.))/storm duration

Phi Index (\emptyset) = P-Q/t

ii-Accounting Methods:



1- Horton Model:

$$f = fc + (fo - fc) exp^{-kt}$$

where:

O

- o f= the infiltration capacity (depth/time) at some (t).
- fc= a final infiltration capacity
- fo= the initial infiltration capacity
- k= a constant representing the rate of decrease in (f) capacity

To estimate fc, fo and k, plot f vs t, pick fc as the right asymptote; plot ln(f-fc) vs t, get k as the -slope and ln(fo-fc) as the intercept.



2- SCS Runoff Curve Number Method

$$\frac{\mathbf{F} = \mathbf{Q}}{\mathbf{S} \quad \mathbf{P} \cdot \mathbf{I} \mathbf{a}} \tag{1}$$

- \circ where F = Actual retention
- S = Potential maximum retention (S is equal to or greater than F)
- Q = Actual runoff volume
- P = Precipitation as rainfall (P is equal to or greater than Q)
- Ia = Initial abstraction
- The actual retention (F), when the initial abstraction (Ia) is considered is:

O

$$F = P - Ia - Q$$

(2)



• Substituting Equation 2 into Equation 1 yields the following:

$$\frac{(P-Ia) - Q}{S} = \frac{Q}{P-Ia}$$
 (3)

• Rearranging Equation 3 to solve for Q results in:

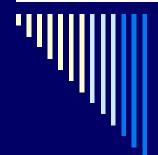
$$Q = (P-Ia)2$$

$$(P-Ia)+S$$
(4)



• The initial abstraction (Ia) is a function of land use, treatment and condition; interception; infiltration; depression storage; and antecedent soil moisture. An empirical analysis was performed by the SCS for the development of the rainfall-runoff relation, and the following formula was found to be best for estimating Ia:

$$Ia = 0.2S \tag{5}$$



• Research performed by the Soil Conservation Service since the development of Equation (5) has suggested that Equation 4-7 may not be correct under all circumstances. However, it remains in use until the SCS performs and accepts a more comprehensive study. It is important to note that Equation 4-7 implies that the factors affecting Ia would also affect S. Substituting Equation 5 into Equation 4 yields:

$$Q = (P-0.2S)2 P + 0.8S$$
 (6)



O While Equation 5 has two unknowns, Ia and S, Equation 6 has been reduced to an equation with one unknown, S. Empirical studies indicate that S can be estimated by:

$$S = (1000/CN) - 10$$
 (7)

where:

CN = Soil-cover complex curve number

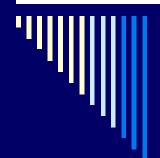
S = Potential maximum retention.





Note

Soil Group table for determining Curve Number (CN) and table of Antecedent Moisture Condition (AMC) will be Distributed in the Class



5-SURFACE RUNOFF

o 5-1 Definitions

When rain falls onto the earth, it just doesn't sit there -- it starts moving according to the laws of gravity. A portion of the precipitation seeps into the ground to replenish Earth's groundwater. Most of it flows downhill as runoff. Runoff is extremely important in that not only does it keep rivers and lakes full of water, but it also changes the landscape by the action of erosion. Flowing water has tremendous power -- it can move boulders and carve out and deposited elsewhere within the catchment.

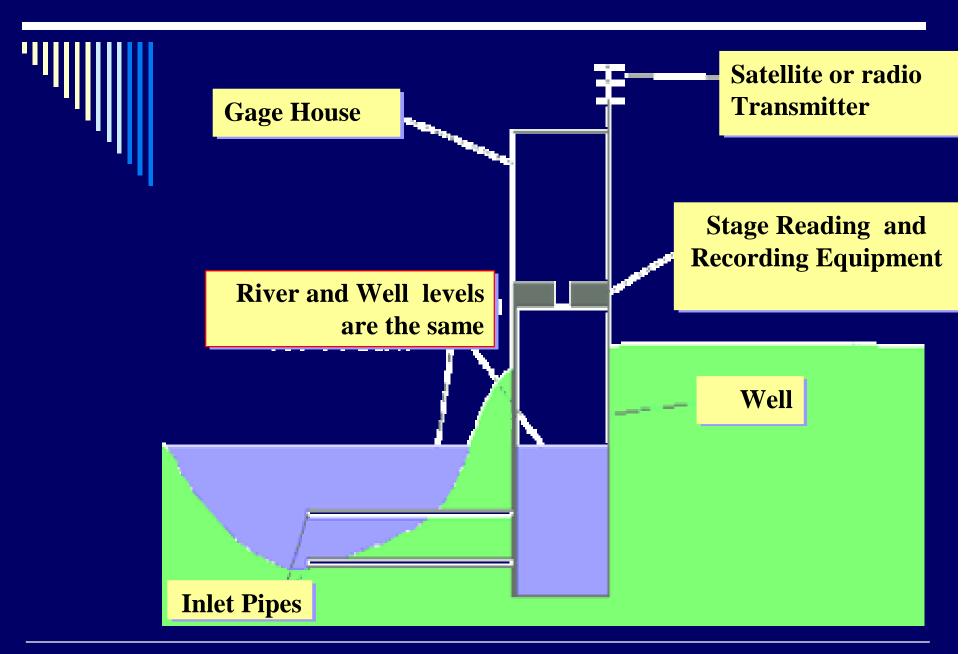


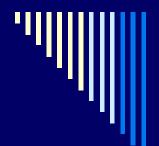
The water that flows over the surface into a stream have the greatest response to rain and snow melt. Amount of Runoff depends on:

- intensity and duration of a rain or snow melt event
- amount of water lost to interception and depression storage
- amount of water lost to infiltration
- characteristics of the drainage basin

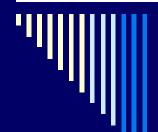


- **5-2 Factor Affecting Surface Runoff**
- Meteorological Characteristics affecting runoff
- Basin Characteristics affecting runoff
- 5-3 Streamflow Measurement
 - **5-3-1 Stage Measurement** (water elevation): Using Staff gage. (Fig. 10a and 10b)





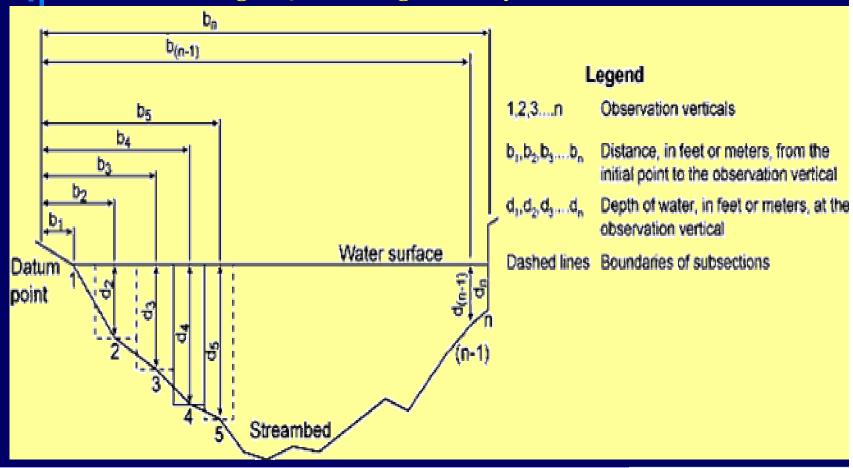


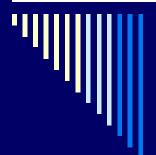


5-3-2 Discharge Measurement:

- For rivers and Streams using the following methods
- 1- Velocity Area Method (Fig. 11)

Discharge (Q)= Average velocity (m/s) X Area (m²)





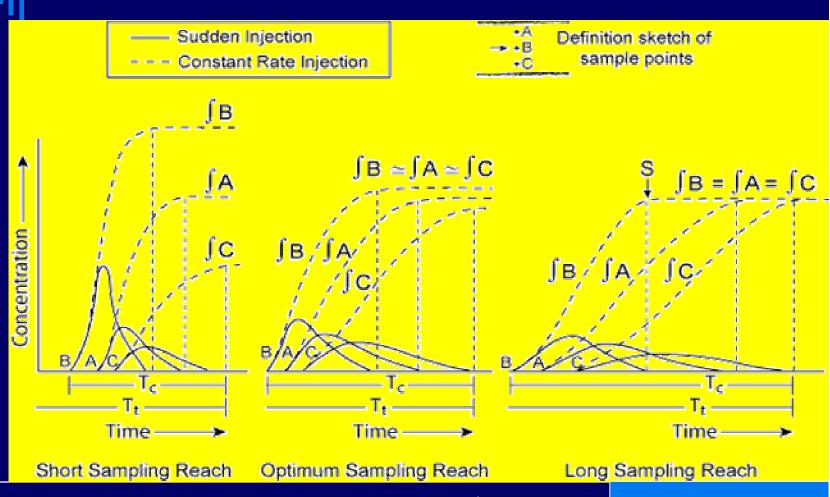
-Velocity measurement, using current meter (Fig. 12)







2-Dyes Method (Fig. 13)



الأستاذ الدكتور / محمود بن سعيد ثابت – قسم جيولوجيا المياه – كلية علوم الأرض

Fig. 13



- For dry wadis using the following approach
- 1- Slope Area Method (Fig. 14)
- The discharge of a stream is typically measured directly by stream gaging or a rating curve. However, conditions sometimes prevent direct measurement of discharge, such as during flooding events, or in remote areas. The slope-area method is used to determine peak discharge along sections of a river or stream where gages are not present. It is particularly useful for (1) determining the discharge needed for flooding along a particular reach of stream after a flood has passed, (2) or to estimate the discharge necessary to cause flooding along a section of river.
- The slope-area method is based on the Manning's equation for determining discharge,

 $Q=(A *R^{2/3} *S^{1/2})/n$

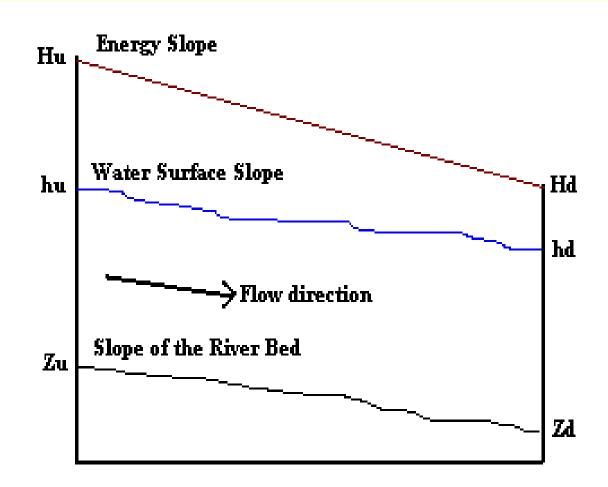


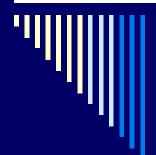
where

- A= is the cross-sectional area (ft2),
- R= is the hydraulic radius (cross sectional area/wetted perimeter (ft),
- S= is the slope (drop in elevation/length (dimensionless), and
- \circ n = is the Manning roughness coefficient (dimensionless).

Thus, the slope-area method is a function of (1) slope, (2) channel dimensions and (3) channel roughness, and therefore field data are required for estimation of peak discharge. These data include determining the elevation and location of high-water marks along the stream, measurement of channel cross section and wetted perimeter by surveying, tape and compass, or GPS, and selection of a roughness coefficient for the section of stream in question.

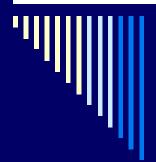






6-UNIT HYDROGRAPHS

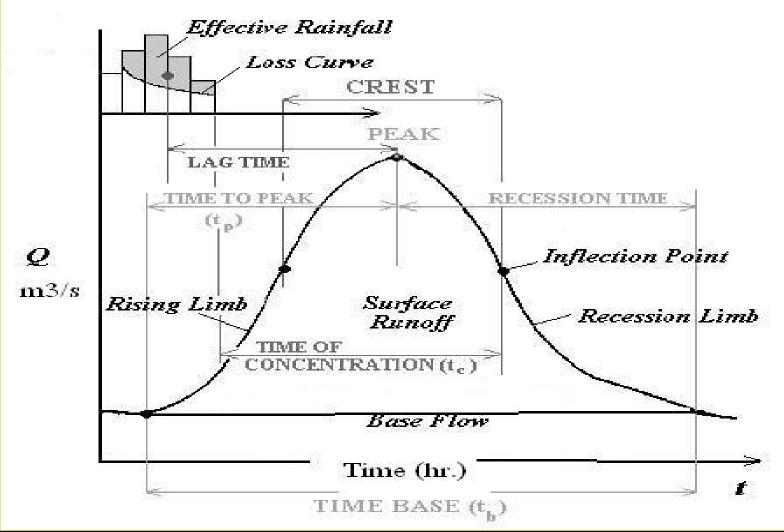
- The unit hydrograph of a drainage basin or watershed is defined as a graph of direct runoff resulting from one inch of effective
- o rainfall generated uniformly over a basin area at a uniform rate during a specified time or duration.
- o 6-1 Definitions
- O Unit Hydrograph Duration:
- Rating Curve:
- o Reach:
- Stream flow:
- Storm Hydrograph:
- Surface Runoff:
- o Travel Time:



6-2 Hydrograph Components

- Rising Limb
- Crest Segment
- Recession Limb
- Point of Inflection (See Fig. 15)







6-3 Hydrograph development:

- Among other uses, a hydrograph is usually needed for reservoir design. The hydrograph represents the unsteady input into the system. Since observed hydrographs are seldom available, they usually must be fabricated. Some methods used are:
 - n Unit hydrograph
 - n Synthetic hydrograph
- The first method requires runoff data which are usually not available for small watersheds. The second method assumes a given shape after which a determination of the peak and volume runoff values would define the hydrograph.

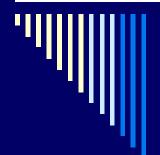


- 6-4 Synthetic Unit Hydrograph
- A. Rational Method
- B. SCS Method
- C. Snyder's Method
- **A- Rational Method**
- Rational method assumptions
- The Rational Method is based on the following assumptions for the determination of peak discharge:
- the peak discharge can be calculated as:

O

Q = C I A

Where:



- Q = Peak discharge in cubic feet per second.
- C = Runoff coefficient which represents the ratio of runoff to rainfall for the drainage area considered.
- i = The average rainfall intensity in inches per hour for a period of time equal to the time of concentration (Tc) for the drainage area under consideration.
- A = The drainage area, in acres, contributing runoff to the point of consideration.

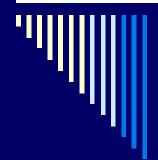
Runoff Coefficient (C)

o Tables 1&2 presents recommended "C" values based on generalized land use types. (It will be Distributed in the Class)



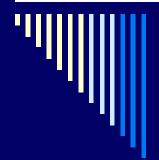
Rainfall Intensity (i)

• Rainfall intensity (i) is the average rainfall rate in inches per hour, and is selected on the basis of design rainfall duration and design frequency of occurrence. The design duration is equal to the time of concentration for the drainage area under consideration. The design frequency of occurrence is a statistical variable which is established by design criteria.



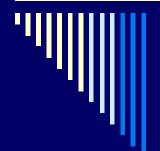
O Drainage Area (A)

The size (acres) of the watershed needs to be determined for application of the Rational Method. The area may be determined through the use of maps and supplemented by field surveys where topographic data has changed or where the contour interval is too great to distinguish the direction of flow. The drainage divide lines are determined by street layout, lot grading, structure configuration and orientation, and many other features that are created by the urbanization process.

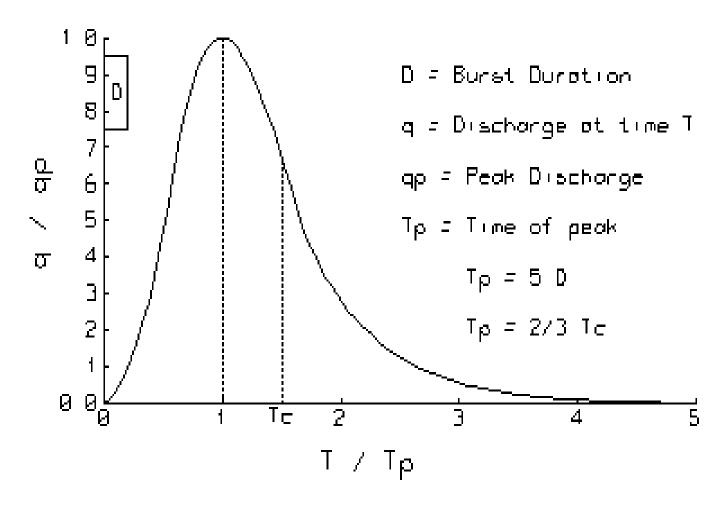


B-SCS method

A method developed by the Soil Conservation Service (SCS) for constructing synthetic unit hydrographs based on a dimensionless hydrograph (Fig. 16). This method is the result of an analysis of a large number of natural unit hydrographs from a wide range in size and geographic locations. It needs only the time peak and the peak discharge.



SCS DIMENSIONLESS UNIT HYDROGRAPH





C- Snyder's Synthetic Unit

- o Snyder's Hydrograph (See Fig. 15)
- 1- The basin lag is (=tp)
- where Ct is a coefficient ranging from 1.8 to 2.2, L is the length of the basin outlet to the basin divide, Lca the length along the main stream to a point nearest the basin centroid.



$$tp = Ct (L.Lca)^{0.3}$$

2. The peak discharge rate is

$$Qp = 640 Cp A/tp$$

- o where 640 will be 2.75 for metric system, Cp is a storage coefficient ranging from 0.4 to 0.8 where
- o larger values of Cp are associated with smaller values of Ct, A is the drainage area.



3. The base time is

 For a small watershed, the base time is determined by multiplying tp by a value ranging from 3 to 5.

$$Tb = 3 + tp/8$$

4. The Snyder' duration is

$$D = tp /5.5$$

• For other rainfall excess duration, the adjusted basin lag is

$$tp = tp + 0.25 (D - D)$$



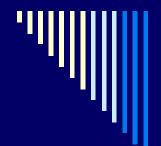
7-WATER BUDGET

• The general equation of groundwater balance is

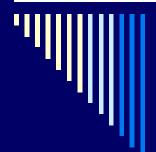
Input – Output =
$$\pm \Delta S$$

By mean:

P - E -T - Int - Ds + Qin + Gin - Qout - Gout
$$\pm \Delta S = 0$$

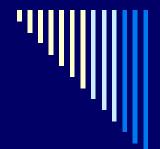


- o where:
- P = Precipitation;
- \circ E = Evaporation;
- T = Transpiration;
- Int = Interception;
- Ds = Detention Storage;
- Qin = Surface Inflow;
- Qout = Surface Outflow;
- Gin = Groundwater Inflow;
- Gout = Groundwater Outflow; and



Basic Hydrology Terms

- Attenuation = The process where the flood crest is reduced as it progresses downstream.
- Automated Local Evaluation in Real Time (ALERT)= A local flood warning system where river and rainfall data are collected via radio signals in real-time at an ALERT base station.
- **O Bankfull Stage/Elevation** = An established river stage/water surface elevation at a given location along a river which is intended to represent the maximum water level that will not overflow the river banks or cause any significant damages from flooding.
- **Dase Station** = A computer, which accepts radio signals from ALERT gaging sites, decodes the data, places the data in a database, and makes the data available to other users.
- **O Base flow** -- Stream flow, which results from precipitation, that infiltrates into the soil and eventually moves through the soil to the stream channel.



- **Basin**= The area, which contributes flow past a specified point.
- Crest= The highest stage or water level of a flood wave as it passes a point.
- Cross-Sectional Area = Area perpendicular to the direction of flow.
- Cubic Feet per Second (CFS) = The flow rate or discharge equal to one cubic foot (of water, usually) per second.
- **o** Current Meter= Device used to measure the water velocity or current in a river.
- O Discharge= The rate at which water passes a given point. Discharge is expressed in a volume per time with units of L3/T.
- Flash Flood= A flood which follows within a few hours (usually 6 hours) of heavy or excessive rainfall, dam or levee failure, or the sudden release of water impounded by an ice jam.
- Flood= Any high flow, overflow, or inundation by water, which causes or threatens damage.



- Flood Stage= An established gage height within a given river reach above which a rise in water surface level is defined as a flood.
- o Gage Datum= The arbitrary datum, which all stage measurements are made from.
- Headwaters= Streams at the source of a river.
- **Headwater Basin** -- A basin at the headwaters of a river. All discharge of the river at this point is developed within the basin.
- Hydrograph= A graph showing the water level (stage), discharge, or other property of a river with respect to time.
- Hydrograph Separation= The process where the storm hydrograph is separated into base flow components and surface runoff components.
- o Inches of Runoff= The volume of water from runoff of a given depth over the entire drainage.
- o Impervious= The ability to repel water or not let water enter.



- o Infiltration= Movement of water through the soil surface into the soil.
- Infiltration Capacity= The maximum rate at which water can enter the soil at a particular point under a given set of conditions.
- o Interception Storage Requirements= Water caught by plants at the onset of a rainstorm. This must be met before rainfall reaches the ground.
- Lag= The time it takes a flood wave to move downstream.
- Parametric Data = Data such as rating curves, unit hydrographs, and rainfall/runoff curves which define hydrologic variables in models.
- Percolation= The movement of water within the soil.
- Porosity= The ratio of pore volume to total volume of the soil. Sandy soils have large pores and a higher porosity than clays and other fine-grained soils.
- Reach= The distance in the direction of flow between two specific points along a river, stream, or channel.



- Staff Gage= A vertical staff graduated in appropriate units, which is placed so that a portion of the gage is in the water at all times. Observers read the river stage off the staff gage.
- Stage= The level of the water surface above a given datum at a given location.
- Stream flow= Water flowing in the stream channel. It is often used interchangeably with discharge.
- Storm Hydrograph= A hydrograph representing the total flow or discharge past a point.
- o Travel Time= The time required for a flood wave to travel from one location to a subsequent location downstream.
- o Unit Hydrograph= The discharge hydrograph from one inch of surface runoff distributed uniformly over the entire basin for a given time period.
- **O Unit Hydrograph Duration**= The time over which one inch of surface runoff is distributed for unit hydrograph theory.
- Flood Hydrology= is related to interflow and surface runoff. These factors are direct response to a rainfall or snowmelt event.
- Gravity= is a force or movement of water in a downward direction.



- Groundwater Flow= moves water through the subsurface to river channels when water cannot percolate downward, collects and forms groundwater.
- o Interflow= is water that enters the soil, percolates a short distance, and then moves horizontally to the stream channel due to a much less pervious soil (*pervious*: capable of transmitting water).

directly contributes to the amount of water found in a river direct response to rainfall and snow melt depends on soil structure of the drainage basin

• Stream flow= consists of three components:

base flow interflow surface runoff



HOME WORK

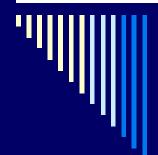
• Problem (2) Station X remained inoperative for a certain period during which a storm occurred. The storm rainfall at the three surrounding stations A, B, and C was recorded as 14.4, 13,8 and 16.8 mm respectively. The normal rainfall at stations X, A, B, and C was observed as 130, 144, 136, and 156 mm respectively. Find the storm rainfall at station X.

- Problem (3) Determine optimum number of raingauges in the basin from the
- o following data so as to limit the percentage error within 10 %;
- (i) Number of existing stations= 5
- \circ (ii) Average rainfall at the stations (mm) = 900, 800, 540, 450 410.



- Problem (4) Compute the mean annual rainfall for wadi basin in the following figure, using the arithmetic mean, the Thiessen polygon and the isohyetal method.
- Problem (5) By using class A Pan the monthly evaporation rate has been determined close to dam lake as shown in the following table. Compute the water volume that loss by the evaporation process and determined the height of the water level after this process.

Month	Evapo. Rate (mm)	Pan Coeff.	Surface Lake Km2
Jan	121	0.65	3.5
Feb	157	0.65	3.7
Mar.	179	0.72	3.1
April	165	0.72	3.4



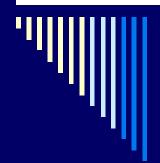
Problem (6) Using the Thornthwaite method to calculate the potential evapotranspiration form the following data

MONTH	Mean Temp.	I	PE
JAN	18.2		
FEB	18.9		
MAR	20.4		
APRIL	21.3		
MAY	22.5		
JUN	23.6		
JULY	23.9		
AUG	24.1		
SEPT	23.6		
OCT.	22.7		
NOV	21.8		
DEC	21.1		



 Problem (7) Using the Turc method to calculate the actual evaporation form the following data

Mean Temperature (C)	Mean Annual Rainfall (mm)
22	121
34	117
27	123
29	103



• Problem (8) Using the slope – area method calculate the flood discharge, where the cross-section area is 46 m² the hydraulic wet 18 m, the basin slope 0.02 and the Manning coefficient is 0.004.



<u>Problem</u> (9) Use the Phi-Index for determined the infiltration rate from flood water in a drainage basin has an area of 150 km2 area , where the direct unoff was 1.79 cm from rain storm illustrated in the following

table.

Time (hour)	Rainfall amount (cm)
13-14	13-14
14-15	14-15
15-16	15-16
16-17	16-17
17-18	17-18
18-19	18-19



Problem (10) Measurements from an infiltrometer with 35 cm diameter are given in the following table. Hence,

a- plot infiltration rate with time

b- find the Horton equation constants, fo and fc c- Calculate the infiltration

capacities at time 10 and 30 min. where K=2.

TIME (min)	0	2	5	10	20	30	60	90	150
Add Water (Cm3)	0	278	658	1173	1924	2500	3345	3875	4595



Problem (11) Using the velocity –area method, find the discharge of the river at the cross section X according to the following data

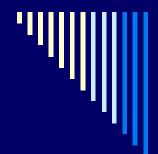
Station Name	Distance from the left Bank (m)	Depth (m)	Area (m2)	Average Velocity (m/s)	Discharge Q m3/s
A	0	0	0	0	0
	10	4			
	20	5			
	30	5.2			
	40	6.4			
	50	4.7			
	60	2.5			



Problem (12) Use the rational method to find the 10-year design runoff for the area 18 km2. The intensity duration frequency rainfall curve (4.2mm) and the runoff coefficient = 0.53.



- Problem (13) From following data and a dimensionless method, construct a 3 hours synthetic hydrograph from Snyder's method:
- Area of drainage basin (A)= 450 km2
- \circ Length (L)= 32 km
- \circ (Lca)= 25 km
- \circ (Ct) = 0.9
- \circ (Cp) = 5.0



- Problem (14) A lake has 15 km2 of surface area. The average inflow and outflow during April were 0.50 m3/sec and 0.44 m3/sec respectively. The monthly rainfall and evaporation amounts are 45 mm and 105 mm, respectively. It is estimated that the infiltration height during the same month from the lakes bottom is 25 mm
- Find the following;
- -the change in the volume of water during this month using the water balance equation;
- -interpret your results.