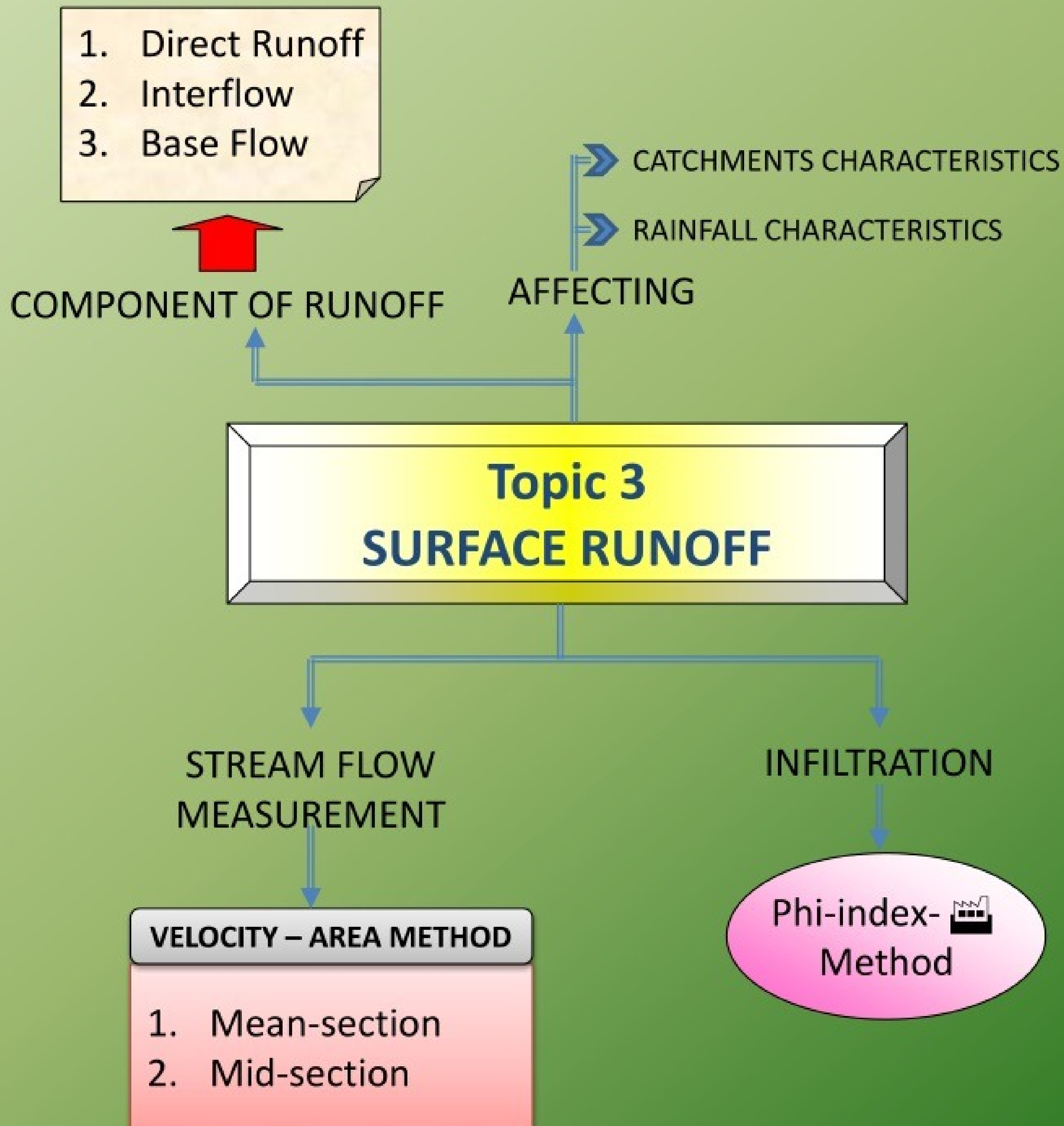
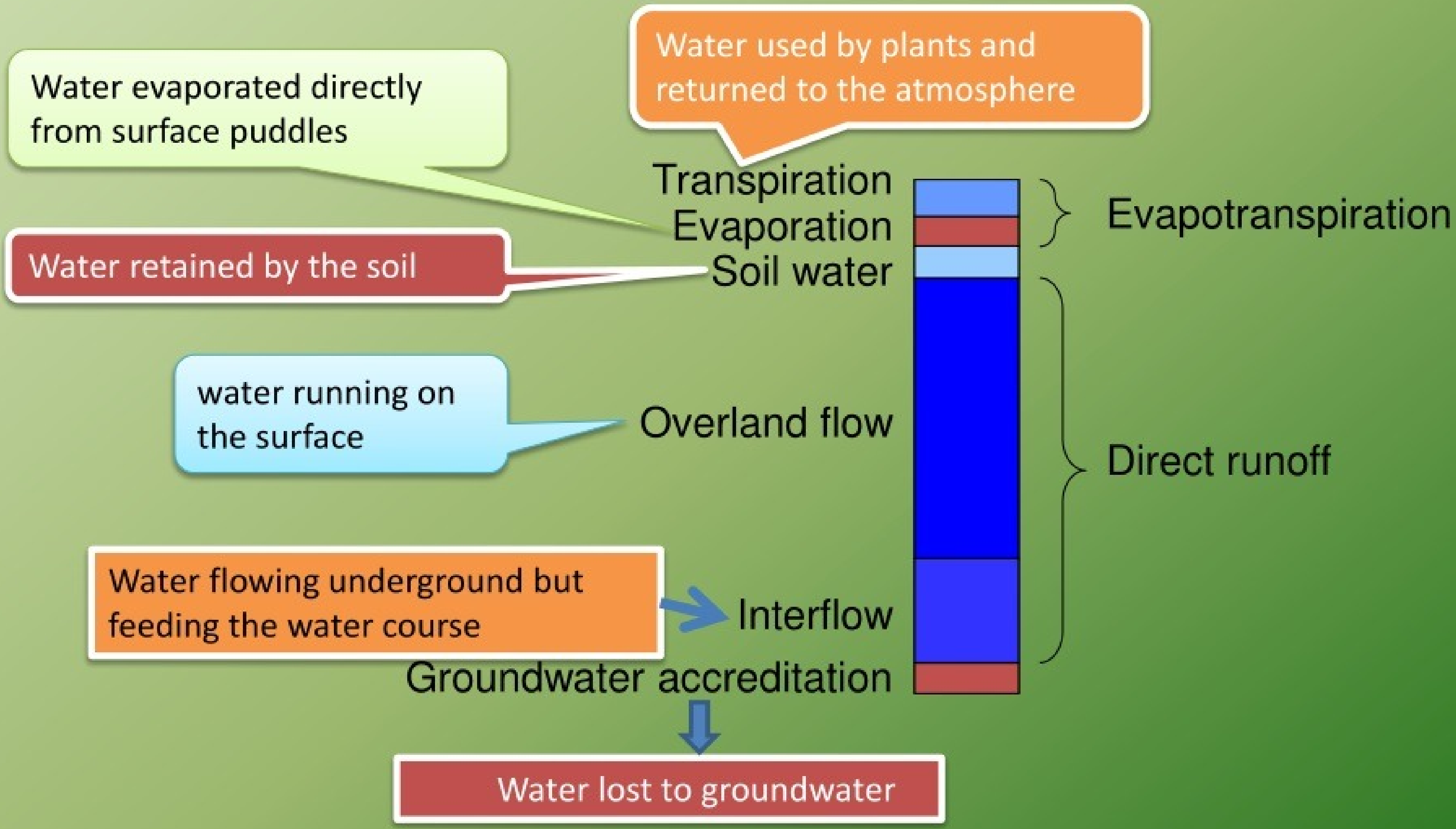

Topic 3
SURFACE RUNOFF
COMPONENT OF RUNOFF
1. Direct Runoff
2. Interflow
3. Base Flow
AFFECTING
CATCHMENTS CHARACTERISTICS
RAINFALL CHARACTERISTICS
STREAM FLOW MEASUREMENT
VELOCITY – AREA METHOD
1. Mean-section
2. Mid-section
INFILTRATION
Phi-index-
Method

INTRODUCTION

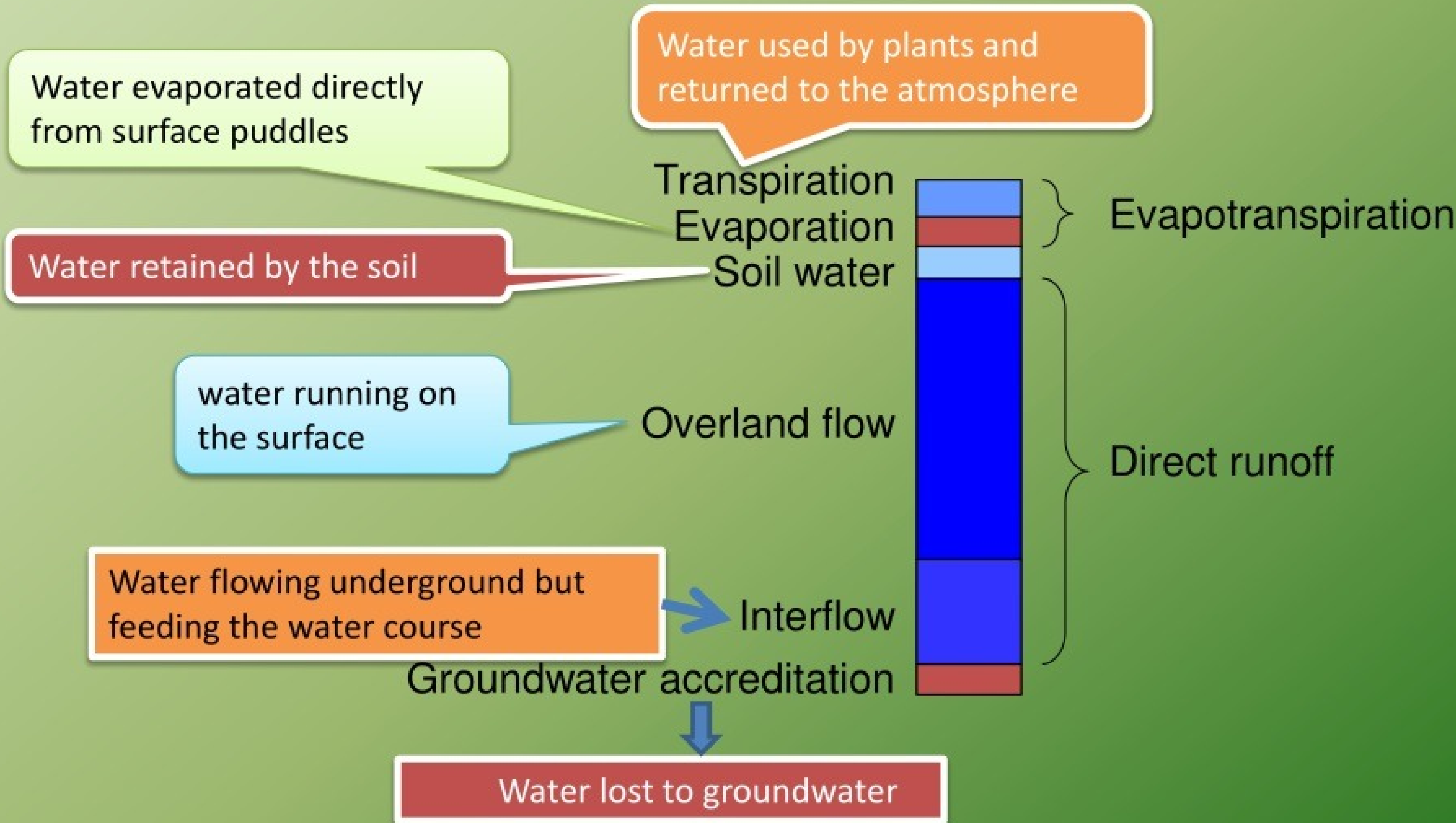
- If the amount of water falling on the ground is greater than the infiltration rate of the surface, runoff or **overland flow** will occur. **Runoff** specifically refers to the water leaving an area of drainage and flowing across the land surface to points of lower elevation.

Runoff flowing into a stormwater drain

COMPONENT OF RUNOFF



COMPONENT OF RUNOFF



Direct Runoff/ Overland Flow

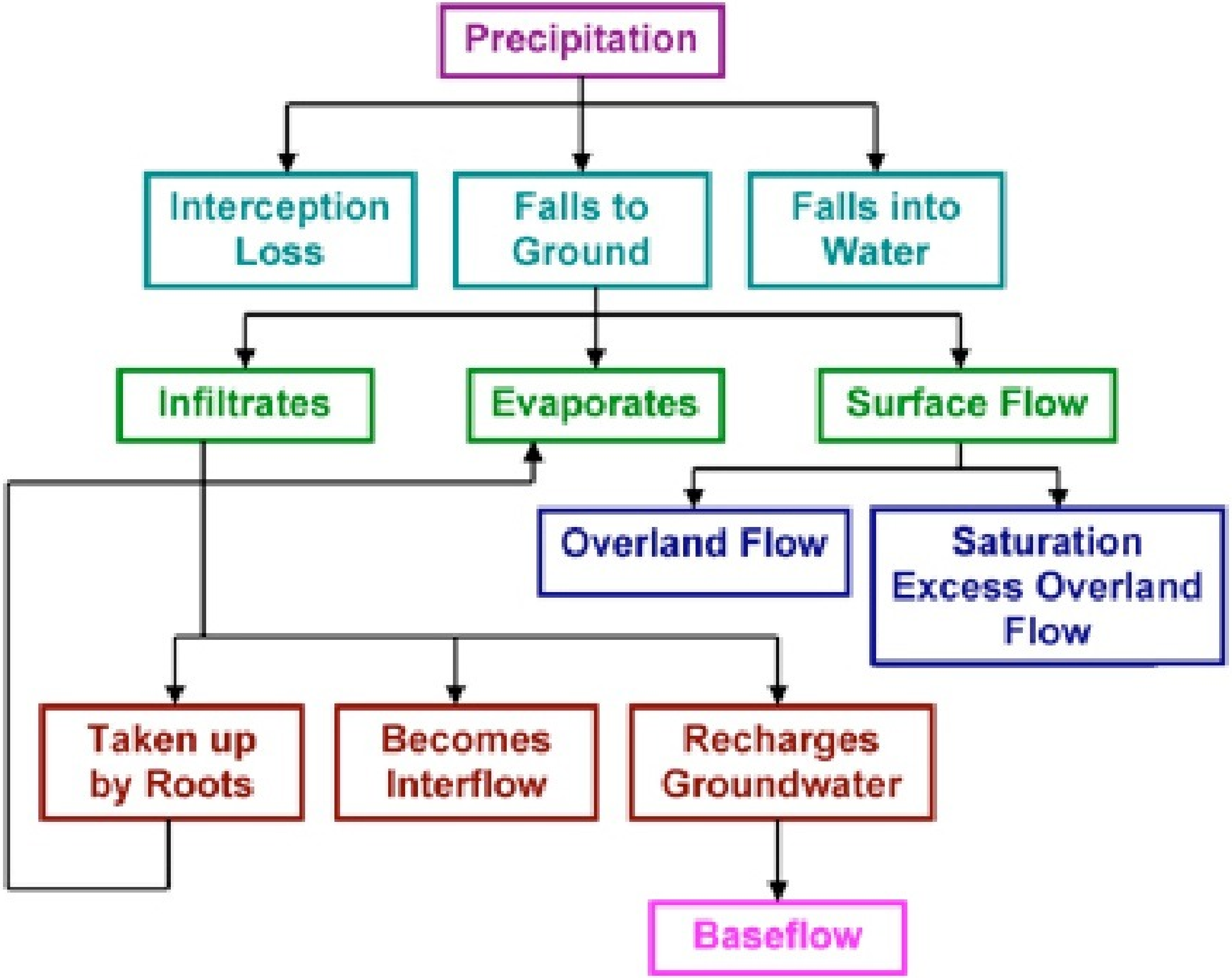
- Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.
- Direct runoff originally from excess rain. Direct runoff magnitude and excess rain is the same

Interflow

- **interflow** is the lateral movement of water that occurs in the upper part of the unsaturated zone, or vadose zone, that directly enters a stream channel or other body of water without having occurred first as surface runoff (as with throughflow).

Base flow

- Base flow (also called drought flow, groundwater recession flow, low flow, and sustained or fair-weather runoff) is the portion of stream flow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow". It should not be confused with groundwater flow.
- is the sustained flow (amount of water) in a stream that comes from groundwater discharge or seepage.
- Stream discharge derived from groundwater sources as differentiated from surface runoff.

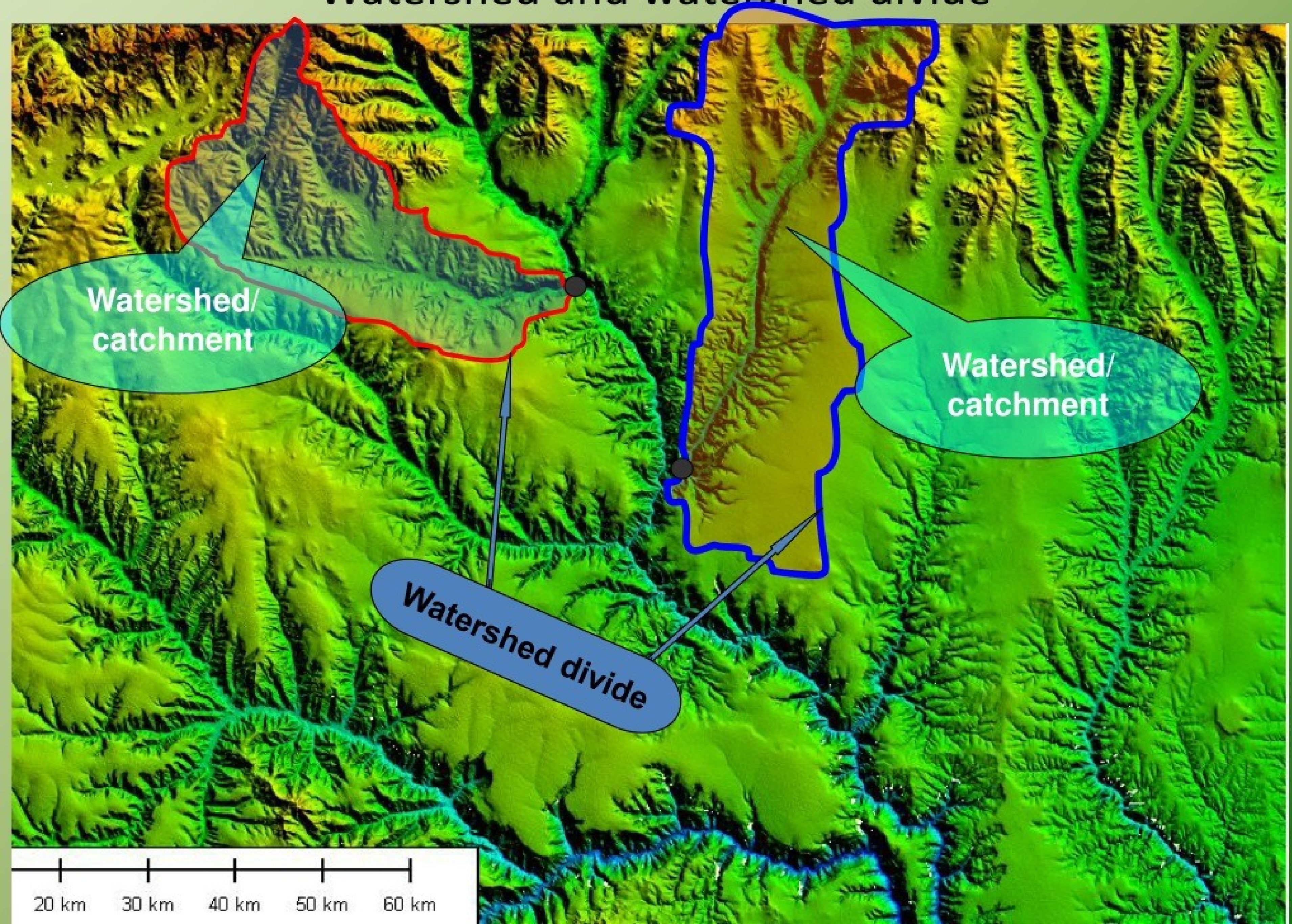


Precipitation
Interception Loss
Falls to Ground
Falls into Water
Infiltrates
Evaporates
Surface Flow
Overland Flow
Saturation Excess Overland Flow
Taken up by Roots
Becomes Interflow
Recharges Groundwater
Baseflow

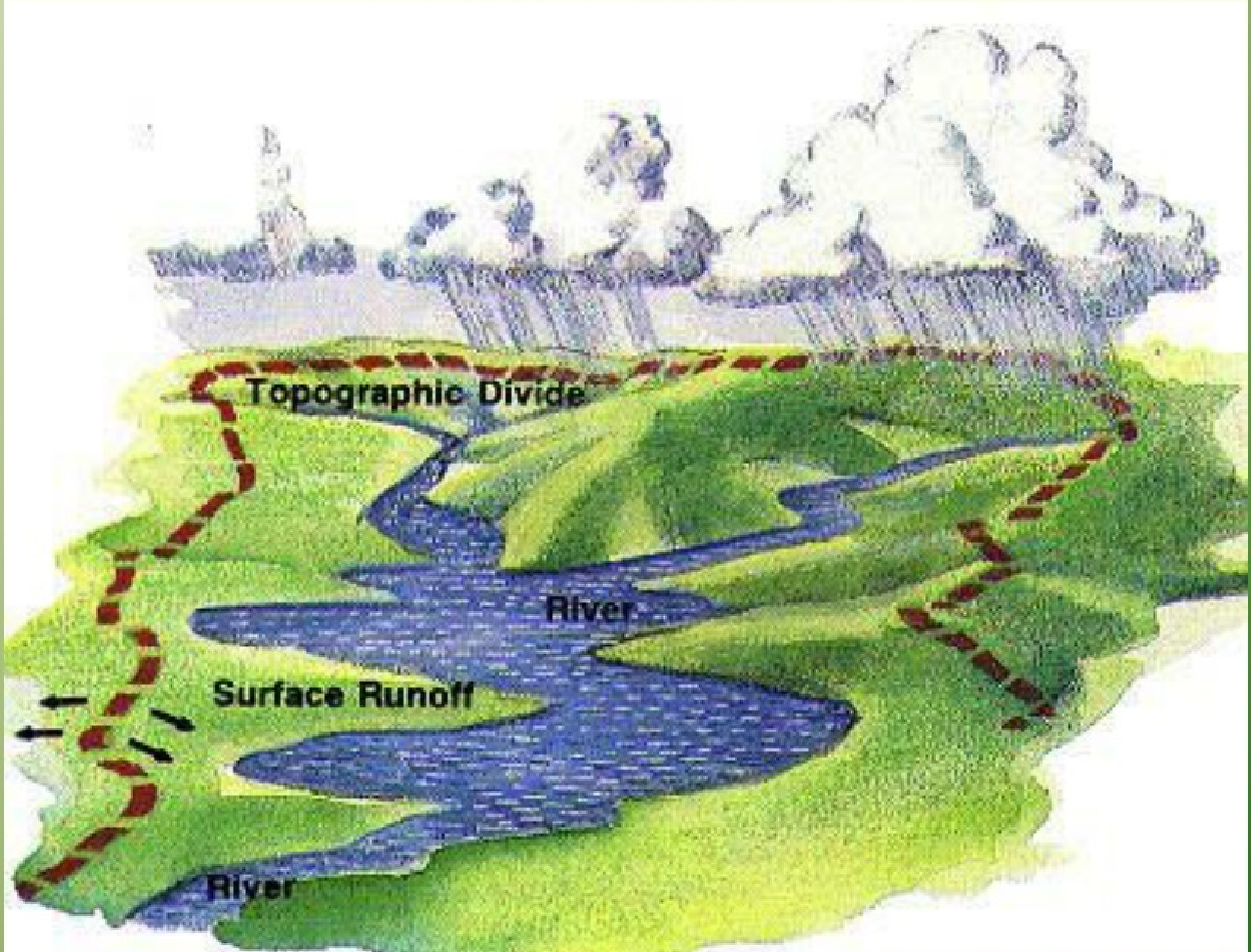
Catchments Area

- The area of land draining in to a stream or a water course at a given location is called catchment area / drainage area / drainage basin / watershed.
- A catchment area is separated from its neighboring areas by a ridge called divide / watershed.
- A watershed is a geographical unit in which the hydrological cycle and its components can be analyses. The equation is applied in the form of water-balance equation to a geographical region, in order to establish the basic hydrologic characteristics of the region. Usually a watershed is defined as the area that appears, on the basis of topography, to contribute all the water that passes through a given cross section of a stream.

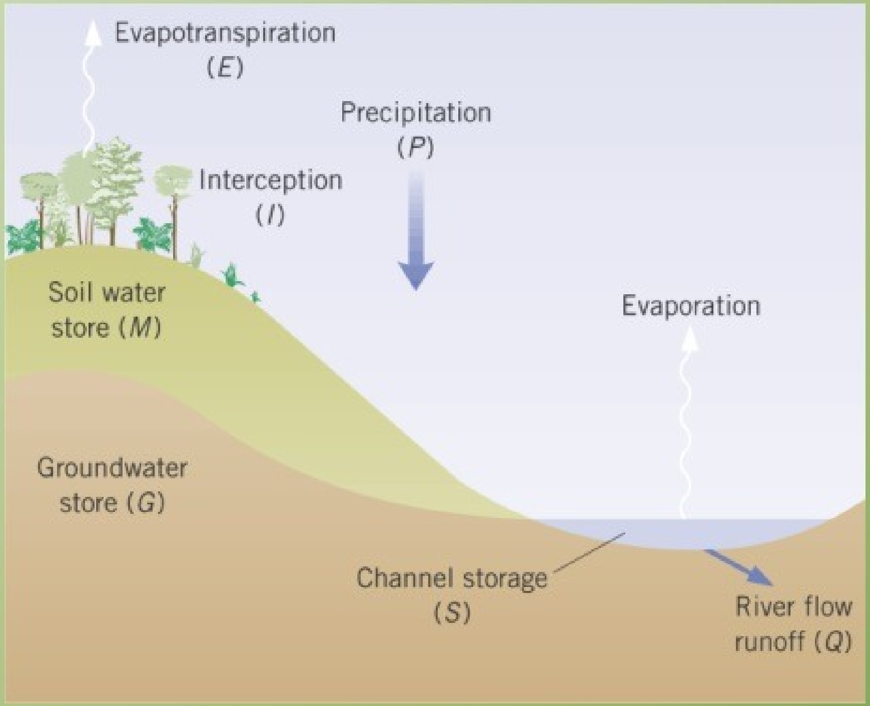
Watershed and watershed divide



Catchment Area



Measuring the components of catchment hydrology



- Historically, catchment studies adopted a **water balance approach**
  - *P = Q + E + I + Δ (M, G, S)*

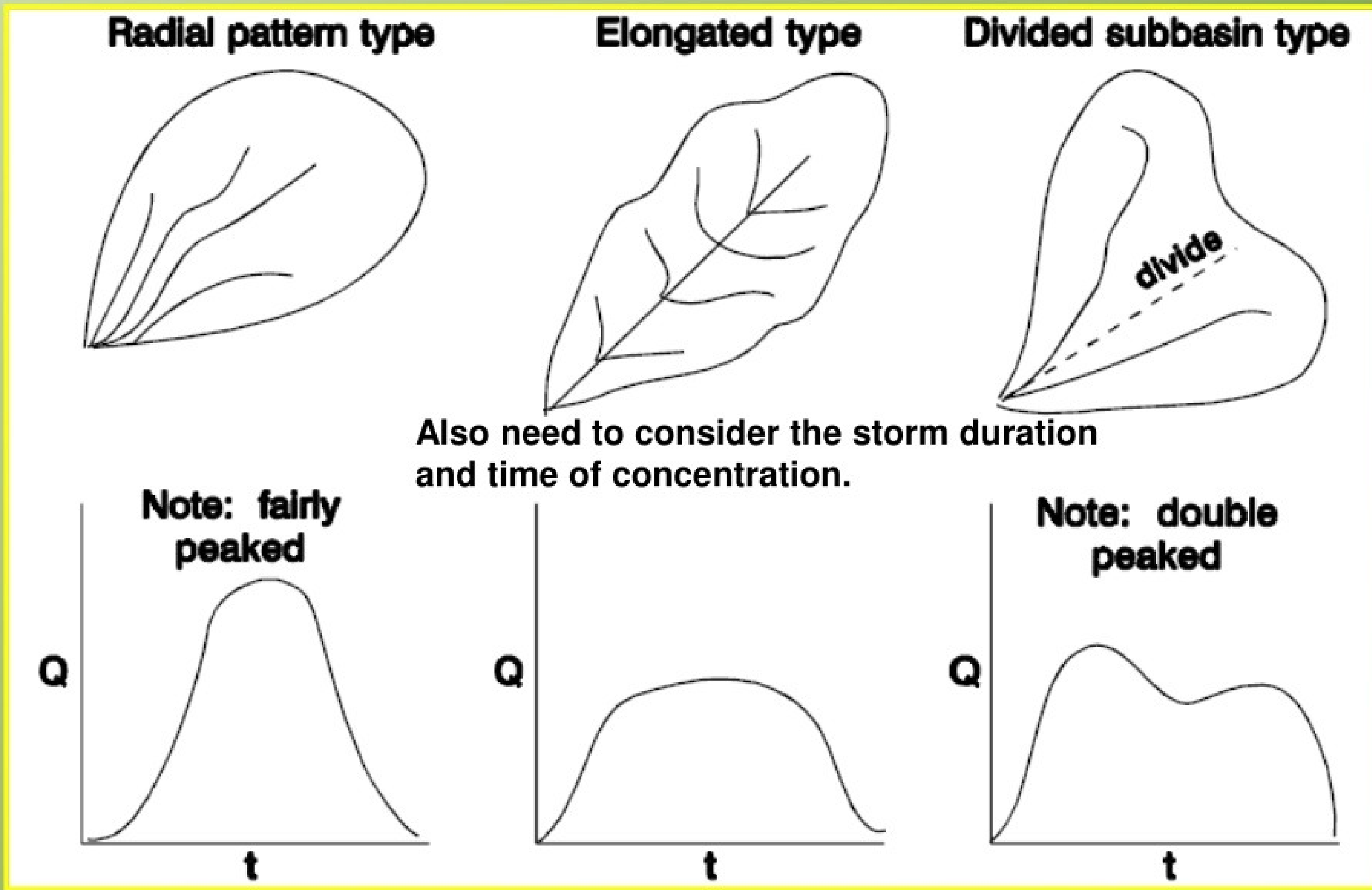
    P is precipitation, *Q* river discharge, *E* evapotranspiration, *I* interception, *M* soil water storage, *G* groundwater storage and *S* is channel and surface water storage
  - Seasonal variations in the balance control seasonal patterns in river flow
- However - simple input/output ratio does not explain processes
  - Need to evaluate the role of *runoff production processes* in generating river flow

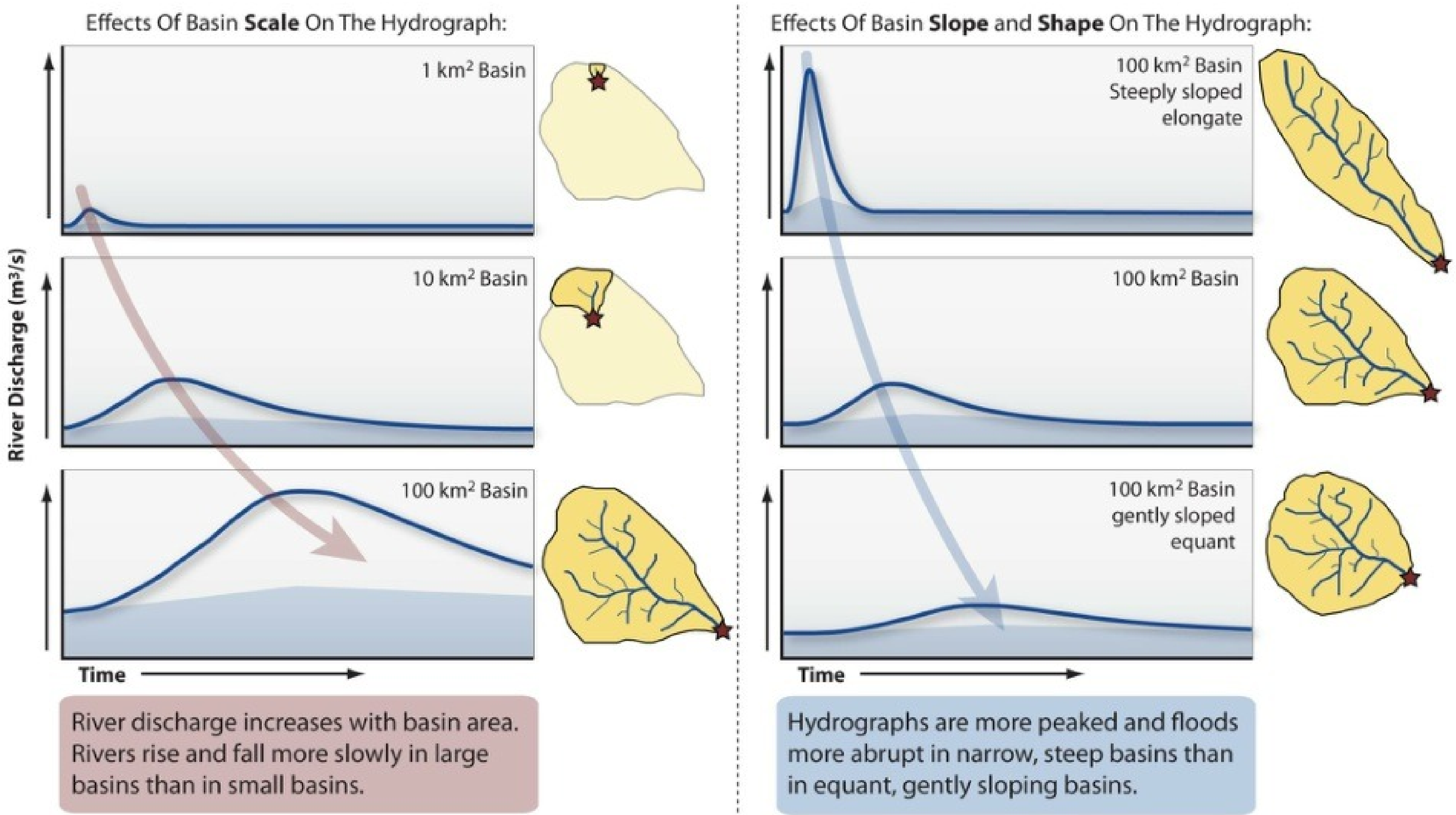
CATCHMENT CHARACTERISTICS AFFECTING DIRECT RUNOFF

- Catchment's Area (size)
- Shape
- Altitude
- Topography
- Geology (soil type)
- Catchment Area Gradient
- Catchment Orientation
- Average Annual Excess Rainfall

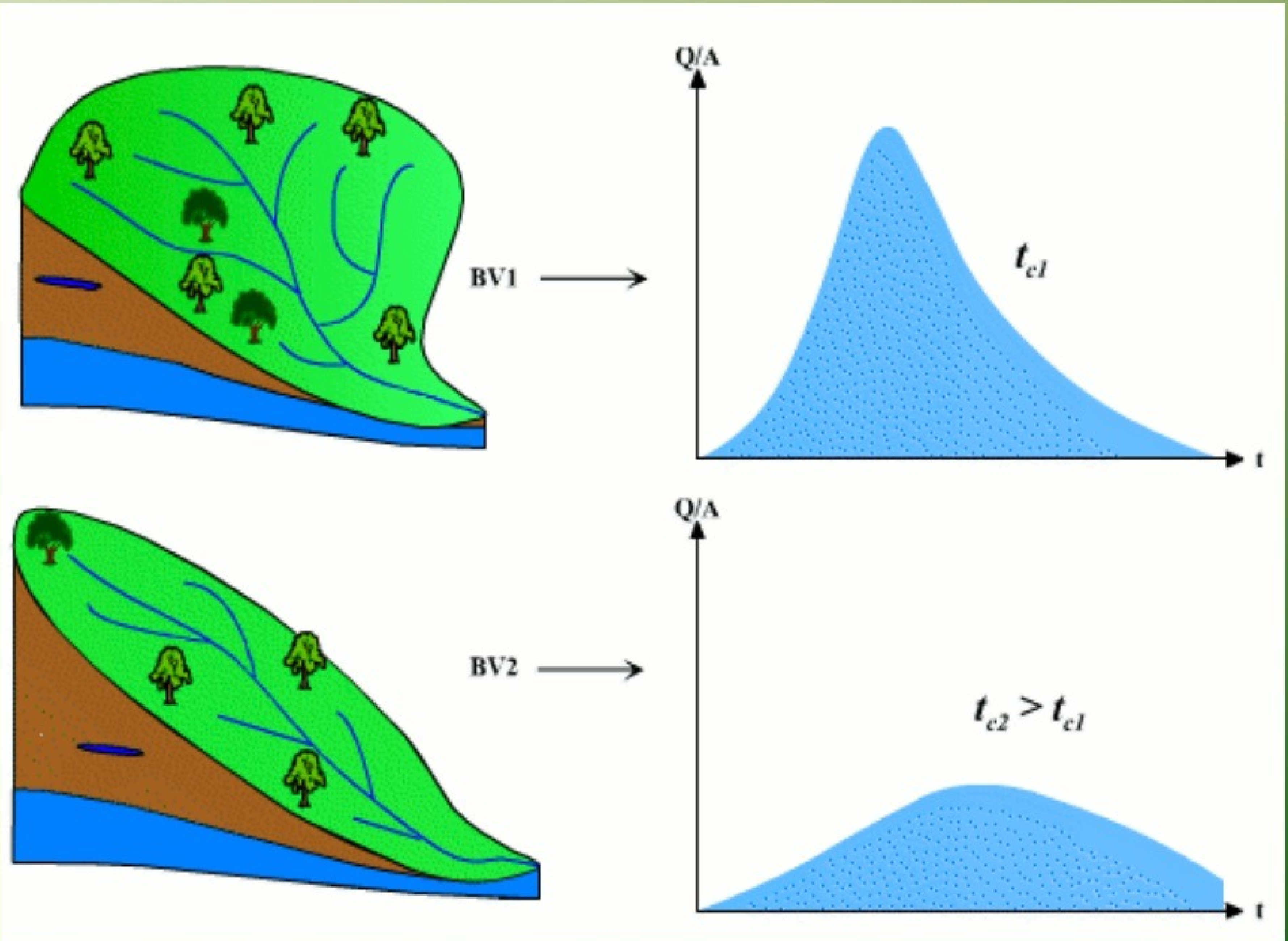
- Stream Frequency
- Base Flow Index
- Lake Area And Reservoir
- Soil Humidity Rate
- Land used (vegetation)
- Type of drainage network
- Proximate to ocean and mountain range

Catchment Area Physical Factor

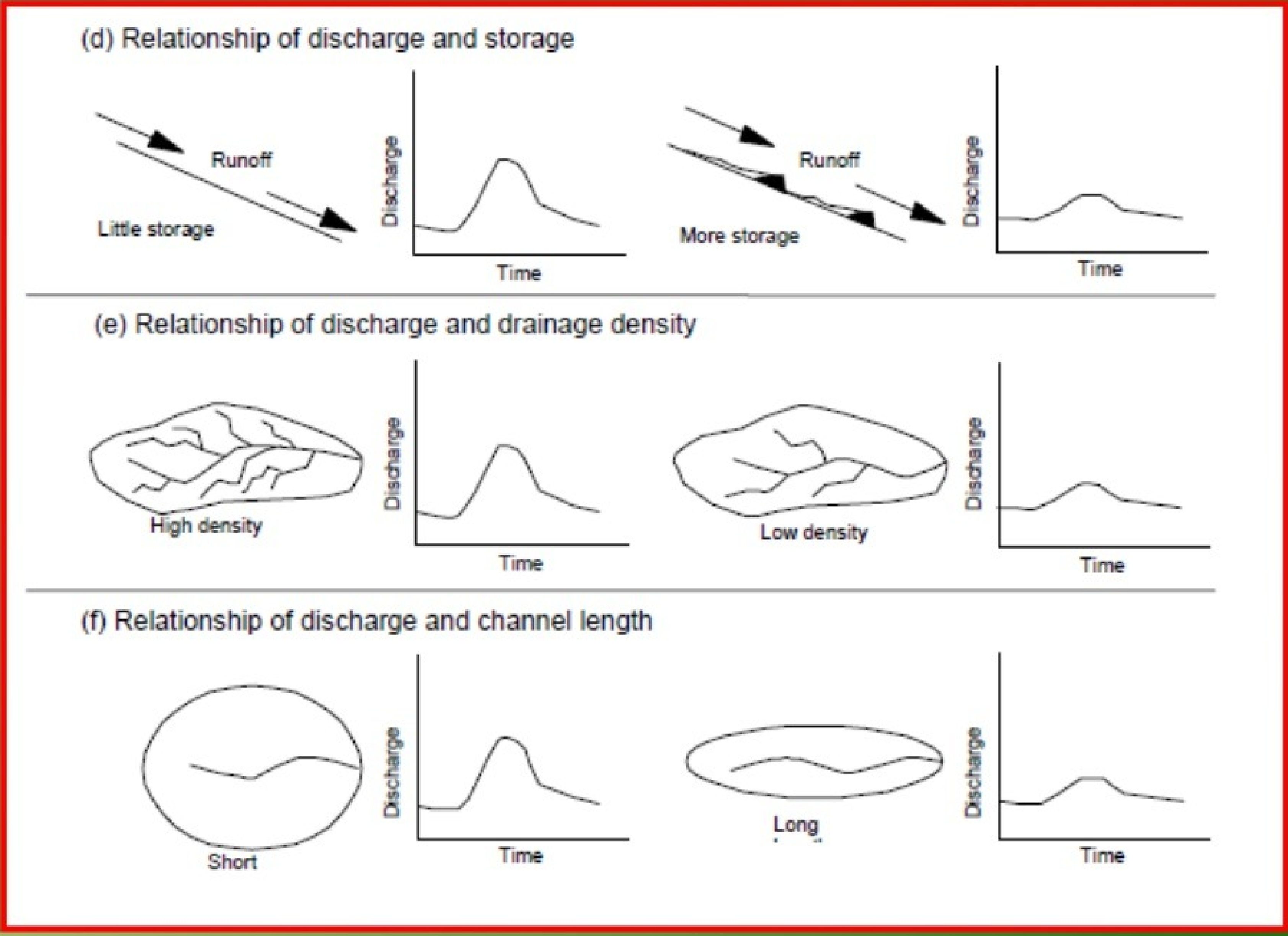



Effects Of Basin Scale On The Hydrograph:
1 km² Basin
10 km² Basin
100 km² Basin
River Discharge (m³/s)
Time
River discharge increases with basin area. Rivers rise and fall more slowly in large basins than in small basins.
Effects Of Basin Slope and Shape On The Hydrograph:
100 km² Basin Steeply sloped elongate
100 km² Basin
100 km² Basin gently sloped equant
Time
Hydrographs are more peaked and floods more abrupt in narrow, steep basins than in equant, gently sloping basins.

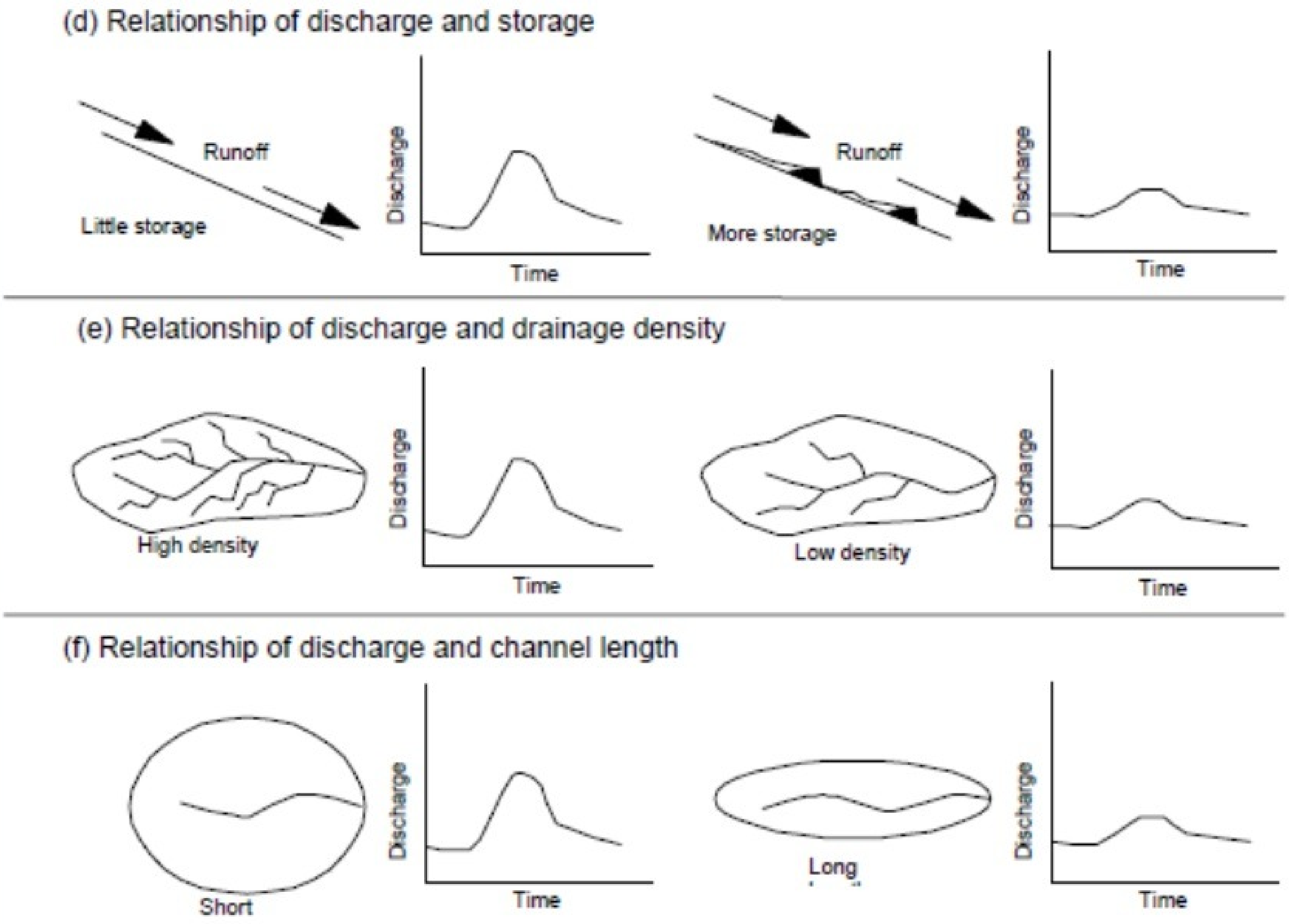
Watershed characteristics



Effects Of Basin Characteristics On The Flood Hydrograph



Effects Of Basin Characteristics On The Flood Hydrograph



RAINFALL CHARACTERISTICS AFFECTING DIRECT RUNOFF

4. **Rainfall Distribution:**

Runoff from a watershed depends very much on the distribution of rainfall. It is also expressed as "distribution coefficient" mean ratio of maximum rainfall at a point to the mean rainfall of watershed. There fore, near outlet of watershed runoff will be more.

5. **Direction of Prevailing Wind:**

If the direction of prevailing wind is same as drainage system, it results in peak low. A storm moving in the direction of stream slope produce a higher peak in shorter period of time than a storm moving in opposite direction

6. **Other Climate Factor:**

Other factors such as temperature wind velocity, relative humidity, annual rainfall etc. affect the water losses from watershed area.

RAINFALL CHARACTERISTICS AFFECTING DIRECT RUNOFF

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STREAM FLOW MEASUREMENT

Stream discharge can be measured using;

(1) Volumetric Gauging (buckets)

(2) Float Gauging,

(3) Current Metering,

(4) Dilution Gauging (Constant Injection Or Salt Gulp Methods),

(5) Structural Methods (weirs, notches, orifices & flumes)

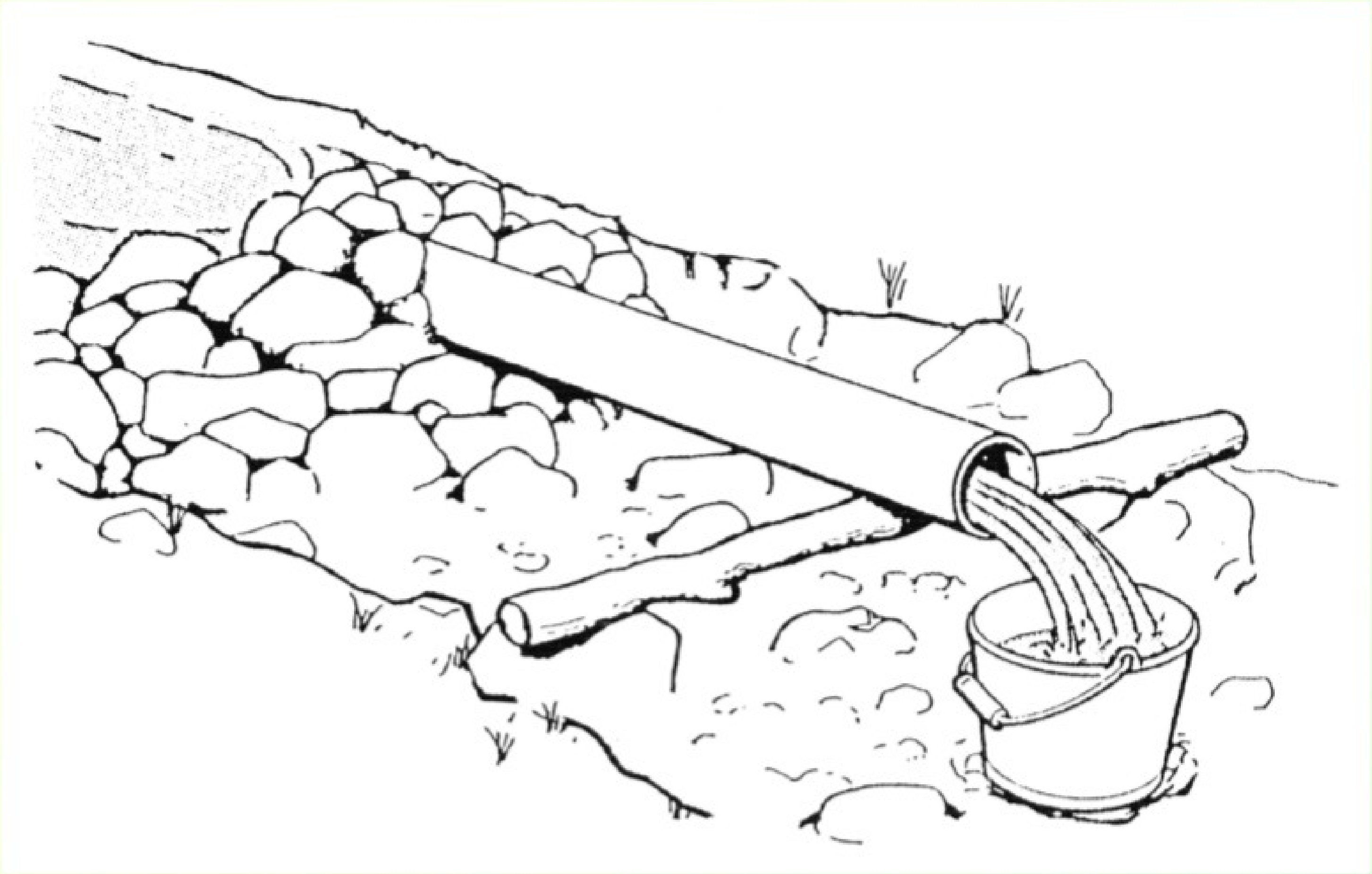
(6) Slope-area Methods.

(7) Rating Curve

} Indirect method

The choice of method depends on the characteristics of the stream and on the application.

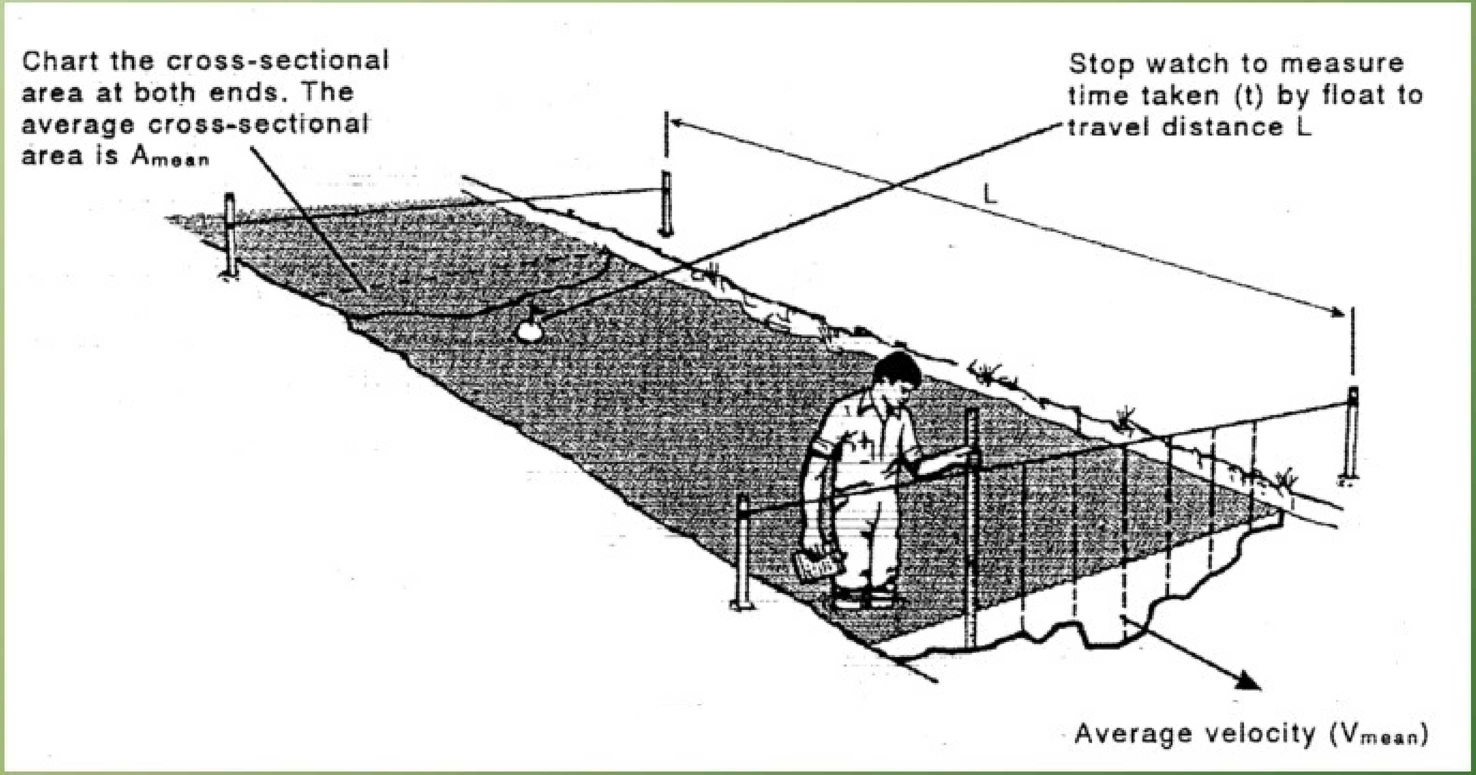
Flow estimation: Buckets



Flow estimation: Buckets: Limitations

- Only useful for flows <20l/s
- Whole flow must be channelled to the bucket

Flow estimation: Float



Suitable for straight channel, $V = L/T$

Flow estimation: Float: Limitations

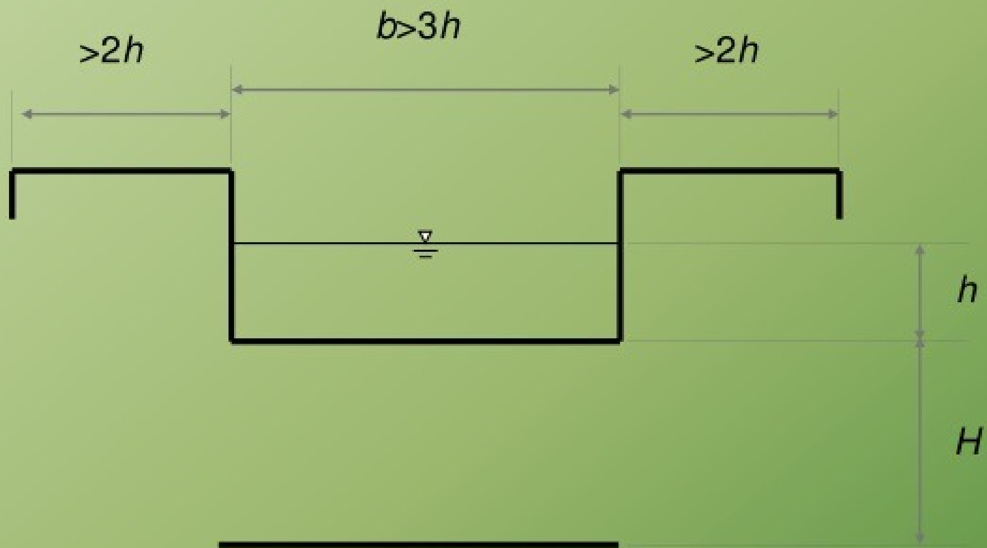
- Average flow can only be inferred from flow at surface
- The stream bed should not have any significant changes over the test length
- Needs a good approximation of the stream bed shape – which can be tedious

Flow estimation: Float: Correction factors

Type	Correction
Concrete channel, rectangular section, smooth	0.85
Large, slow clear stream (>$10m^2$)	0.75
Small regular stream (<$10m^2$), smooth bed	0.65
Shallow (<0.5m) turbulent stream	0.45
Very shallow (<0.2m) or rocky stream	0.25

Flow estimation: Weirs

Flow estimation: Weirs: Calculation for rectangular weirs



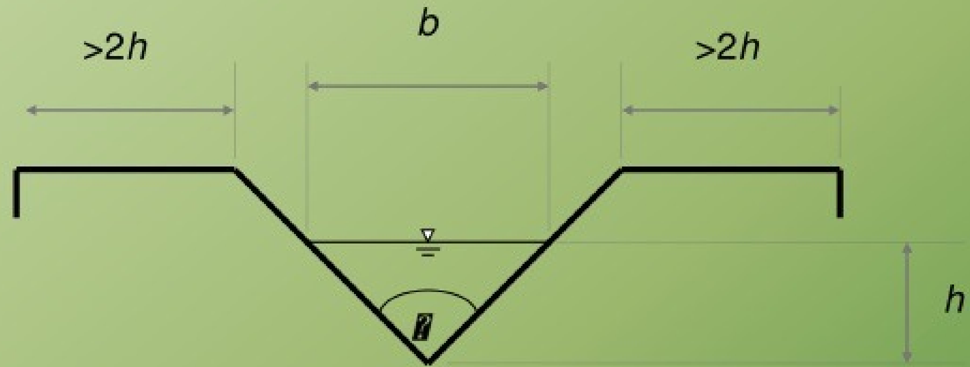
$$Q = C_w \frac{2}{3} b \sqrt{2g} \left[\left(h + \frac{v_0^2}{2g} \right)^{3/2} - \left(\frac{v_0^2}{2g} \right)^{3/2} \right]$$

$$= C_w b h^{3/2}$$

Flow estimation: Weirs: Calculation: Weir coefficients for rectangular weirs

	Head on weir						
h/H	**0.2**	**0.4**	**0.6**	**0.8**	**1**	**2**	**5**
0.5	2.31	2.28	2.27	2.27	2.27	2.26	2.26
1	2.07	2.05	2.04	2.03	2.03	2.03	2.03
2	1.95	1.93	1.92	1.92	1.91	1.91	1.90
10	1.85	1.83	1.82	1.82	1.82	1.82	1.81
¥	1.83	1.81	1.80	1.80	1.79	1.79	1.79

Flow estimation: Weirs: Calculation for triangular weirs



$$Q = \frac{8}{15} C'_w \tan\left(\frac{\theta}{2}\right) \sqrt{2g}\, h^{5/2}$$

$$= C'_w \tan\left(\frac{\theta}{2}\right) h^{5/2}$$

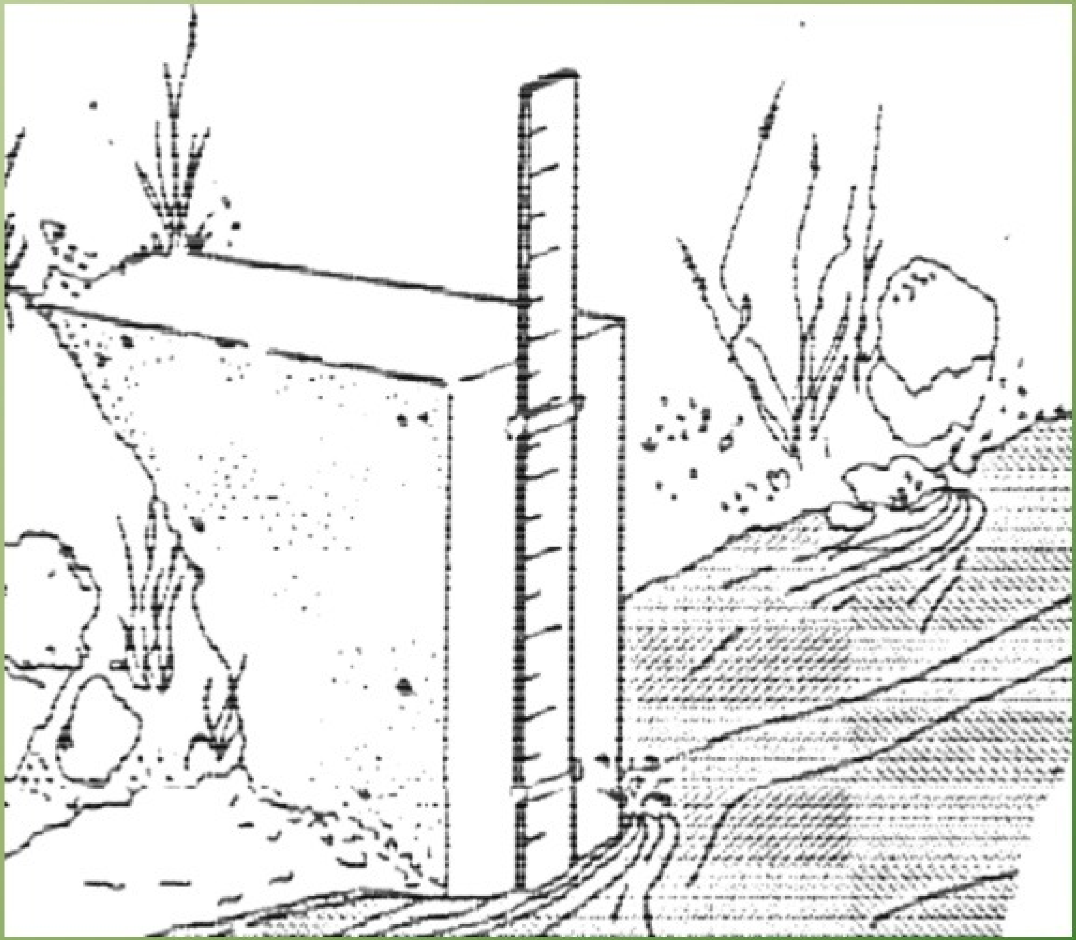
Flow estimation: Weirs: Calculation: Weir coefficients for triangular weirs

1.39

Flow estimation: Weirs: Limitations

- An initial flow estimate is required to ensure the notch is an appropriate size
- The weir must be perfectly sealed
- Permanent weirs are costly
- Even a temporary weir can be problematic and time consuming to construct

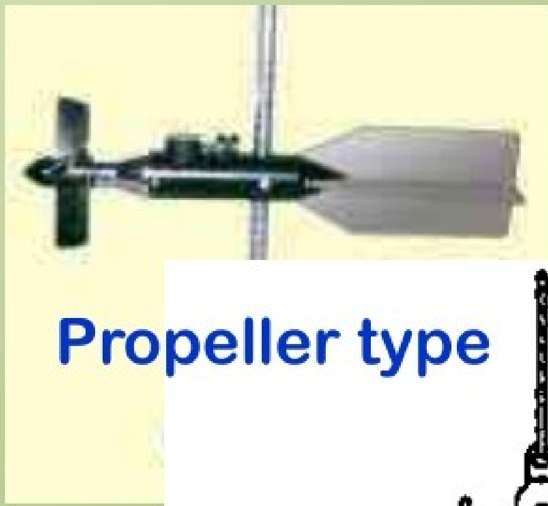
Flow estimation: Staff gauge



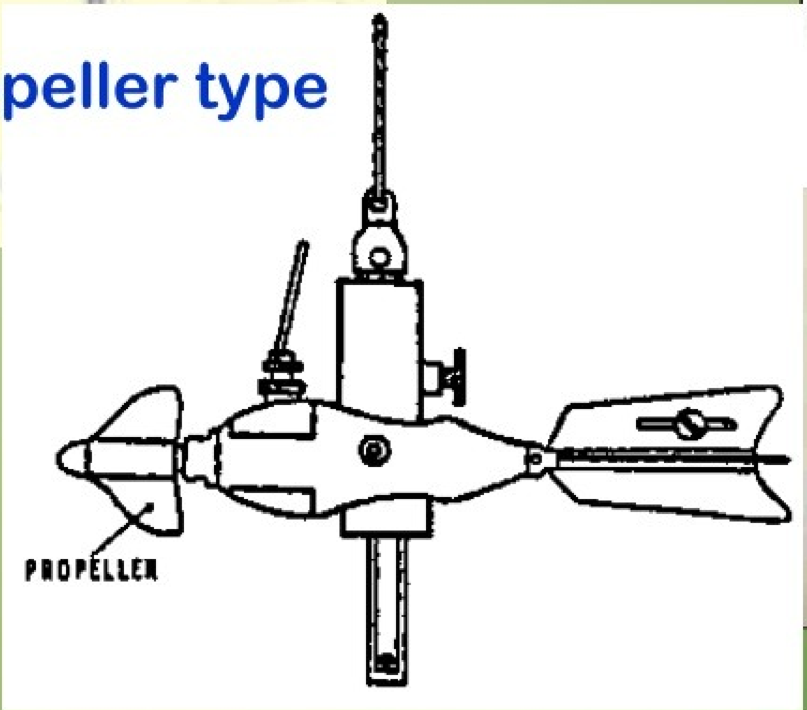
Flow estimation: Staff gauge: Limitations

- Needs a good approximation of the stream bed shape which must remain valid – erosion/siltation will effect the validity of measurements
- Only valid for comparing flows over time – an initial flow reading must be taken by another method
- "weir coefficients" will change with water height

Flow estimation: Current meters

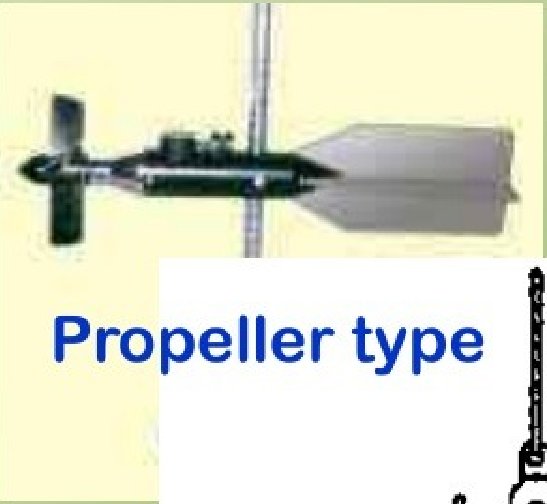


Propeller type

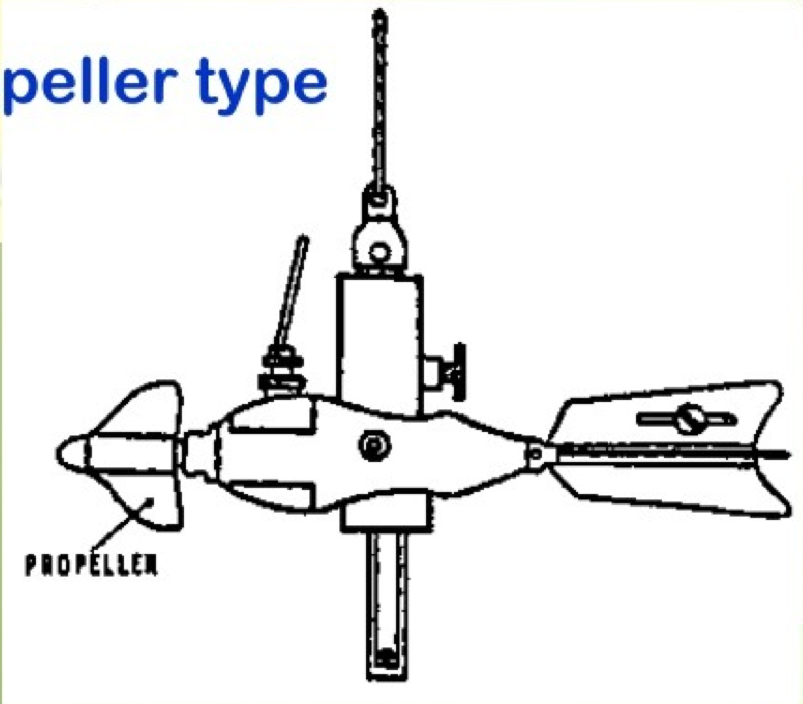


Inductance

Flow estimation: Current meters



Propeller type



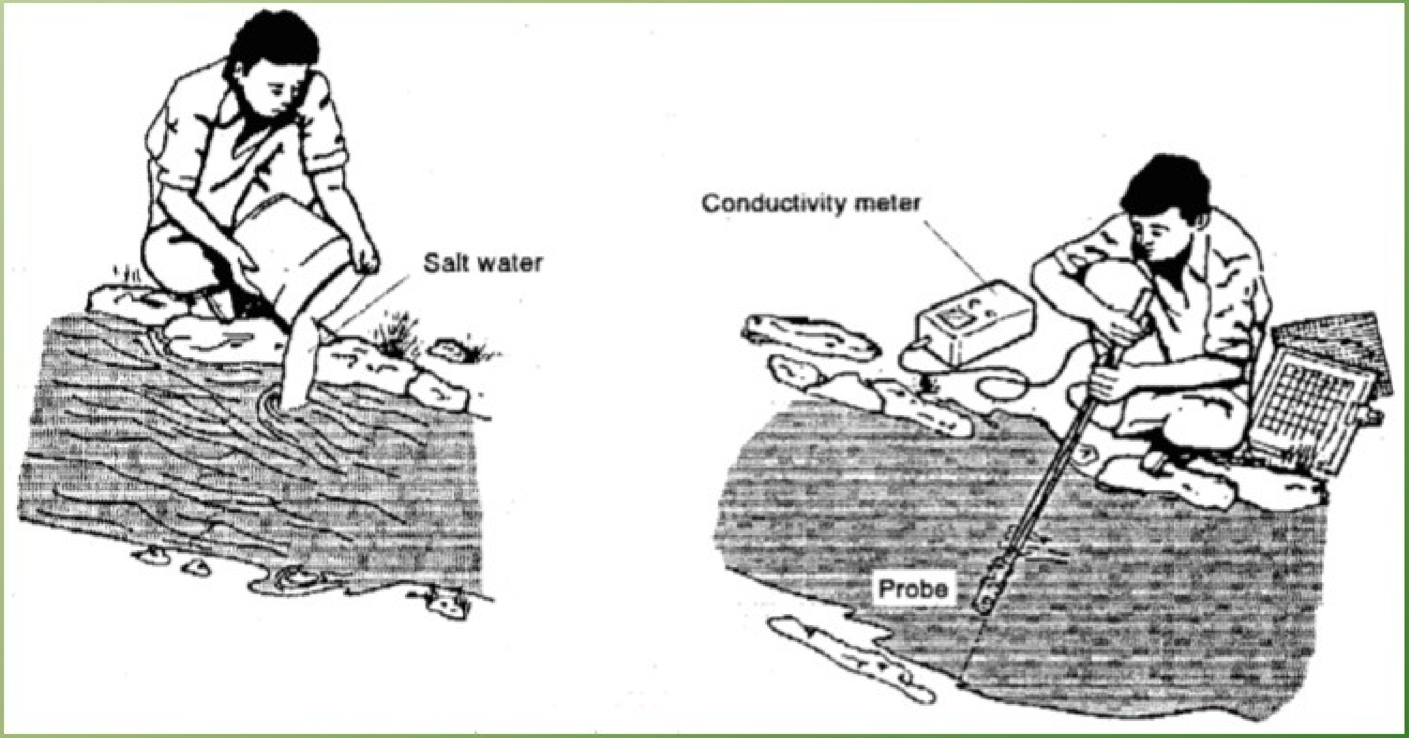
Cup-type

Inductance

Flow estimation: Current meters: Limitations

- Needs a good approximation of the stream bed shape
- Cost?
- Fragility?

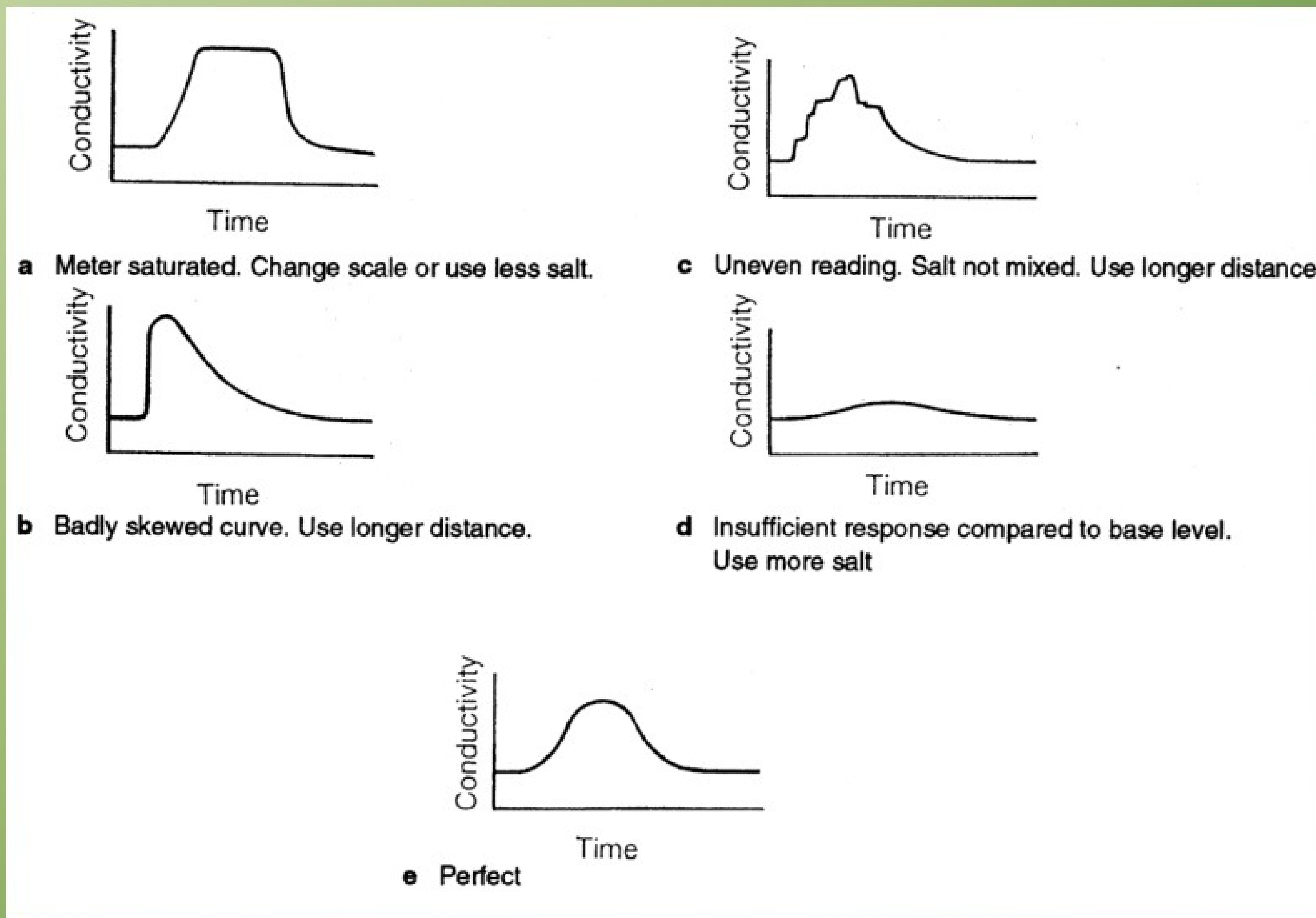
Flow estimation(Dilution Gauging): Salt gulp



Flow estimation: Salt gulp

Flow estimation: Salt gulp

Flow estimation: Salt gulp: Problems



a Meter saturated. Change scale or use less salt.

b Badly skewed curve. Use longer distance.

c Uneven reading. Salt not mixed. Use longer distance.

d Insufficient response compared to base level. Use more salt

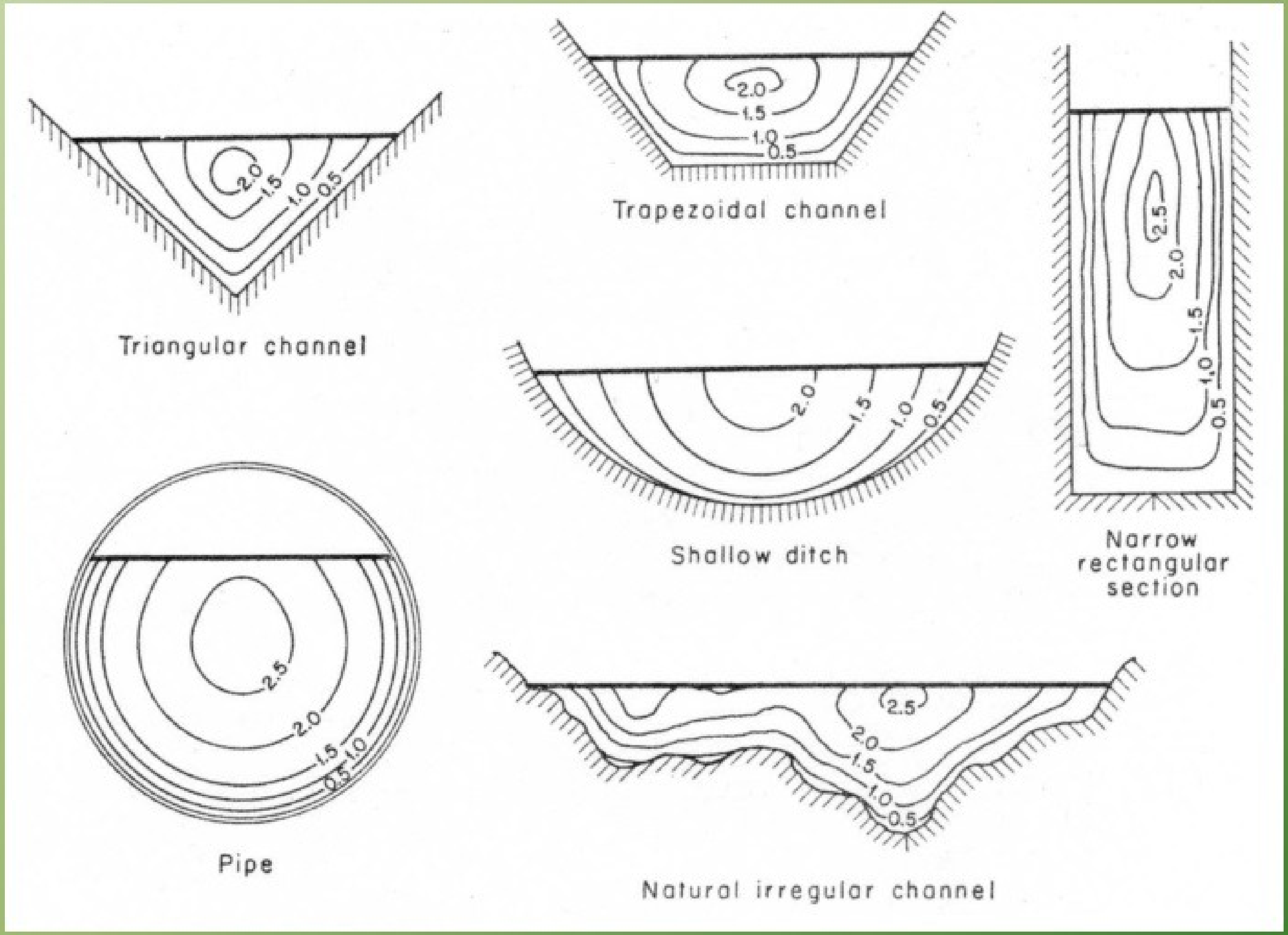
e Perfect

Flow estimation: Salt gulp: Limitations

- Automated equipment can be expensive – non automated procedure is complex
- Needs skill to take readings and interpret duff ones
- Errors may not be apparent unless maths is done on-site

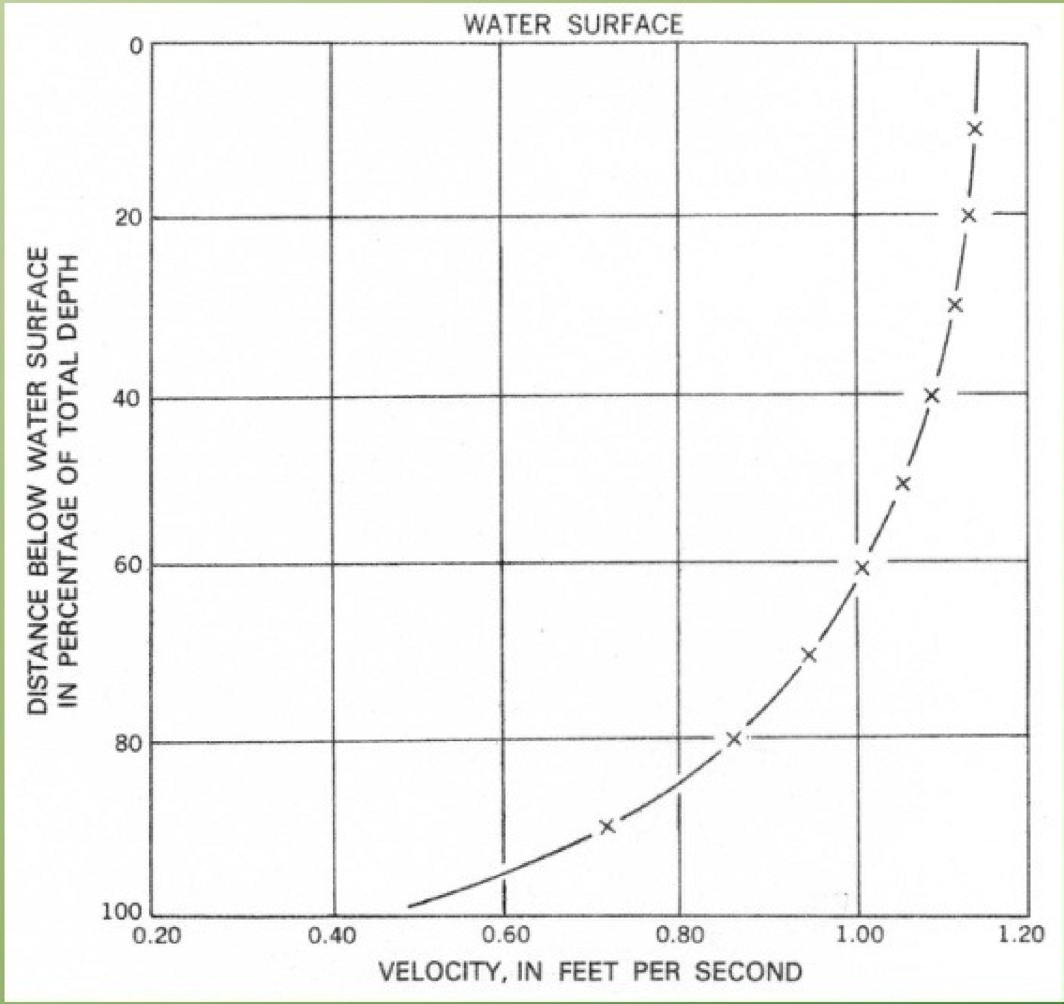
Velocity – Area method

- Determination of cross-sectional area of stream
- Estimation of water velocity (using an impeller meter) multiplied by area of water in a cross section



Velocity Distributions

Vertical Velocity Distribution



Mean Flow Velocity Estimation

- **Mean Velocity**

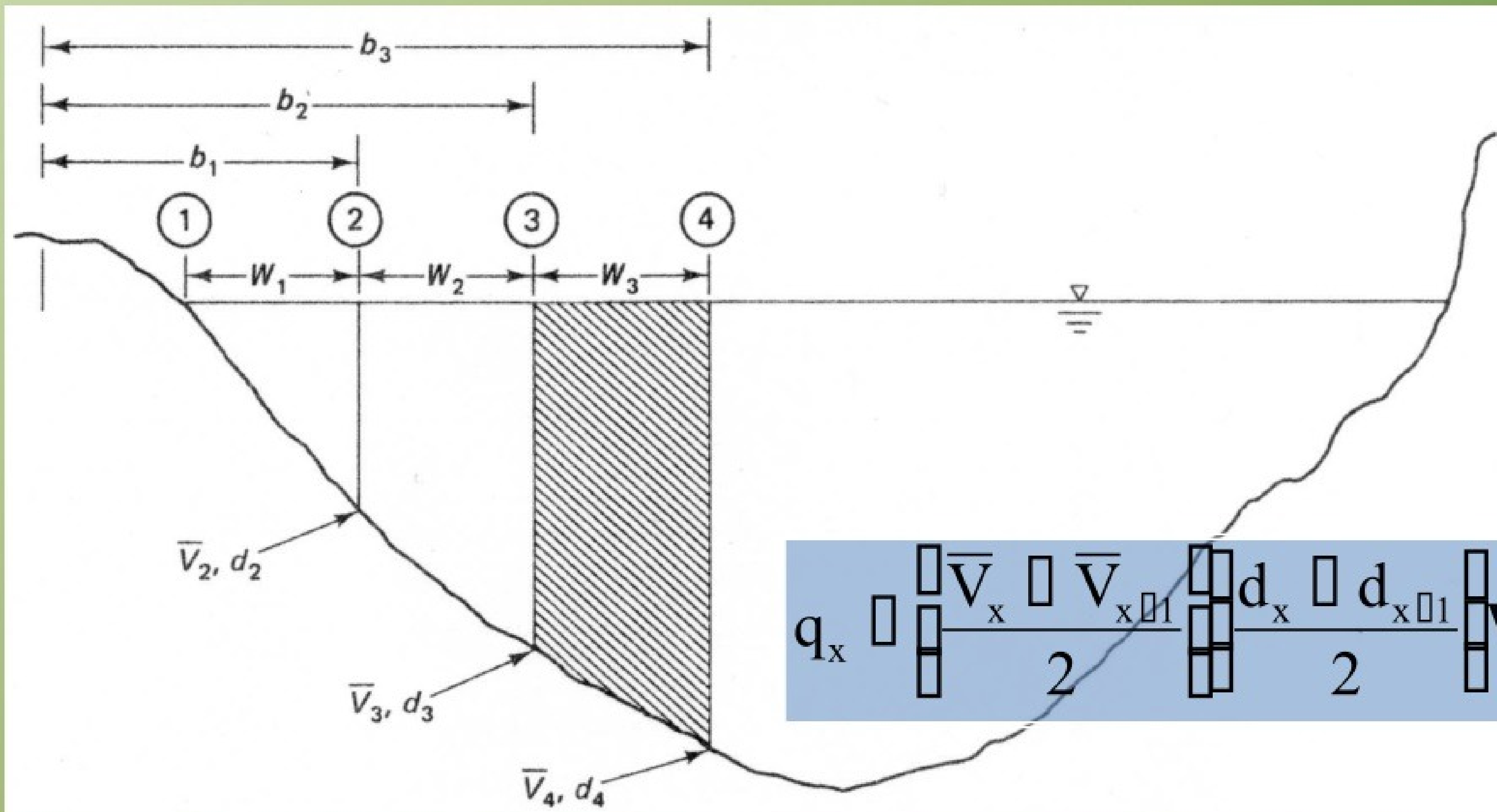
Velocity distribution in a nonuniform channel.

Depth $< 0.6m$ $\quad \bar{V} = V_{0.6d}$; 0.6 water depth from the water surface

$0.6m \le$ Depth $\le 2m$ $\quad \bar{V} = \dfrac{V_{0.2d} + V_{0.8d}}{2}$

Depth $\ge 2m$ $\quad \bar{V} = \dfrac{V_{0.2d} + 2V_{0.6d} + V_{0.8d}}{4}$

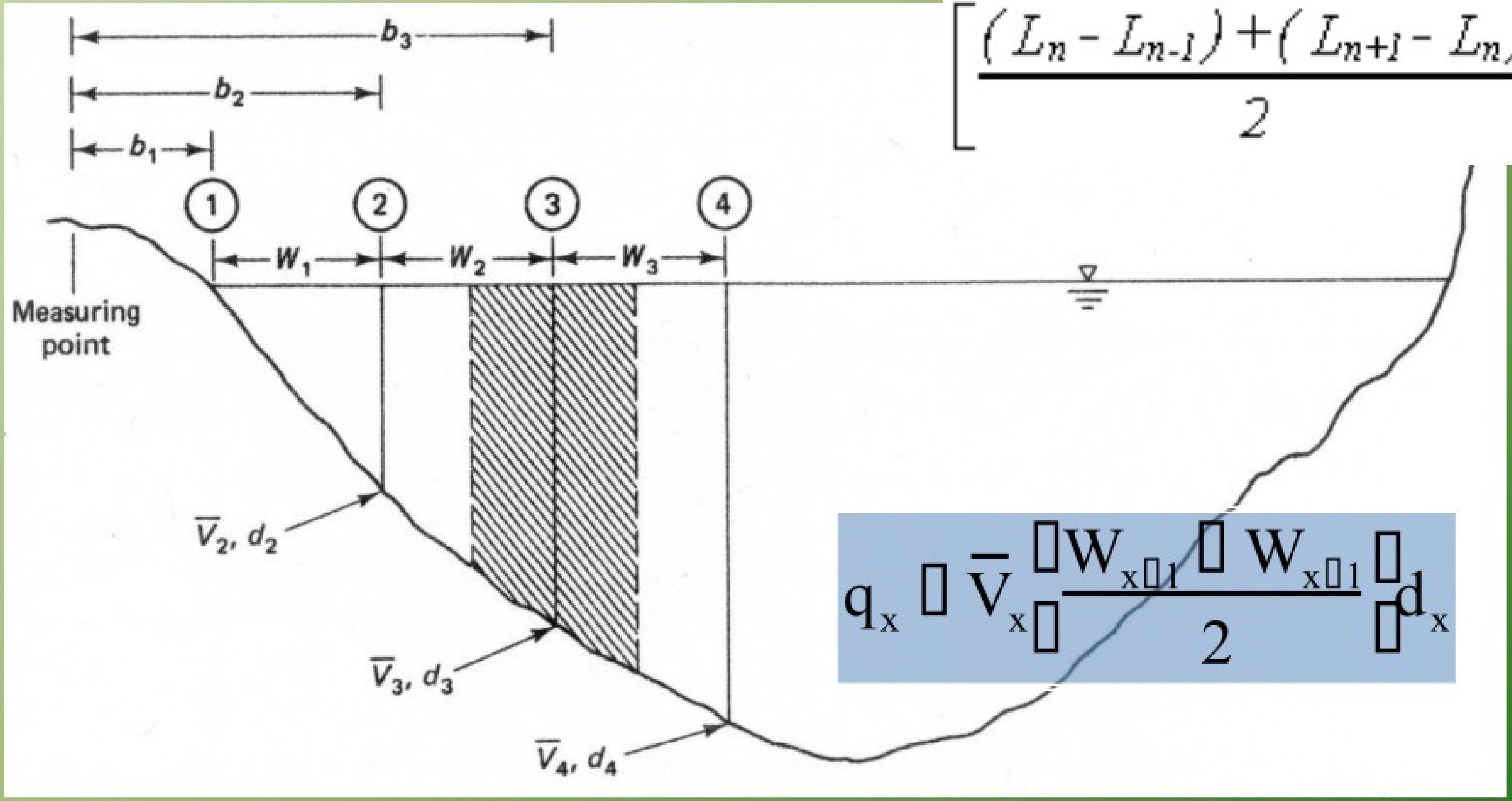
Mean-section Method



$$q_x = \left(\frac{\overline{V}_x + \overline{V}_{x+1}}{2}\right)\left(\frac{d_x + d_{x+1}}{2}\right)W_x$$

Mid-section Method

$$\left[\frac{(L_n - L_{n-1}) + (L_{n+1} - L_n)}{2}\right]$$



$$q_x = \bar{V}_x \left[\frac{W_{x+1} - W_{x-1}}{2}\right] d_x$$

Exercise 3a:

Given V = 0.5N + 0.04 m/ s. Determine streamflow discharge using velocity-area method.

Distance From River Bank	Vertical Depth	Depth of Measurement	Time	Number Of Rotation	Number Of Rotation Per time	Velocity			Width	Vertical Depth Average	Area	Flow
						At Point	Vertical Average	Horinzontal Average				
1	0.2	0.6D	50									
2	0.36	0.6D	50									
4	0.82	0.6D	50									
6	1.3	0.2D	50									
		0.8D	50									
8	1.44	0.2D	50									
		0.8D	50									
10	1.32	0.2D	50									
		0.8D	50									
12	0.84	0.6D	50									
14	0.58	0.6D	50									
16	0.3	0.6D	50									

Exercise 3b:

Given V = 0.3N + 0.05 m/ s. Determine streamflow discharge using velocity-area method.

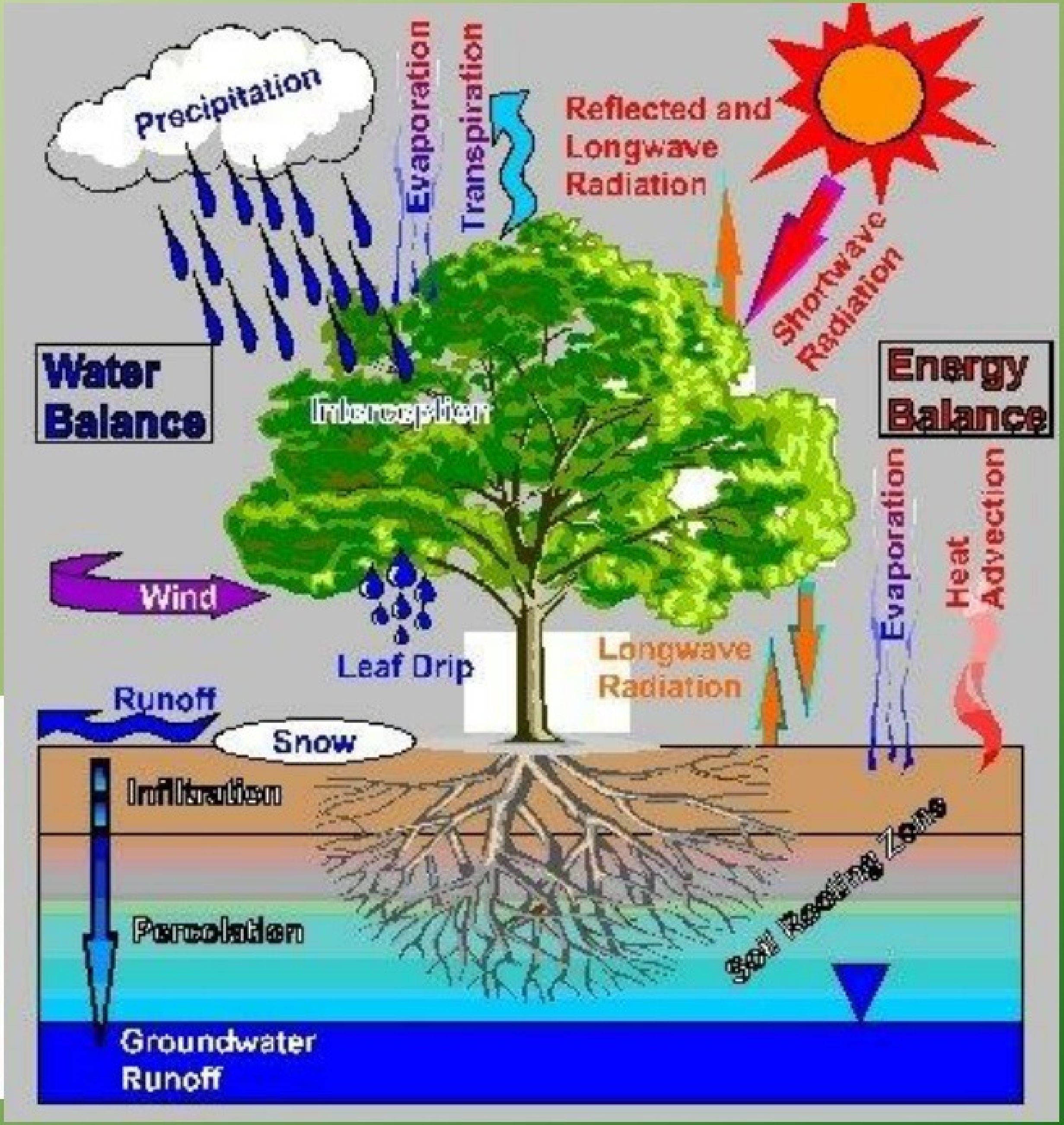
Distance from Datum (m)	Stream depth (m)	Current meter reading					
		0.6D		0.2D		0.8D	
		Rotation	Duration (s)	Rotation	Duration (s)	Rotation	Duration (s)
3	1.2	10	60				
6	3.0			35	62	20	65
9	5.7			42	65	28	62
12	8.5			50	68	25	64
15	4.6			57	65	30	68
18	3.8			40	60	32	60
21	2.5			34	62	25	65
24	1.5	15	60				

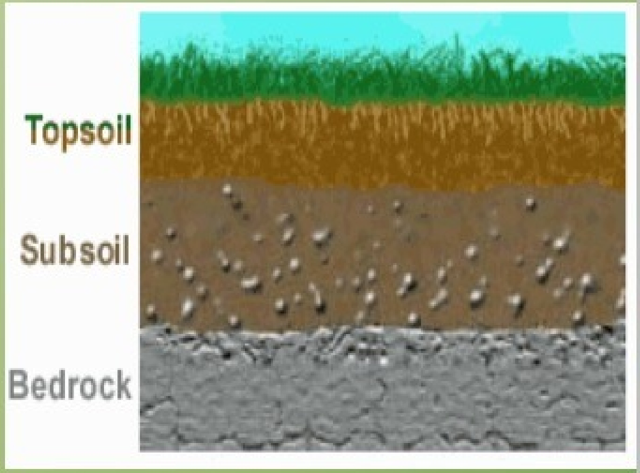
Infiltration

- is the process by which water on the ground surface enters the soil. *Infiltration rate* in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer.

Infiltration:
process that precipitation moves downward through the surface of the earth into soil.

Factor affecting infiltration rate
(1) vegetation cover
(2) condition of surface crust
(3) temperature
(4) rainfall intensity
(5) physical properties of soil
(6) water quality





Phi Index-Φ method

- Constant rate of loss yielding excess rainfall hyetograph with depth equal to depth of direct runoff (kadar kehilangan yang akan menghasilkan hujan lebihan yang sama magnitudnya dengan larian terus)

$$r_d = \sum_{m=1}^{M} (R_m - \phi \Delta t)$$

r_d = depth of direct runoff

R_m = observed rainfall

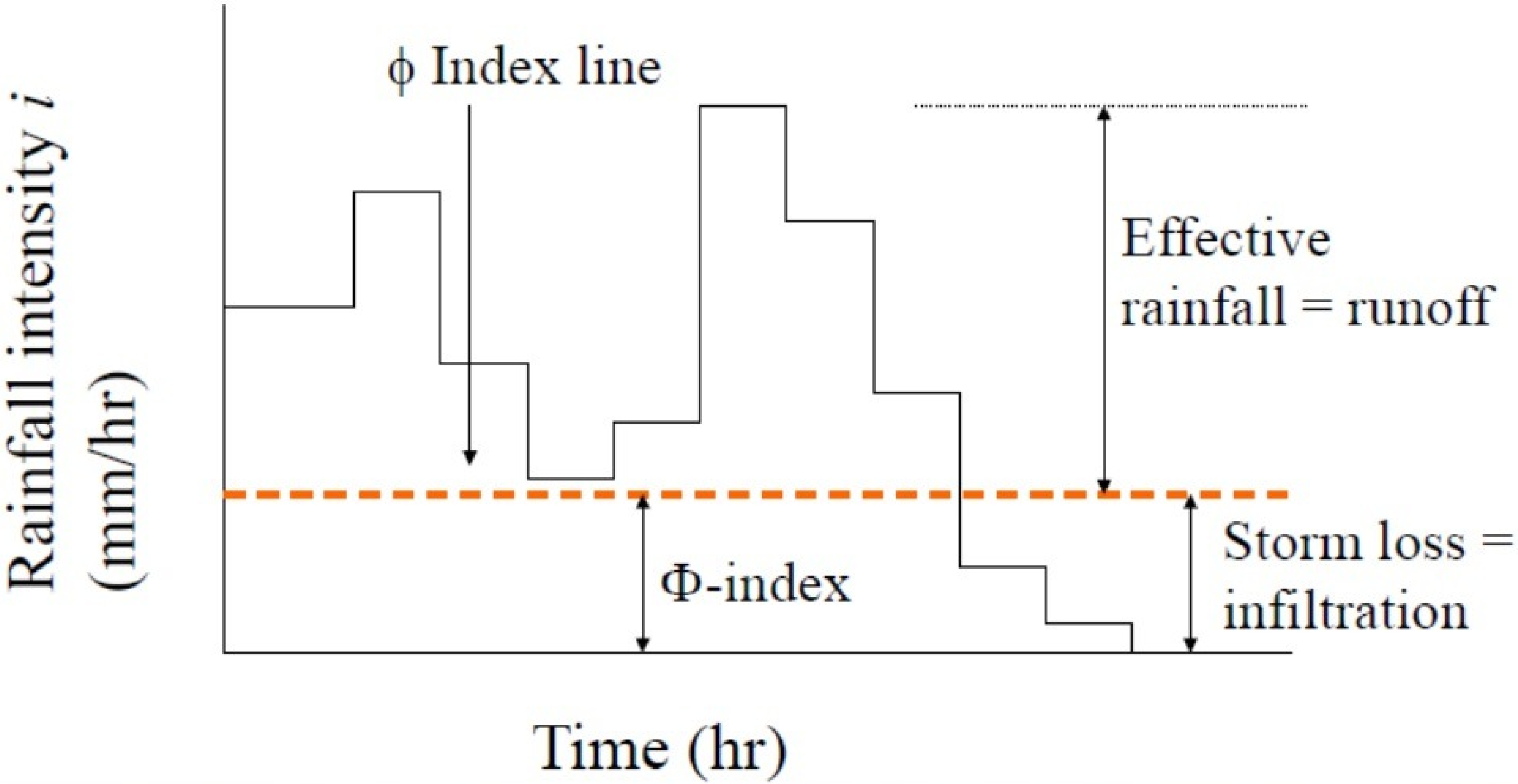
ϕ = Phi index

M = # intervals of rainfall contributing to direct runoff

Δt = time interval

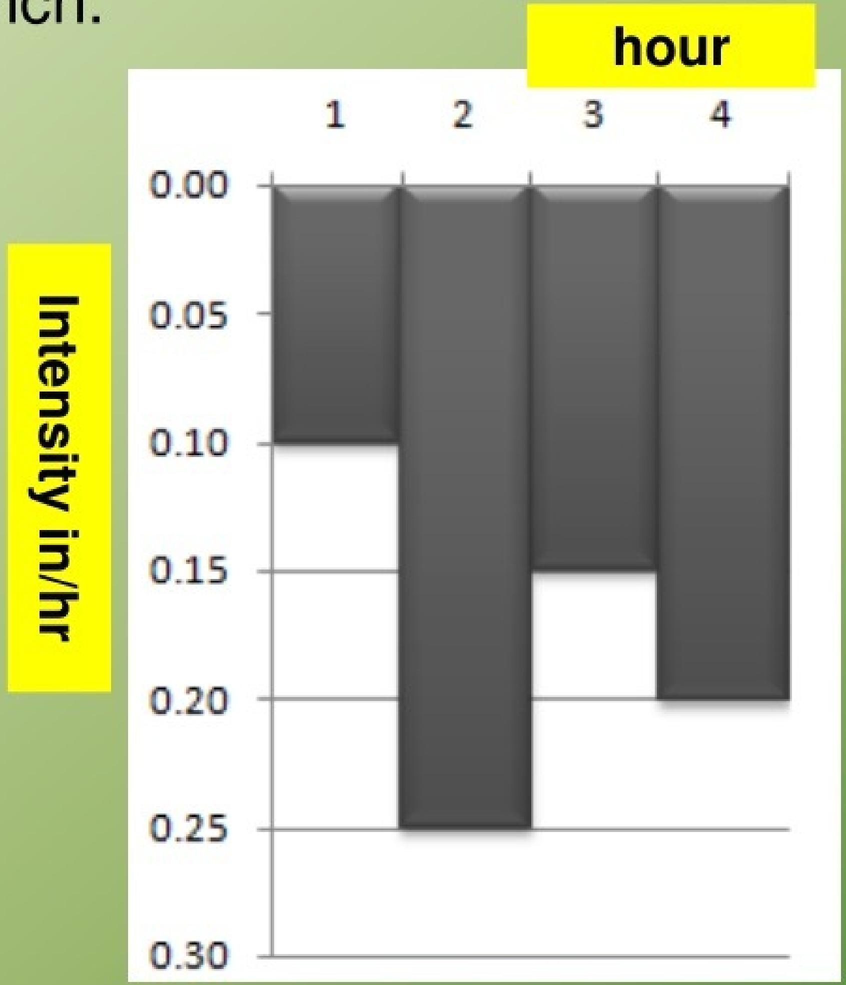
m = interval index

Infiltration Loss by Φ -Index



Example 3a: Phi Index-Φ method

Below, histogram shows rainfall hyetograph for the catchment. Calculate phi-index if direct runoff equal 0.4 inch.



P = 1 x (0.1 + 0.25 + 0.15 + 0.20)
= 0.7 inch

L = 0.7 – 0.4
= 0.3 inch

Φ = 0.3 in / 4 hr
= 0.075 in/ hr

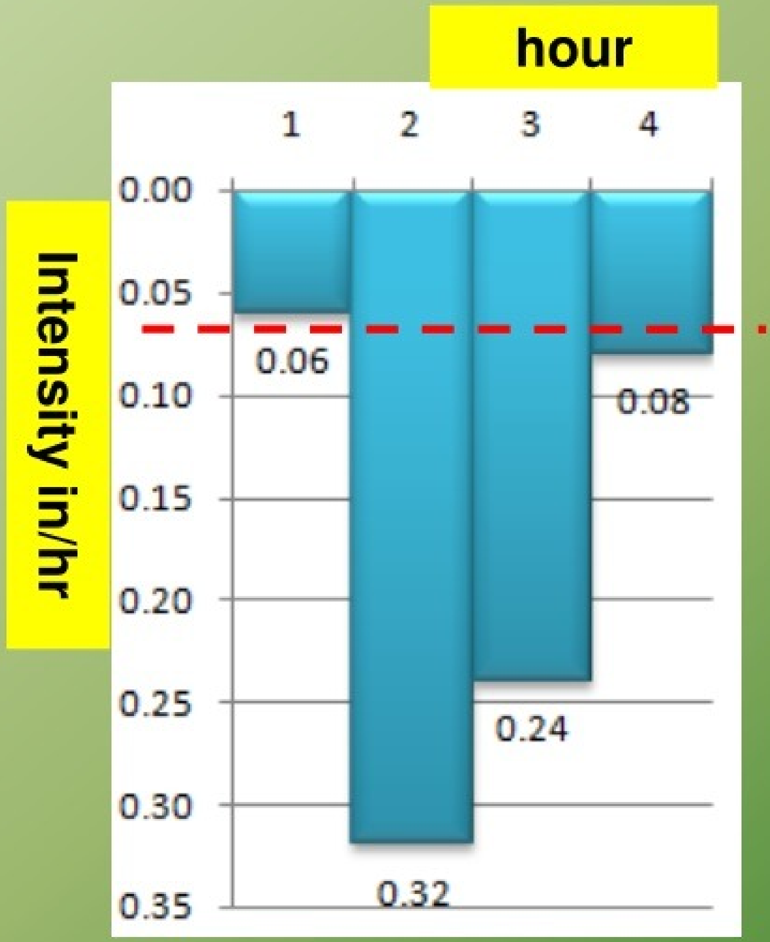
P_e = 1 x ((0.1-0.075) + (0.25-0.075) + (0.15-0.075) + (0.20-0.075))
= 0.4 inch

Constant rate of loss yielding excess rainfall hyetograph with depth equal to depth of direct runoff (kadar kehilangan yang akan menghasilkan hujan lebihan yang sama magnitudnya dengan larian terus)

P_e = DRO = 0.4 inch

Example 3b: Phi Index-Φ method

Refer to rainfall hyetograph below, Calculate loss using phi-index if direct runoff given 0.4 inch.

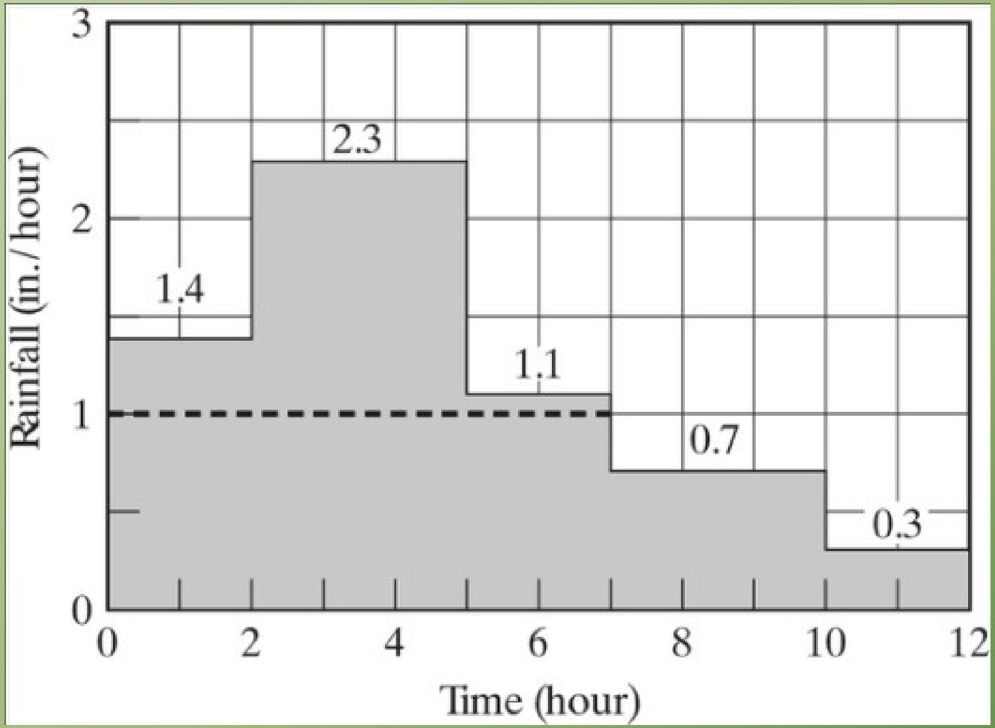


Exercise 3c

Use the rainfall data listed to determine the ϕ index for a watershed having a total runoff of 4.9 inches for this storm.

t (hr)	rainfall (in/hr)
0-2	1.4
2-5	2.3
5-7	1.1
7-10	0.7
10-12	0.3

Solution exercise 3c;



$$2(1.4-\phi)+3(2.3-\phi)+2(1.1-\phi)+3(0.7-\phi)+2(0.3-\phi)=4.9$$

References

1. http://www.es.lancs.ac.uk/people/nickc/104/case16.htm
2. http://agriinfo.in/default.aspx?page=topic&superid=8&topicid=60

3. http://www.fao.org/docrep/U3160E/u3160e05.htm
4. http://www.derm.qld.gov.au/land/management/pdf/c3scdm.pdf