WRE 303

Hydrology

Nasrin mam

Lec 1

27/02/17

[illegible] (always) + [illegible] (after mid)

→ precipitation

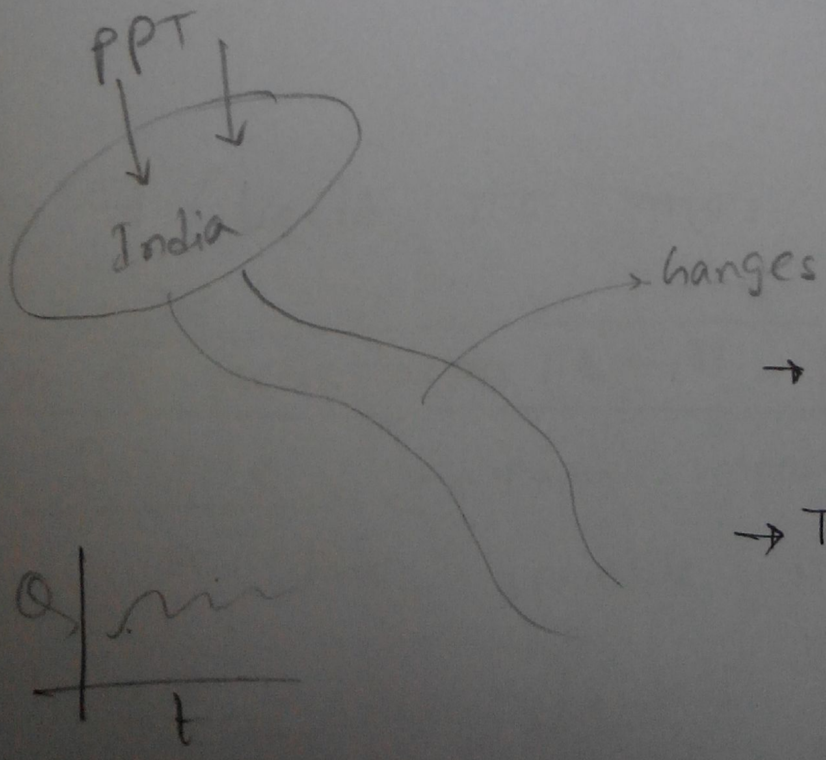
→ Evaporation and evapotranspiration

→ Infiltration

→ Remote sensing + app of telemetry

→ streamflow

→ Hydrologic routing.



→ computing the WL in d/s by updated info from u/s is called routing.

→ To forcasting flood routing is needed.

* Defination of hydrology

* Braches " "

* app " "

→ reservoir storage capacity

→ peak discharge and its vol^m in design of irrigatin

→

* 1 CT sudden → 1 CT আগে বলছে।

Chapter 2

Precipitation

→ all forms of moisture that reach the ground from atm.

ex: rain, snow.

formation:

* vapour ⟶ nuclei + dust + vapour ⟶ drop তৈরী করে
↓
বড় size হলে gravity র টানে নিচে চলে আসে

* buyoance(↑) + gravity(↓) + friction/drag(↑) ⟶ এই force গুলো কাজ করে।

* solid / liquid হতে পারে।
↓
ক্রিস্টাল

$\boxed{\text{form of precipitation (2.2 বই)}}$

* **Drizzle** . < 0.5 mm intensity 1 mm/hr

A fine sprinkle of numerous water drops of size less than $\boxed{0.5 \text{ mm}}$, and intensity less than $\boxed{1 \text{ mm/hr}}$.

* Rain : ($0.5\ mm < size < 6\ mm$)

* Rain : light
  moderate
  heavy

Rain → size $> 0.5\ mm$

* Snow : density $0.1\ g/cm^3$.

* Glaze : খুব ঠান্ডায় থাকলে ($0^\circ c$)
  its glaze / freezing rain

* Sleet : rain + snow simultaneously.

* Hail (শিলাবৃষ্টি) : size > ~~8mm~~ $> 8\ mm$

* Front :
  → interface betn two distinct air masses.

Diff density র দু'টি mass একসাথে হলে
(cold, warm)
যে interface হয় সেটি front.

Weather system for precipitation (2.3)

Type:

1. Cyclonic precipitation
2. Convective "
3. Orographic "

1. **Cyclonic:** low pressure area

   নিম্নচাপ

Type: 1. tropical cyclon
2. extra tropical " .

2. **convective:** → Bd এ main compnent
   warm বাতাস উপরে উঠে

3. **Orographic:** সমুদ্রের বাতাস উপরে উঠে বাধাপ্রাপ্ত হলে condensation হবে, precipitation হবে, যে এ পাহাড়ি pass করতে পারে সেটিতে moisture থাকেনা।

শীতকালে উত্তর-পূর্ব ⟶ no moisture, no rain
গরমে দক্ষিণ-পশ্চিম ⟶ বৃষ্টি হয় কারণ moisture আসে from ocean

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Lec 2

06/03/17

* Cyclonic cyclone:

* Tropical cyclone: মকরক্রান্তি - কর্কটক্রান্তির মাঝামাঝি zone (tropical zone এ)

middle এ (0°) wind speed ↓ rainfall ↑.

* Extratropical cyclone:

* Anticyclone:

* Convective precipitation:

[*] Rain fall characteristics:

- size: → 0.5 – 6mm dia.

- intensity, duration and depth.
  ↳ (mm/hr) (height এর water) (mm) time

- intensity = $\frac{mm}{hr}$ (rate)
- duration = hr (time)
- depth = mm (height)

$$\text{Depth} = \text{intensity} \times \text{duration}$$

$$= \frac{mm}{hr} \times hr$$

$$= mm.$$

* intensity ↑ duration ↓ vice versa

- Intensity and area
- " and raindrop

Measurement of precipitation: (2.5)

- Measurement: climate station এর instrument দিয়ে measure করে, It's called rain gauge.

rainfall vol^n = area × ht.

intensity = ও সময় (incremental time)

$\boxed{*}$ Rain gauge setting:

→ must be level

→ must be set ~~set~~ near the ground.

→ 5.5m × 5.5m area কে set করো,

→ obstruction যাতে না থাকে,

* Short description:

→ Symon's gauge.

→ recording gauge (2 funels)

→ recording gauge (const reading)

→ non recording gauge ([illegible] time reading)

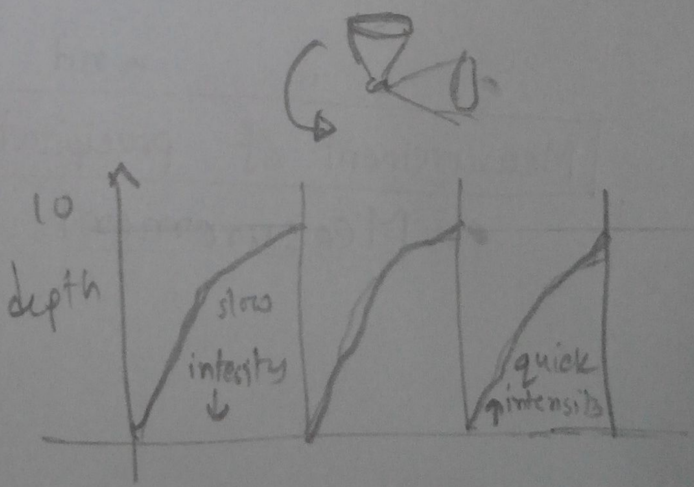

fig ō 2.6

✱ Raingauge network (2.6)

flat regions ⟶ Ideal : 1 station $600-900\ km^2$
acceptable : " " $900-3000$ "

mountainuous ⟶ Ideal : " " $100-250\ km^2$
Acceptable : " " $250-1000$ "

~~desert~~ arid and polar ⟶ " " $1500-10,000\ km^2$

islands ⟶ " " $25\ km^2$

✱ Adequacy of rain gauge stations (2.6.2)

optimal no. of stations, $N = \left(\frac{C_v}{\varepsilon}\right)^2$

Co-eff of variation, $C_v = \frac{(100\,\sigma_{m-1})}{\bar{P}}$

$$\sigma_{m-1} = \sqrt{\left[\frac{\sum_{1}^{m}(P_i - \bar{P})^2}{m-1}\right]}$$

sample হলে $(m-1)$
population হলে m

$$\bar{P} = \frac{1}{m}\left(\sum_{1}^{m} P_i\right)$$

Problem Type 1: Adequate station

Example:

The avg annual rainfalls in cm at 4 existing raingauge stations in a basin are 105, 79, 70 and 66. If the average depth of rainfall over the basin is to be estimated within 10% error. Determine the additional number of gauges needed.

Soln:

$$\sigma_{4-1} = \sqrt{\frac{\sum_{1}^{4}(P_i - \bar{P})^2}{4-1}}$$

Here, $\bar{P} = \frac{105+79+70+66}{4} = 80$

$$\therefore \sigma_3 = \sqrt{\frac{(105-80)^2 + (79-80)^2 + (70-80)^2 + (66-80)^2}{3}}$$

$$= 17.53$$

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$$C_v = \frac{100\,\sigma_{m-1}}{\bar{P}} = \frac{17.53 \times 100}{80} = 21.91$$

no. of station, $N = \left(\frac{C_v}{\varepsilon}\right)^2$

$$= \left(\frac{21.91}{10}\right)^2$$

$$= 4.8$$

$$\approx 5$$

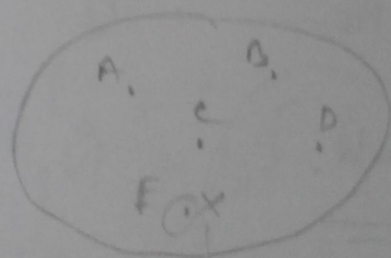
$\therefore$ additional $= 1$.

এটা ৩১ ex $\boxed{\text{example } 2.1}$ (এটা)

$\boxed{X}$ $\boxed{\text{Preparation of data :}}$ (2.7)

→ যদি station এর মাঝে variation ±10% এর মধ্যে থাকে then it's applicable. ঐ stationগুলোর avg নিয়ে বসিয়ে দিতে পারব।

→ But ±10% না হলে



If malfunc
2010 (ok)
2011
missing data calc করতে হবে for long record.

formula 1 : (when ≯ 10%) simple avg
formula 2 : (when > 10%)

$$P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right]$$

বৃষ্টিপাত
rainfall

avg annual rainfall

	E	A	B	C	D
	$\frac{P_E}{N_E}$	$\frac{P_A}{N_A}$	$\frac{P_B}{N_B}$	$\frac{P_C}{N_C}$	$\frac{P_D}{N_D}$
July 1 - 2010					
Sep 2 - 2010	?				

$$\frac{P_E}{N_E} = \text{avg of other } \frac{P_x}{N_x}$$

formula 2 (when > 10%) : $P_E = N_E \times \left[\text{avg } \frac{P_x}{N_x}\right]$

$$\boxed{\begin{array}{ll} \text{when diff} < 10\%, & P_x = \frac{1}{M}\left[P_1 + P_2 + \cdots + P_m\right] \\ \text{" \quad " } > 10\%, & P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right] \end{array}}$$

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Problem Type 2 : missing rainfall

Ex: Raingauge station X didn't func for a part of a month during which a storm occurred. The storm produced rainfalls of 84, 70, 96 mm at three surrounding stations A, B, C respectively. The normal annual rainfalls at the stations X, A, B, C are respectively 770, 882, 736 and 944 mm. Estimate the missing storm rainfall at station X.

Ans: 75 mm

Sol^n: $P_x = \frac{1}{3}\left[\frac{N_x}{N_a}P_a + \frac{N_x}{N_b}P_b + \frac{N_x}{N_c}P_c\right]$

$P_x = \frac{1}{3}\left[\frac{770}{882}\times 84 + \frac{770}{736}\times 70 + \frac{770}{944}\times 96\right]$

$= 75$ mm

example 2.2 (or)

Lec 3   13/03/17

Test for consistency of record (2.7.2)

data collect করার অনেকদিন পর climate এ/topograpy তে change হল।

or বাঁধ দেওয়ার জন্য পানি obstruct হয়

or fire লাগলে বন পুড়ে ক্ষতিগ্রস্ত [illegible] হয়।

তখন আগের info কে modify করে এখনকার regime এ নিয়ে আসি। এই inconsistency হয়।

Causes:

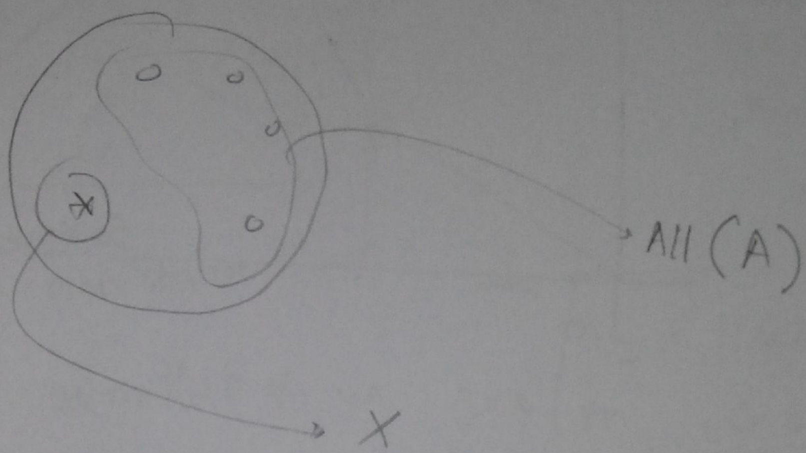
→ shifting of a rain gauge to a new station

→ the neighborhoods change

→ ecosystem change due to forest fire, land slide

→ record error.

Adjustments of ~~prep~~ precipitation data:



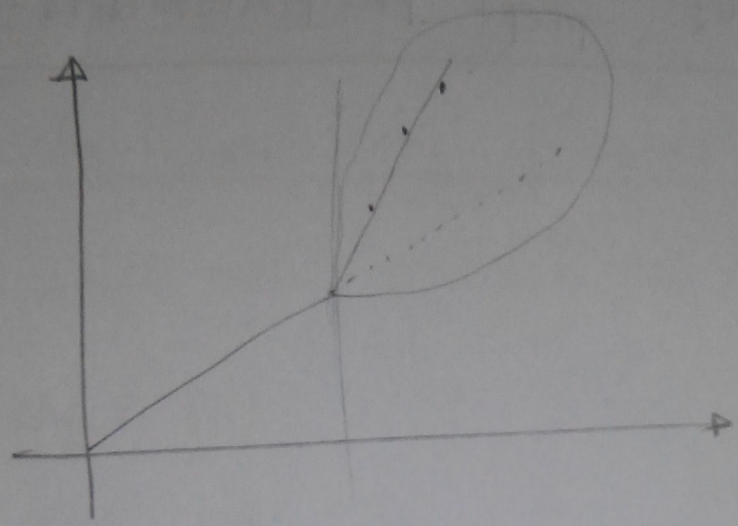
⊛ একাধিক হলে আলাদা করে নিয়ে কাজ করব but কোনটা inconsistant তাই দিবে।

⊛

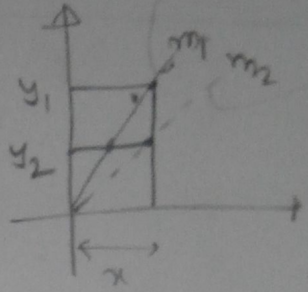
yr	X rainfall	A (Avg rainfall)
1971		
1972		

⊛ reverse থেকে plot করব, current থেকে past এ যাব.

accumulated precipitation station X, ΣP_x



avg acc. P of other



$y_1 = m_1 x$

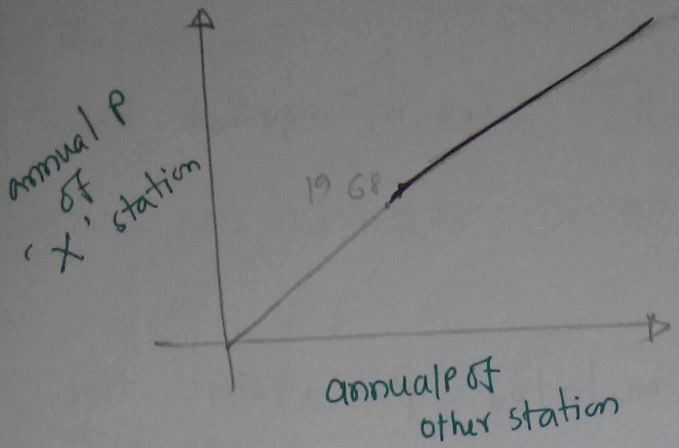
$y_2 = m_2 x$

$$\boxed{y_2 = m_2 x \frac{y_1}{m_1}}$$

* Problem:

Problem Type 3: consistency of data

yr	Annual rainfall M	Annual Others avg	Cumilative	Annual others cumilitive
1979	612	588	612	588
1978	426	410	1038	998
1977	825	787	1863	1785
1976	685	653	2548	2438
1975	356	377	2904	2815
~~1987~~ 1974	568	570	3472	3385
1973	438	390	3910	3775
1972	386	400	4296	4175
1971	497	490	4793	4665
1970	635	590	5428	5255



series 1
series 2

$m_2 = 1.0295$
$m_1 = 0.8779$

graph এ cumilative করতে হবে,

but $y_2 = m_2 \times \frac{y_1}{m_1}$

এটি cumulative না

example 2.3 (পড়)

Presentation of Rainfall data (2.8)

Hyetograph (2.8.2)

→ plot of rainfall intensity against time.

Mass curve (2.8.1)

→ plot of accumulated P against time.

Point rainfall / station rainfall (2.8.3)

→ It refers to the rainfall data of a station.

Mean precipitation over an area: (2.9)

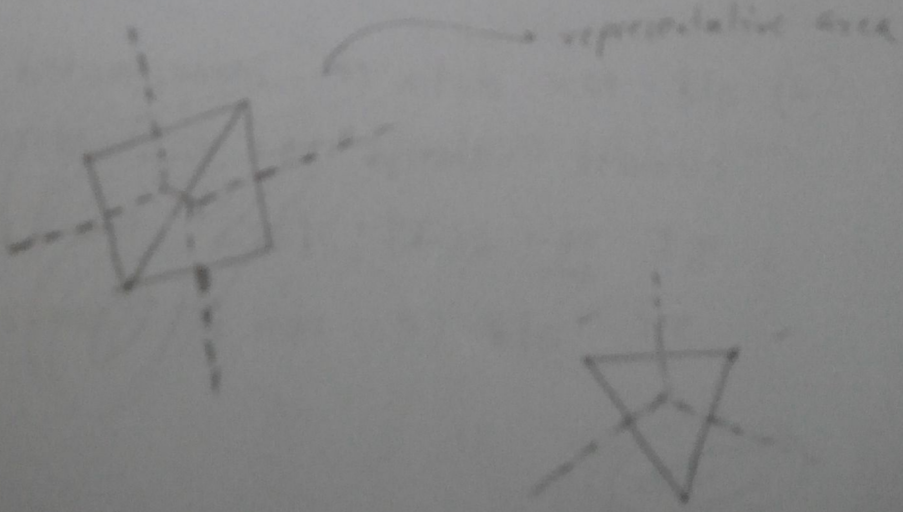
Theissen

① [illegible] station [illegible] add [illegible] triangle form [illegible],

② middle → [illegible] [illegible]

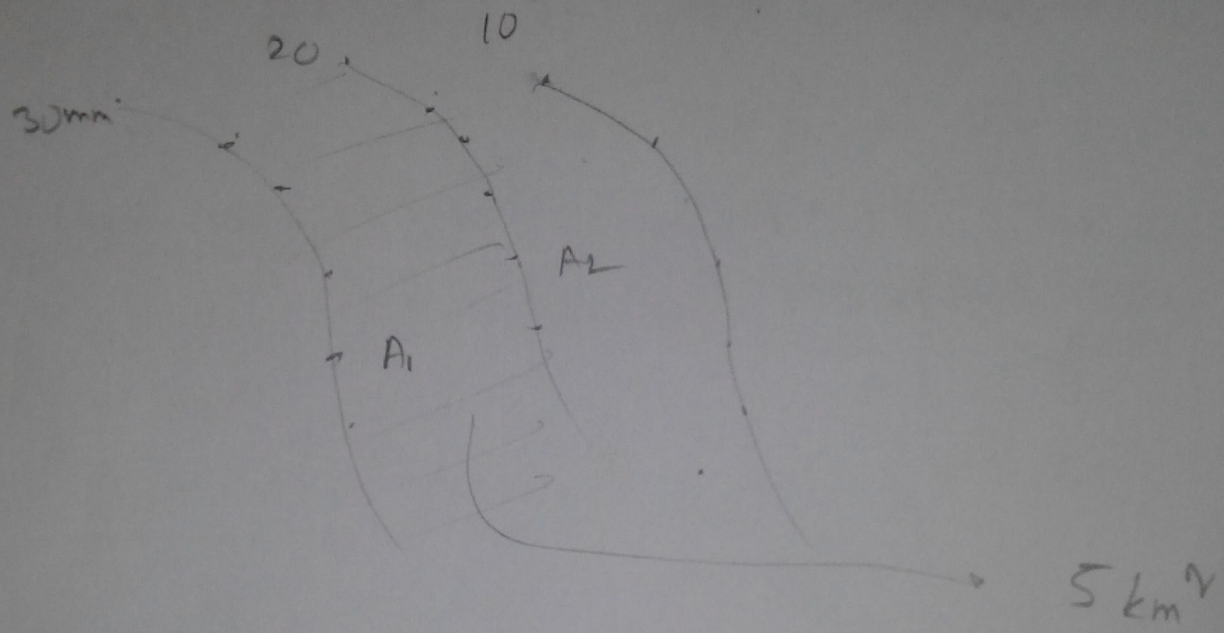
③ vol^m, $\sum P \times A$

④ avg: $\boxed{\dfrac{\sum P \times A}{\sum A}}$



→ vol^m : depth × area

3. <u>Isohyetal</u> : same height এর rainfall



$$vol^m = \underset{km^2}{5} \times \underset{(mm)}{25}$$

$$avg = \frac{vol^m}{Area}$$

(*) old - new data কে incorporated করতে লাগছে।
climate change এর জন্য করতে হয়।
শুধু new data হলো নিলে time short হয়ে যায়,
তাই old কে new কে convert করি।

Problem Type 4: Average depth (Thiessen + A.M.) + Isohyte 13/6004

Problem: (Thiessen polygon)

ex : 1 Thiessen polygon

Isohyet (mm)	Area (km^2)	vol^m (mm^3)
75	10	$10 \times 75 = 750 \times 10^{12}$
85	85	7225×10^{12}
95	113	10735×10^{12}
105	98	10290×10^{12}
115	136	15640×10^{12}
125	67	8375×10^{12}
	$\Sigma A = 509$ km^2 $= 509 \times 10^{12}$ mm^2	$\Sigma 53015 \times 10^{12}$

$$\therefore \text{average} = \frac{53015 \times 10^{12}}{509 \times 10^{12}} \text{ mm}$$

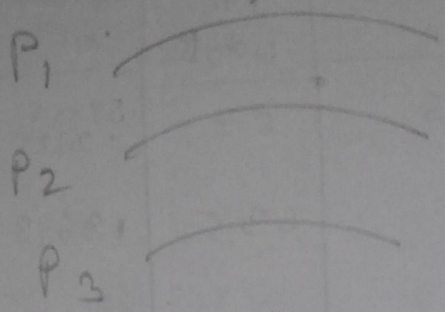
$$\cancel{= 104.155 \times 10^{3} \text{ mm}}$$

$$= 104.155 \text{ mm}$$

example 2.5 + 2.6

Lec 4 18/03/17

আগের দিনের math



(খ) প্রতিটি storm এর একটি centre থাকে যেখানে rainfall অনেক বেশি হয়। যত দূরে যায় তীব্রতা কমে।

Ex: [Isohyte]

ex 2 : Isohyte

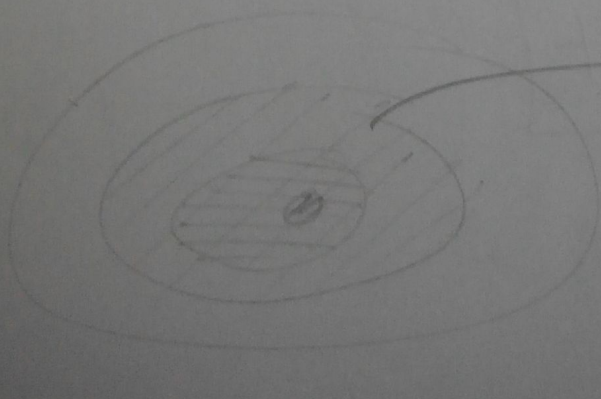
Isohyt (mm)	57	50	45	40	35	30	25	20	15	10
Enclosed area (km^2)	55	310	1300	2060	2700	2955	3600	4030	4800	6000

area → cumulative area

The data

Starting: Isohyte 57 mm. $A = 55\ km^2$ (storm centre)

আগের দিন 2টি isohyte এর আমার area দেয়া ছিল, আমাদের cumulative area দেয়া আছে

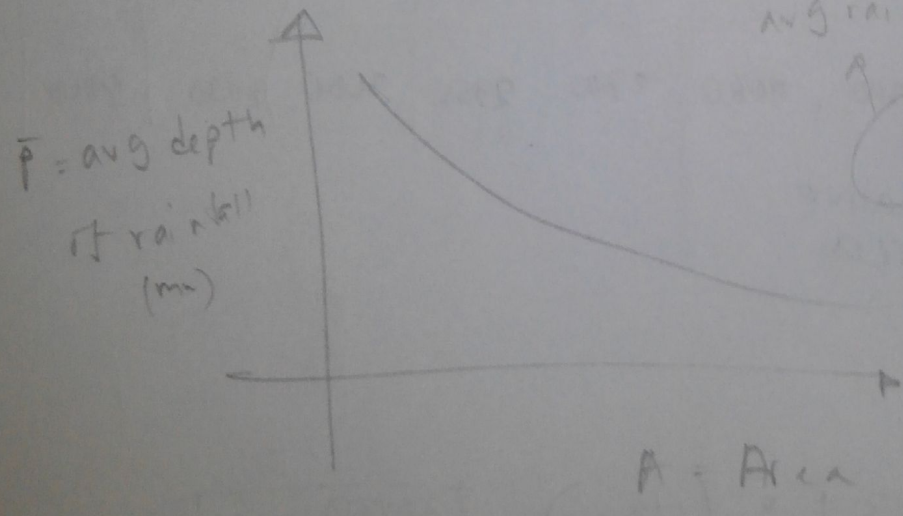


area টি যদি contour map থেকে graph এ plot করে count করি, it's time consuming. এর জন্য এমন instrument আছে (planimeter) যার সাহায্যে area বের করা যায়

Soln:

① Isohyte	② Enclosed area	③ Increment area	④ avg isohyte	⑤ incremental volm	⑥ Total volm	⑦ avg depth = Total volm / total area
57	55	55	57	57×55 = 3135	3135	$\frac{3135}{55} = 57$
50	310	255	53.5	13643	16778	$\frac{16778}{310} = 54$
45	1300	990	47.5	47025	63802	49

[illegible] intensity [illegible] intensity [illegible]



Avg rainfall

$$\bar{P} = 57 e^{-0.0001 A}$$

Total area under that contour

example 2.7

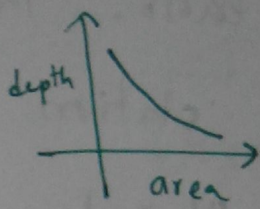
$\boxed{x}$ Depth-area duration relationship (2.10)

Depth-area relation: (2.10.1)

$$P = P_0 \exp(-kA^n) = P_0\, e^{-kA^n}.$$

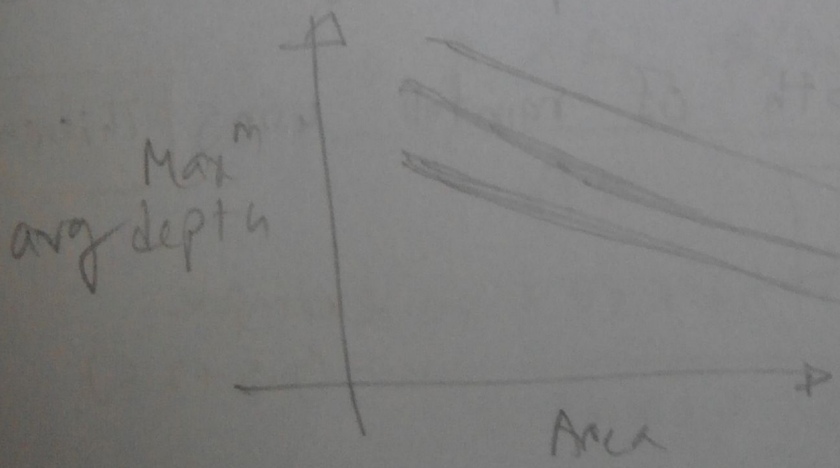
(x) 5000 km² এর under এ $\bar{P}$ কত?

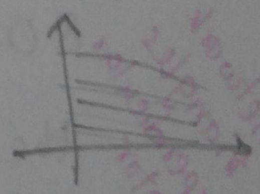
= graph / eqn



(x) কোন দিনের max^m rainfall নিয়ে কাজ করব তাতে max^m precaution নেয়া।

$\boxed{x}$ Max^m depth area duration (2.10.2)





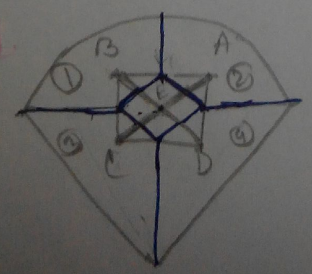
DAD curve.

ex 3: Thiessen polygon

Ex: A semicircle of diameter 20 km with an equilater triangle of side 20 km below its dia is a ~~clot~~ close approximation to a river basin. The position co-ordinates of 5 raingauges station A, B, C, D, E located within the base w.r.t. a co-ordinate axes system whose x-axes and origin are coincidents with dia and centre are (5, 5), (-5, 5), (-5, -5), (5, -5) and (0, 0) km respectively. If the rainfall recorded at these raingauge are 85, 92, 77, 80 and 105 mm respectively determine the avg depth of rainfall using Thissen polygon method.

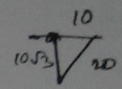
① network of triangles
② perpendicular bisector
③ polygons and the boundary around each station

example (2.5 + 2.6)



1316004

$$\text{Total area} = \frac{\pi \times 20^2}{2} + \frac{1}{2} \times 20 \times 10\sqrt{3}$$



$$= 330.285 \text{ km}^2$$

A_1, A_2 area $\Rightarrow$

$$\frac{\pi \times 10^2}{4} - 12.5$$

$$= 66.04 \text{ km}^2$$

$\frac{1}{2} \times 5 \times 5$

$= 12.5$

A_3, A_4 area $\Rightarrow$

$$\frac{1}{4} \times 20 \times 10\sqrt{3} - 12.5$$

$$= 74.1025 \text{ km}^2$$

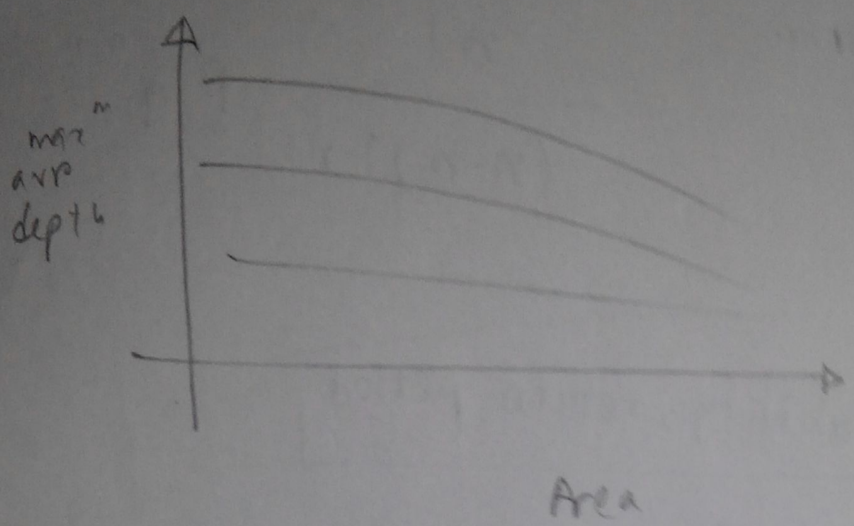
$A_5 = 12.5 \times 4$

$= 50 \text{ km}^2$

$$\text{ans} = \frac{P_1 \times A_1 + P_2 \times A_2 + P_3 \times A_3 + P_4 \times A_4}{A_4}$$

$$= \frac{85 \times 66.04 + 92 \times 66.04 + 77 \times 74.1025 + 80 \times 74.1025 + 50 \times 105}{66.04 \times 2 + 74.1025 \times 2 + 50}$$

$$= 86.51 \text{ mm}$$



rainfall ...
intensi...
(কম)।

example 2.8 (Not ...)

frequency of point rainfall: (2.11)

T বেশি ← Q_{1988} → large

T কম ← Q_{1991} → small

~~$Rain_{1991}$ → small~~

high value কে exceed করার probability কম।

$$P = \frac{1}{T}$$

P → probability flood আসার

T → যত বছরে একবার আসতে পারে।

T = return period.

1988 এর flood 50 yr এ একবার আসতে পারে এই return period = 50

n yr

r সংখ্যক বার আসার probability →

P, n, r

না হওয়ার probability

$$P_{r,n} = {}^nC_r \, P^r q^{n-r} = \frac{n!}{(n-r)!\,r!} P^r q^{n-r}.$$

$q = (1-P) = (1-\frac{1}{T})$

$P = \frac{1}{T}$

Problem — **Type 5: Probability, return period**

(x) 30 yr এর annual rainfall data থেকে ৫ থেকে ছোট গড় আবার।

<u>Step:</u>

→ ~~sor~~ collect R

→ sort in decreasing order (descending)

→

m	
1	R_1
2	R_2
3	R_3
4	R_4

$R_1 > R_2 > R_3 > R_4$

wei bull $\longrightarrow P = \dfrac{m}{N+1}$ → No. of data

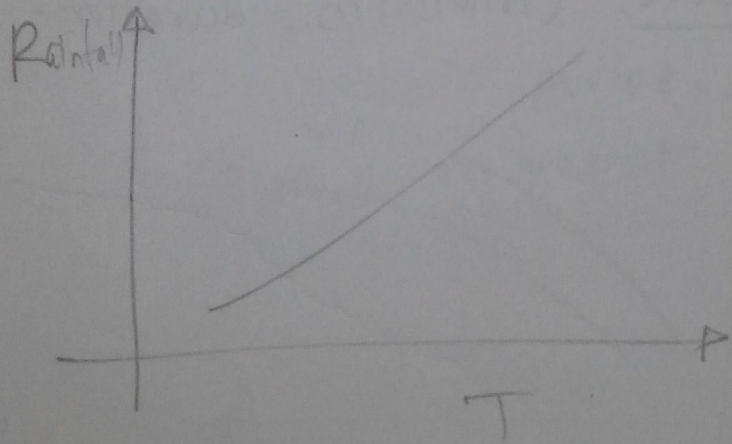
highest, $P = \dfrac{1}{1+30}$ $\quad T = \dfrac{1}{P}$

2nd . , $P = \dfrac{2}{1+30}$

3rd . . . $P = \dfrac{3}{1+30}$

⋮

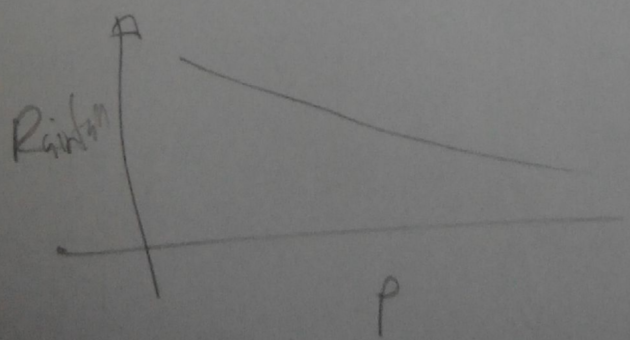
30th . . $P = \dfrac{30}{31}$ (অবশ্য: P বেশি)



example

2.9 +

2.10 +



→ বেশী data থাকলে ভালো

└→ plotting করে।

1980 → 1990 নিলে, T = 12 (11+1)

└→ 1988 এর T = 100 yr

1985 – 1988, T = 4+1 = 5.

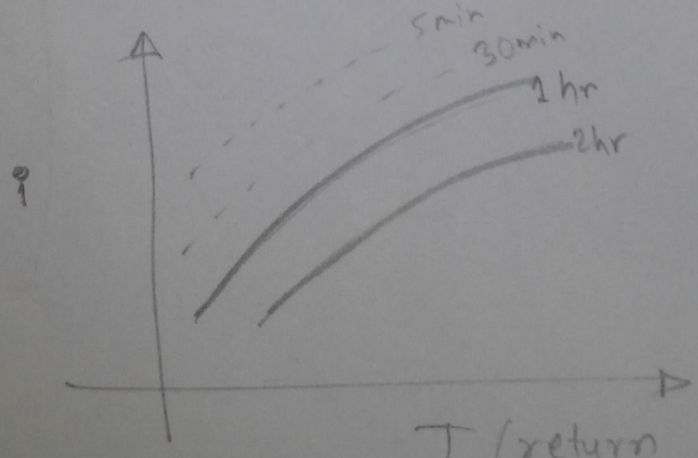
└→ T = 100 yr

→ sampling data বেশী হলে correct হয়।

→ 100 yr এর জন্য P আনতে হইলে 100 yr/99 yr এর ডাটা লাগলে হবে।

I-D-F curve: (Intensity – duration – frequency curve)

Maximum I-D-F relationship (2.12)

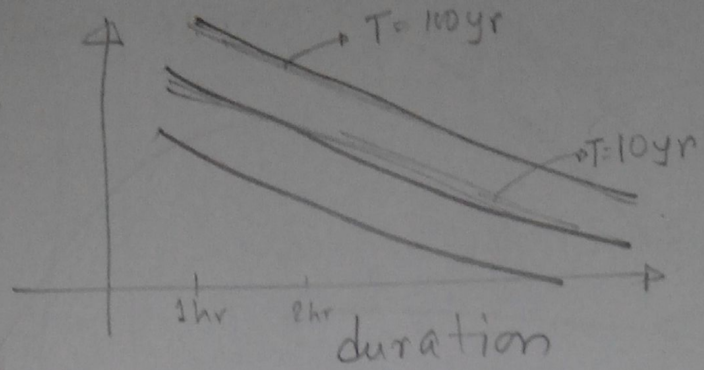


intensity = $\frac{\text{Rainfall}}{\text{duration (1hr)}}$

P↑ i↑

1 ঘন্টা ব্যাপী rain দিয়ে ভাগ করি।

এই time frame কম হলে i↑



exam → qualitative curve draw

Duration ↑ i ↓

T ↑ i ↑

$$\boxed{i = \frac{k\, t^{x}}{(D+a)^{n}}}$$

→ equn (2.15)

P ↑ i ↓

T ↑ i ↑

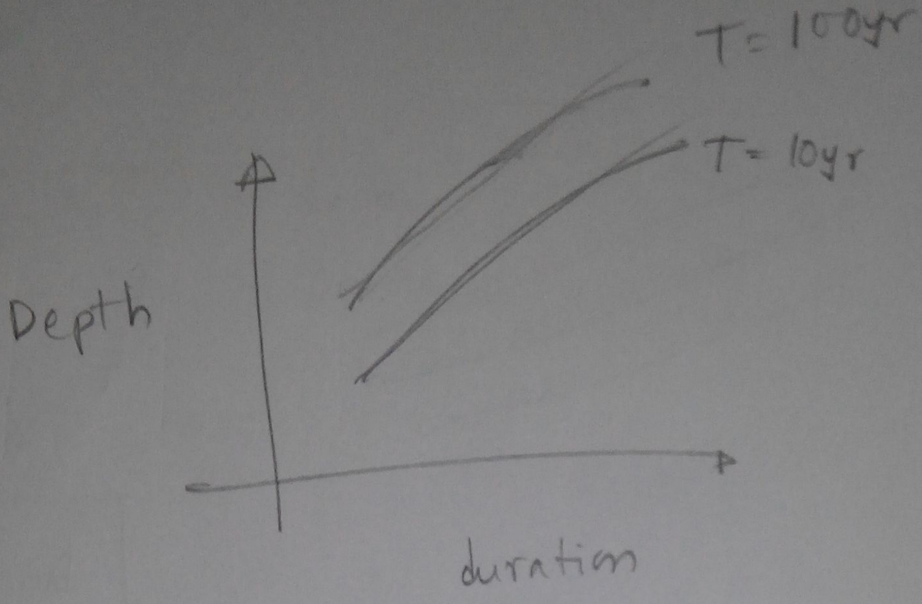
$i \propto t$

$i \propto \frac{1}{D}$

D = duration

t = return period.

k, x, a, n = const



duration ↑ depth ↑
(cumulative)

$d \propto D$

$\boxed{X}$ Probable max^m precipitation (PMP) (2.1③)

Short note

$$PMP = \bar{P} + k\sigma .$$

$\bar{P}$ = mean of annual max^n rainfall

σ = st. deviation

k = frequency factor

Problem: Type 6: PMP

consecutive [illegible] that hr's max^m intensity = ?

	1 hr (mm)	2nd hr (mm)	3rd hr (mm)	max^m 1 hr	max^m 2nd hr	3rd hr
Day 1	5	4	6	6	10	
Day 2	3	3	4	4	7	
Day 3	4	2	5	5	7	
Day 4	3	1	1	3	4	
				max^m P = 6	max^m P = 10	

4 দিনের মধ্যে 1 hr এর ~~জন্য~~ জন্য max^m P = 6 mm

$\therefore$ intensity $= \frac{6}{1}$ mm/hr $= \boxed{6 \text{ mm/hr}}$

4 দিনের মধ্যে 2 hr এর জন্য max^m P = 10 mm

$\therefore$ intensity $= \frac{10}{2}$ mm/hr $= \boxed{5 \text{ mm/hr}}$

exercise: moving avg →

Type 7: Moving average

example: 2.4

Lec 6 — 03/04/17

Year	Month	Date	01	02

Assignment:

Compute 5 day moving avg at max^m intensity for 5 day duration.

[৫দিন করে করে নিয়ে month এর ৬টি বের করব.]

total depth পাব

then intensity.

Chapter 3

Abstractions from precipitation

a. Evaporation

b. ET

c. Initial loss (গাছের পাতায় থাকে, depression এ থাকে)

d. Infiltration. (vertically to the ground)

(*) loss → because it doesn't contribute in run-off.
বলি কেন

* A. Evaporation ($\frac{mm^3}{mm^2}$ = mm হয়, actually $\frac{mm}{time}$)

Factoring affecting Evaporation:

1. Vapour pressure at the water surface (e_s) and air above (e):

   VP ↑ E ↓.

→ saturated VP : ঐ temp এ এতো যে বেশি moisture hold করতে পারবে.

→ max^m — current moisture = Vapour pressure deficit. (↑ E ↑)

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

2. Air & water temp : temp ↑ water hold capasity ↑

   E ↑

3. Wind : ↑ ↑ . (as water moisture বয়ে নেয়)

4. Atm pressure : উচ্চতে E ↑ .

5. Quality of water :

   impurities থাকলে temp change হয়।

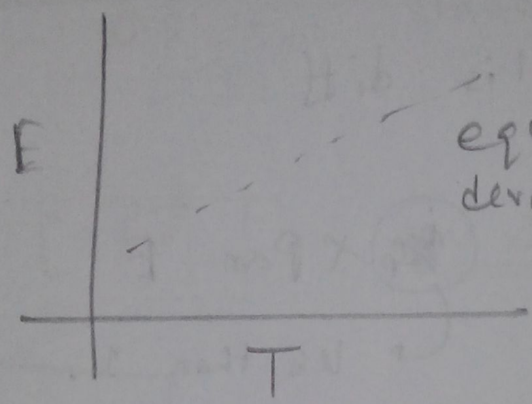
6. Size of water boy : A ↑ E ↑ .

7. Heat storage in water body :

   depth ↑ storage capacity ↑ .

Measurement :

1. evaporimeter data
2. Emperical equⁿ
3. Analytical methods.



data plot করে equⁿ (for that locality) develop

Analytical এ অনেক ঝামেলা এত variable থাকেনা।
তাই emperical easier.

Evaporimeter:

(a) Class A
(b) ISI
(c) colorado suken pan
(d) US geological survey Floating pan

এদের একটির বর্ণনা পড়তে ~~হবে~~

Evaporimeter:

* E from lake < E from pan. Why?

→ heat $\boxed{\text{storing capacity}}$ diff.

→ $\boxed{\text{height of rim}}$

→ heat $\boxed{\text{transfer characteristics}}$ of pan materials diff.

$$\text{Lake } E = C_p \times \text{Pan } E$$

less than 1.

* pan co-eff $= C_p$

exam এ না আসলে

$(0.7 - 0.8)$

* **Empirical Evaporation eqn:**

$$E = K f(u) \left[e_w - e_a \right]$$

u_9 = monthly mean vel (km/hr) at 9m above the ground

Meyer's : $E = K_m (e_w - e_a)\left(1 + \frac{u_9}{16}\right)$

u_9 = monthly mean vel (km/hr) 9m above from groud

k_m = 0.36 for large deep water [f d] [E P]

0.5 " shallow " "

Example [৩২] ex 3.1

A. Measurement

B. analytical method

1. water-budget method
2. energy-balance "
3. Mass-transfer method

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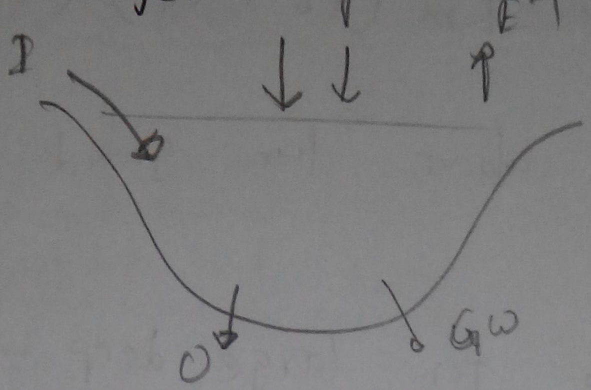
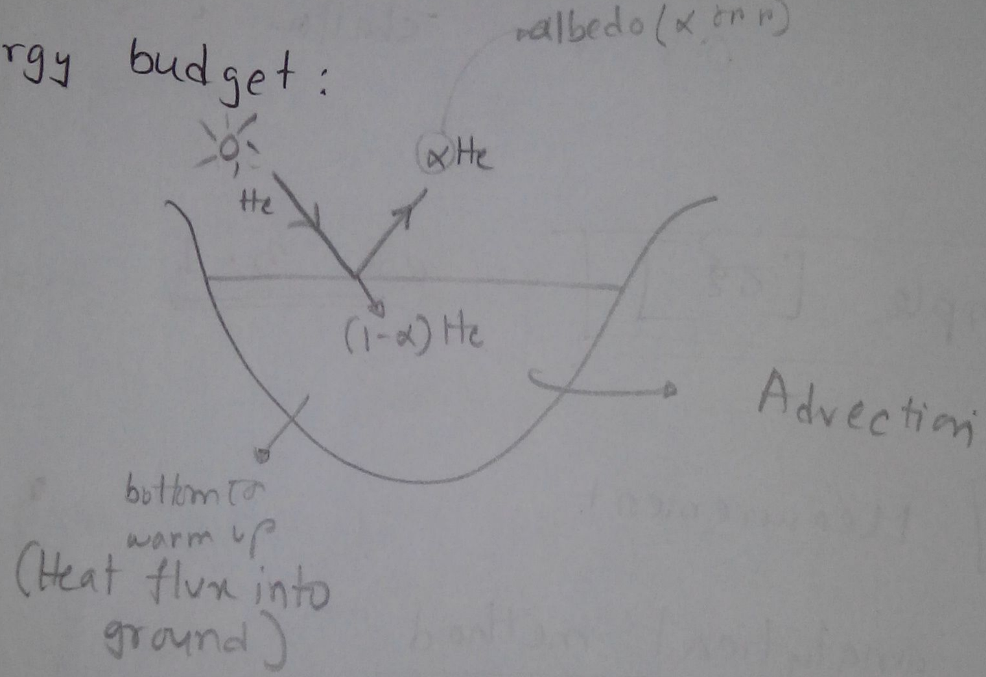
1. water - budget



P ⊕
I ⊕
O ⊖
ET ⊖
GW ⊖

2. Energy budget :



$$H_n = (1-\alpha) H_e .$$

black body radiation [যাদের temp > 0°c তারাও একটি radiation emit করে, It's also loss]

$$H_n = H_a + H_e + H_g + H_s + H_i$$

Methods of reduce evaporation :

→ surface area কমিয়ে depth বাড়াতে পারি।

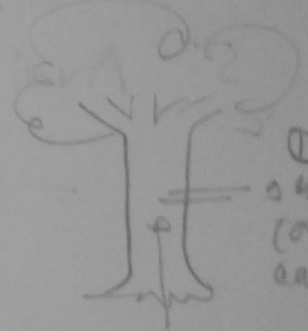
→ oil উপরে ছড়িয়ে দিলে (chemical films)

→ Mechanical cover.

Evapotranspiration :

E → water body + soil mass থেকে

T → trees থেকে ।



① গাছের কান্ডে T cale করতে পারি

② গাছের পাতায় পাতায় T cale করতে পারি

→ Time consuming

Penman's equ^n : (Theory + empirical mixed)

$$PET = \frac{AH_n + E_a \gamma}{A + \gamma}$$

analytical, exp,

সব variable জানিনা → time consuming

Defn:

exam ***

1. Potentia ET [max^m অবস্থায় যত ET হতে পারে] unlimited energy & temp

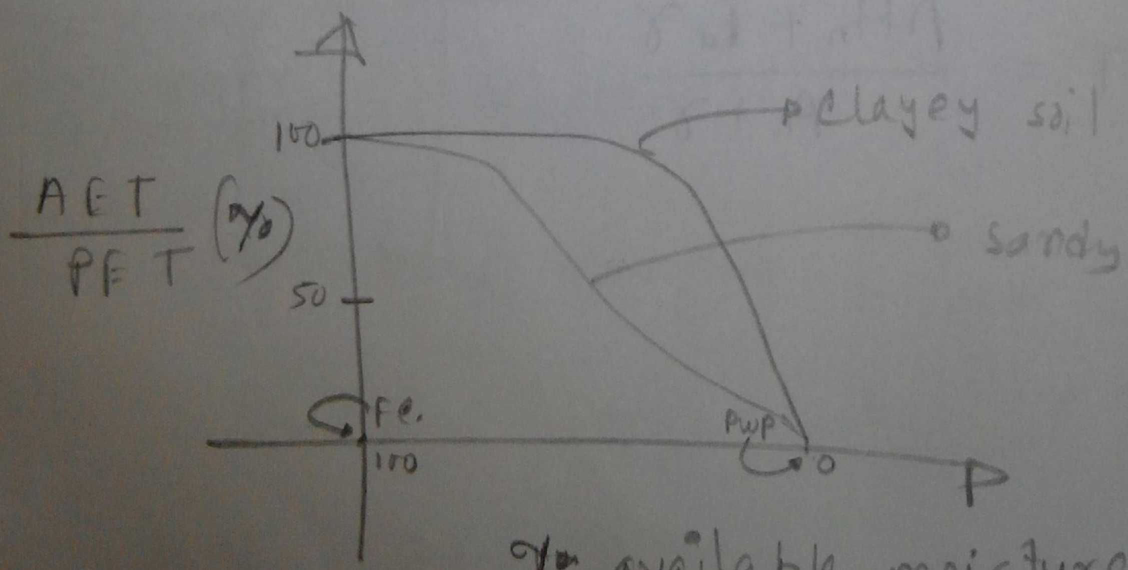
2. Actual ET [Existing অবস্থায় এ ET]

3. Field capacity [max^m এ moisture hold করতে পারে]

4. Permanent wilting point [dry হতে হতে একটি moisture কখনো remove করা যায় না, যেটি]

5. Available water

= Field capacity − Permanent wilting point.



[water holding capacity বেশি, pore ছোট]

[দ্রুত drain out হয়ে যায়]

% available moisture

Fc = 100% m/c
PWP = 0% m/c

exam এ 60 — 90
rearrange ↓ ↓
করা যেতে 0 100
পারে।

CT → 9th week (Precipitation)

Lec 7

ex 2.11 [3rd edition]

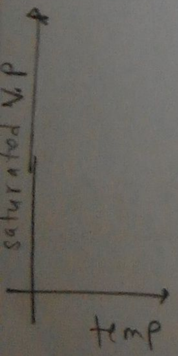
- humidity ↑ sunlight ↓ হলে ET ↓.

⊛ water budget equ^n.

⊛ ET experimentally tough. তাই, equ^n দিয়ে ET calc করি।

⊛ Penman's equ^n for ET:

$$PET = \frac{AH_n + E_a \gamma}{A + \gamma}$$



A = slope of saturation vapour pressure vs temp curve at mean air temp [KPa/°C]

H_n = net radiation [$H_n = (1-\alpha) H_e$]

E_a = wind velocity parameter

γ = psychrometric const. = 0.49 mm mercury/°C albedo

মোট পাচ্ছি sunlight

1. $H_n = H_a (1 - r)\left(a + b\frac{n}{N}\right) - \sigma T_a^4 \left(0.56 - 0.092\sqrt{e_a}\right)\left(0.1 + 0.9\frac{n}{N}\right)$

actual/incident radiation

max^m possible sunlight

ধ্রুবক ← $\boxed{2.01 \times 10^{-9}\ \text{mm/day}}$

actual vap pressure

2. $E_a = 0.35\left(1 + \frac{u_2}{160}\right)(e_w - e_a)$

km/day

$$\boxed{\text{relative humidity} \times e_w = e_a}$$

3. $e_w = 4.584\, e^{\left(\frac{17.27 \times t}{237.3 + t}\right)}$ $\boxed{\text{mm of Hg}}$

4. $A = \dfrac{4098\left[0.6108\, e^{\frac{17.27\, T}{T + 237.8}}\right]}{(T + 237.3)^2} \times \dfrac{760}{101.325} \dfrac{\text{mmHg}}{\text{kPa}}$

°C

*] Problem:

Calc. PET in June by (a) Penman
(b) Thornthwaite

lat = 28°N

elv = 230 m above MSL

Mean obs. sunshine = 9h / day.

Month	Temp (°c)	Relative humidity	wind vel at 2m above GL (km/h)
Jun	33.5	52	10.0

Soln:

$$A = \frac{4098\left[0.6108\, e^{\frac{17.27T}{T+237.3}}\right]}{(T+237.3)^2} \times \frac{760}{101.325}$$

$$= 2.16$$

saturated vap. pressure, $e_w = 4.584\, e^{\frac{17.27 \times 33.5}{237.3 + 33.5}}$

$$= 38.82 \text{ mm of Hg}.$$

28°N, June এর জন্য, Table থেকে, interpolation.
$H_a = 16.36$ mm/day

$N = 13.94$ hr/day. [from Table]

$n = 9$ hr/day.

$e_a =$ relative humity (RH) $\times e_w$

$= 0.52 \times 38.82$

$= 20.177$ mm of Hg.

$\boxed{\gamma = 0.49} \rightarrow$ মুখস্থ

latitude

$a = 0.29 \cos \phi$

$= 0.29 \cos 28$

$= 0.256$

$\boxed{b = 0.52} \rightarrow$ মুখস্থ

albedo, $r = 0.05$, $\sigma = 2.01 \times 10^{-9}$
[For waterbody]

$T_a =$ in Kalvin

$H_a = 16.36$ [table 3.4]

$$H_n = \boxed{16.36} \times (1-0.05)\left(0.256 + 0.52 \times \frac{9}{13.94}\right) - \left[2.01 \times 10^{-9} \times \underbrace{(33.5+273)^4}_{\text{at kalvin}}\right.$$

$$\left. \times \left(0.56 - 0.092 \times \sqrt{20.177}\right) \times \left(0.1 + 0.9 \times \frac{9}{13.94}\right)\right]$$

$= 9.1966 - 1.77$

$= 7.42$

$$E_a = 0.35\left(1 + \frac{u_2}{160}\right)(e_w - e_a)$$

$$= 0.35\left(1 + \frac{10 \times 24}{160}\right)(38.82 - 20.177)$$

$= 16.31$

(a) $$PET = \frac{2.16 \times 7.42 + 16.31 \times 0.49}{2.16 + 0.49}$$

$= 9.064$ mm/day

$= (9.064 \times 30)$ mm in June

$= 271.9$

Scanned by CamScanner

exam ⊛⊛⊛ Why actual ET differs from PET

→ soil saturated [illegible] [illegible] [illegible] [soil dry [illegible] [illegible]]
→ vegitation [illegible] [coverage diff]
→

Lec 8

যদি এমন জায়গায় যাই যেখানে wind speed, sunshine hour নাই or এত জানি না সেখানে empirical formula use করা হয়।

But that's not accurate much.

* Blaney - Criddle equ^n:

$$\boxed{E_T = 2.54\, K f}$$

$$f = \sum P_n \bar{T}_f / 100$$

$\bar{T}_f$ at °F

Tables:

1. K এর একটা table আছে (differs by crops)
2. Monthly day time hour %

✱ Problem:

For an area in South India (Lat = 12°N) the mean monthly temp are given

Month	June	July	Aug	Sep	Oct
Temp (°C)	31.5	31.0	30	29	28
Temp (°F)	49.5	49.2	48.6	48.1	47.6

Calc the seasonal consumptive use of water for the rice crop in the season June 16 to Oct 15. using Blaney-Criddle formula.

not whole month ($\frac{1}{2}$ দিয়ে multiply)

[illegible] last by [illegible]

Sol^n:

$$F = \sum P_h \bar{T}_f / 100$$

June $\Rightarrow \frac{1}{2} \times P_h \times T_f = \frac{1}{2} \times 8.68 \times 49.5$

July $\Rightarrow P_h \times T_f = 8.94 \times 49.2$

Aug $\Rightarrow P_h \times T_f = 8.76 \times 48.6$

Sep $\Rightarrow P_h \times T_f = 8.26 \times 48.1$

Oct $\Rightarrow \frac{1}{2} \times P_n \times T_f = \frac{1}{2} \times 8.31 \times 47.6$

$$\sum P_h \bar{T}_f = 1675.9$$

$$F = \frac{\Sigma P_h T_f}{100}$$

$F = 16.754$

For rice, $k = 1.10$.

$E_T = 2.54 \times 1.10 \times 16.754$

$= 46.81$ (in a crop season) in cm

$= 46.81$ cm.

☒ Thornthwaite formula:

adjustment of no. of hours of daylight and days in month (related to Lat)

in °C

$$E_T = 1.6\, L_a \left(\frac{10\, T}{I_t} \right)^{a}$$

empirical const

$$= 6.75 \times 10^{-7} I_t^3 - 7.71 \times 10^{-5} I_t^2 + 1.792 \times 10^{-2} I_t + 0.49239$$

the total 12 monthly values of heat index

$$= \sum_{1}^{12} i, \text{ where } i = \left(\frac{T}{5} \right)^{1.514}$$

PET in cm

1) $i = \left(\frac{T}{5} \right)^{1.514}$

2) $I = \sum_{i=1}^{12} i$ [12 মাসের sum]

3) $a \rightarrow f(I)$

4) $L_a \rightarrow$ Table or

5) ET

Problem:

~~Calc the PET in the month of June by (a) Penman~~

A catchment area near Mysore is at latitude $12°18'$ N and at an elev. of 770m. The mean monthy temp are given below:

Month	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov.	Dec
temp	22.5	24.5	27	28	27	25	23.5	24.	24	24.5	23	22.5

Calc the monthly and annual PET for this catchment using Thornthwaite formula

[illegible] 15days [illegible] Then $\frac{1}{2}$ [illegible]

Reference Crop Evapotranspiration (ET_0)

→ যে গাছের পাতার surface area ↑ ET ↑

→ age বেশী হলে ET ↓

certain crop কে reference হিসেবে নিয়ে, Then তার basis এ অন্য গুলোর জন্য বের করব।

FAO → Food & agriculture organization.

Def^n: hypothetical grass এর ht = 0.12 m

surface resistance = 70 sm^{-1}

albedo = 0.23

হলে যে ET সেটিই standard $\boxed{ET_0}$

again, $\boxed{ET} = k\,(ET_0)$

reference crop এর জন্য

অন্য গাছের জন্য

ওই গাছের জন্য $k > 1$

crop co-efficient

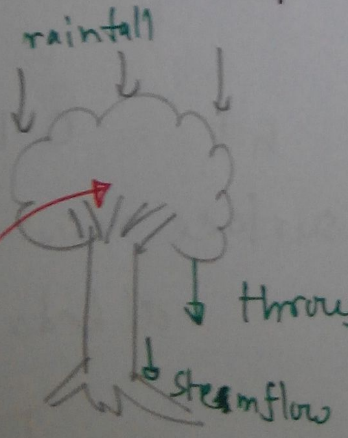
বই থেকে k / Kc এর table

* Measurement of ET:

দুই
- → Lysimeter [soil moisture এর wt নিয়ে calc করে] যত বেশী ET↑ wt↓.
- → Field plot [plot নিয়ে পানি দিব. গাছ থাকবে, কী পরিমান পানি গেল সেটাই calc]

* e. Initial loss → যেটা run-off এ participate করেনা

1. Interception.

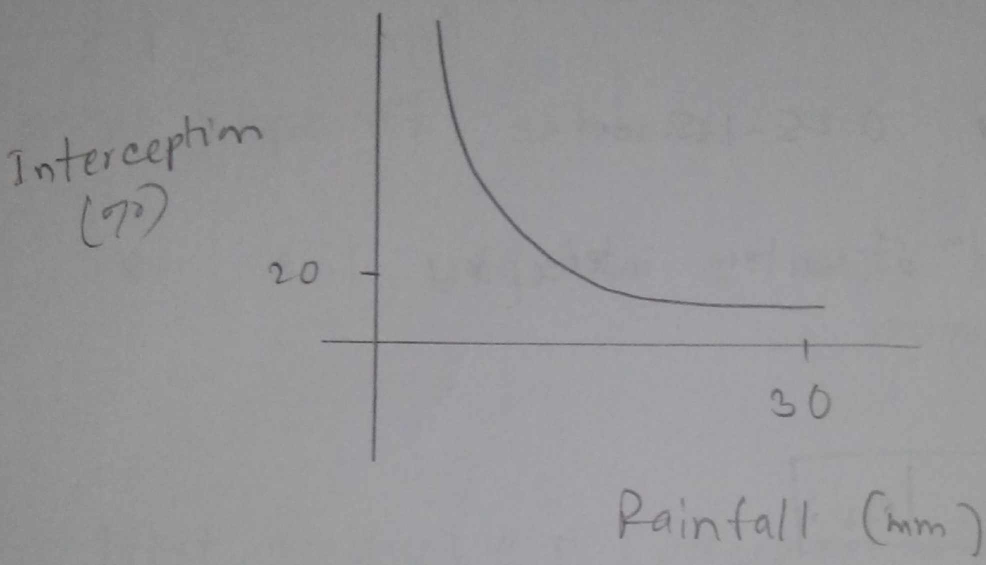


বৃষ্টির পর যে পানি গাছের পাতা ধরে রাখে সেটা.

Interception = Rainfall − stemflow − throughfall.

বৃষ্টির শুরুতে interception হার বেশি.
(intensity কম)

" শেষে " বেশী " " কমতে থাকে,



Factors:

→ গাছের পাতার surface area

→ " crown যত বড়

→ (1) storm characteristic : wind speed, intensity

→ (2) vegetation :

→ (3) season : শীতে interception কম।

Estimation of interception:

$$I_i = S_i + K E t$$

$K E$ → Evapotranspiration

t → duration

S_i → guess করে নিবে (exam এ দিবে missing থাকলে)

S_i → 0.25-1.25 mm

I_i → vol^m of water intercepted

Initial loss:

2. **Depression storage**

→ বড় গর্ত হলে বেশী

→ material এর উপর

sand হলে infiltrate বেশি

clay " " কম

→ run-off এ contribute কম করে,

→ " " " বেশী " .

Influencing factor:

1. Type of soil : sand, clay.
2. condition of surface : amount and nature
3. slope of catchment
4. soil moisture : কম হলে suck বেশী করবে.

Next monday : CT (precipitation)

এই ২য় example.

Lec 9 — 24/08/17

D. Infiltration

→ certain depth পর্যন্ত যে moisture থাকে সেটি tree use করে ET করে।

→ এর নিচের water টি infiltrate হয়ে যায়,

X ***exam

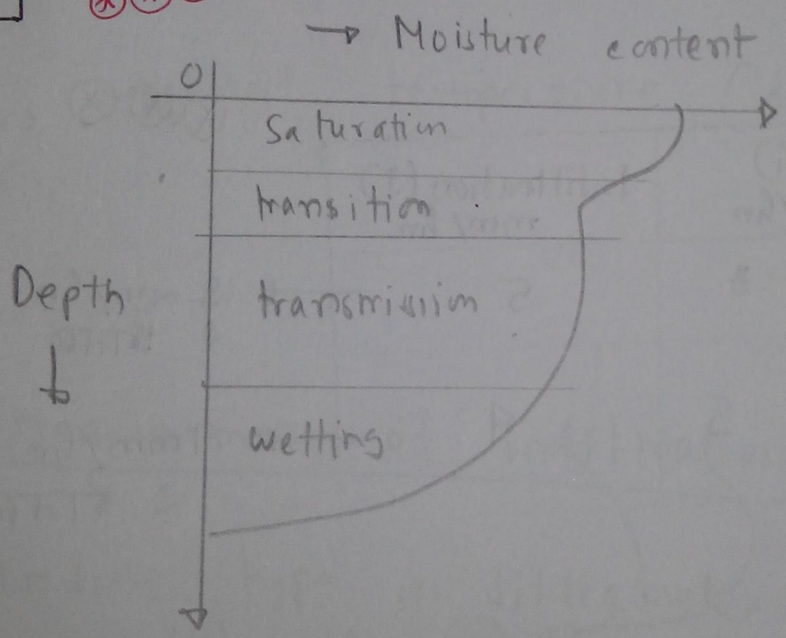


fig: Distribution of soil moisture in the infiltration process

max^m rate at which a given soil at a given time can absorb water (cm/h)

$I = I_e$ when $i \geq I_e$

$I = i$ when $i < I_e$

	Rainfall (i) mm/hr	Infiltration (I) mm/hr
cond^n 1	3	5
cond^n 2	5	4

✱✱✱ exam

→ 3 mm/hr rate এ টানবে

→ 4 mm/hr rate এ টানবে।

→ 4 hr এ infiltration = 16 mm

run off = 4 mm

[x] factors affecting infiltration:

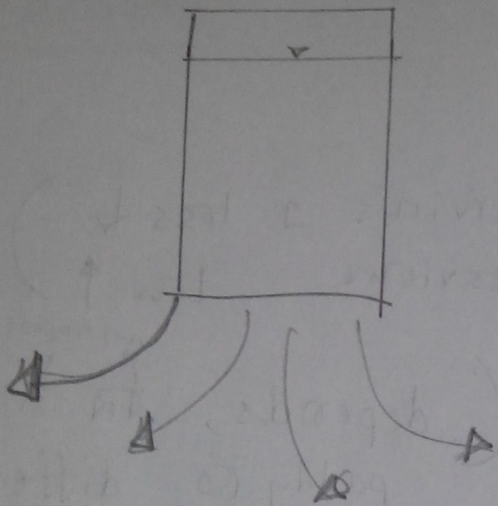
- → soil type
- → soil surface (impervious এ loss ↓
  pervious loss ↑)
- → vegetation cover (depends, বন & rice or paddy তে different)
  root compact
  root loose
- → moisture content
- → soil temperature (dry এ temp ↑
  wet " " ↓)
  কারণ water এর heat holding capasity বেশী।

[x] Measurement of infiltration:

Flooding type infiltrometer → simple ~~& double ring~~
→ double ring

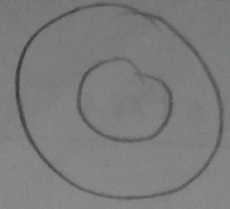
hollow cylinder মাটিতে ঢুকিয়ে এ পানি দিয়ে reading নিচ্ছি। আস্তে আস্তে পানি কমবে। [যদি বৃষ্টি হয় then বাড়তে পারে if rainfall rate > infiltration rate]

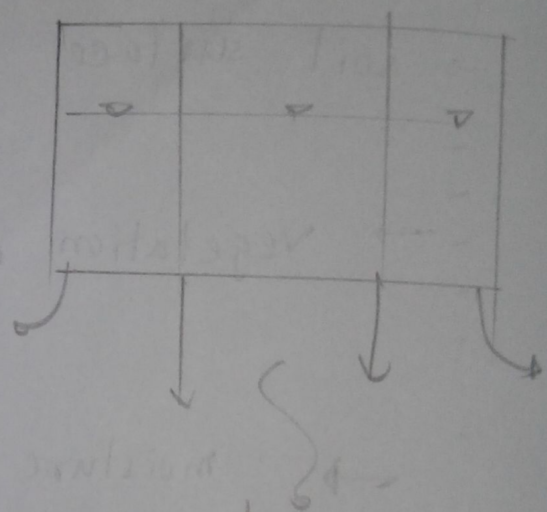
Simple (tube type)



radially ছড়িয়ে যাচ্ছে।

Double ring





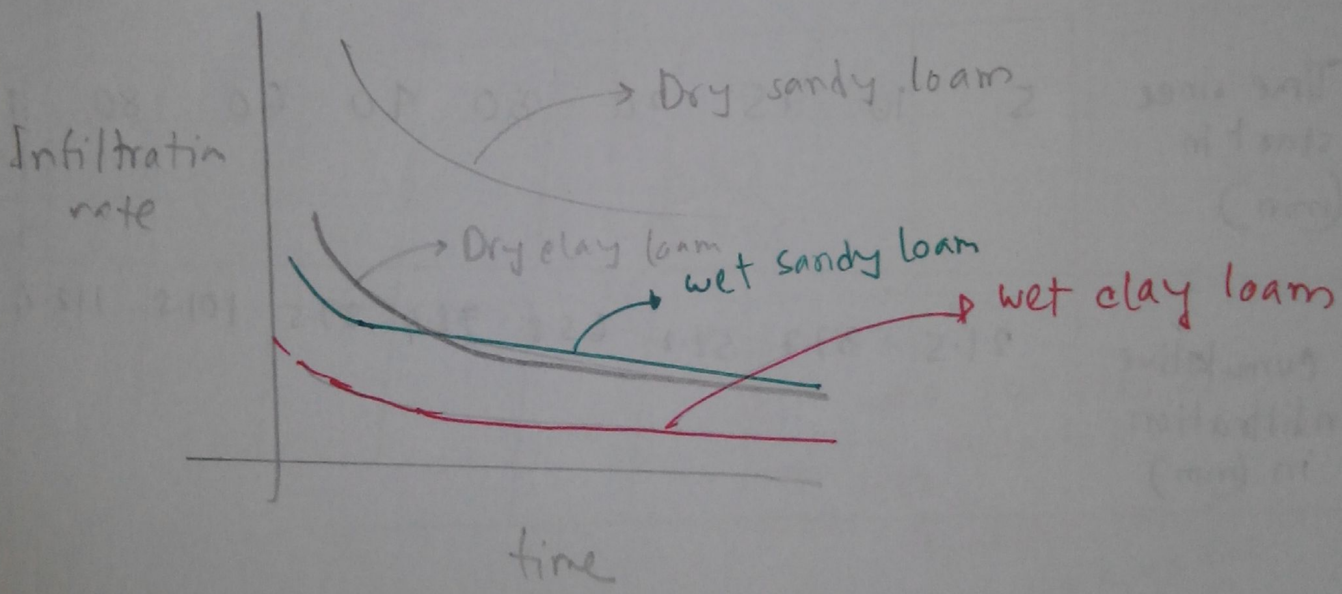
এখানে vertical reading যায়।

এখানে inner tube এর পানি verti
যাচ্ছে, radiall
যেতে পারছে ন

☒ Horton's Infiltration Model :

$$f_p = f_c + (f_0 - f_c)e^{-k_h t} \quad \text{—— (1)}$$

dry soil এ infiltration capacity ~~কম~~ বেশী। বৃষ্টি continous পড়লে " " কমতে কমতে constant



$$(1) \Rightarrow (f_p - f_c) = (f_0 - f_c)\, e^{-k_h t}$$

$$\Rightarrow \underbrace{\ln(f_p - f_c)}_{y} = \underbrace{\ln(f_0 - f_c)}_{\substack{c \\ \text{(intercept)}}} - \underbrace{k_h}_{m}\, t \longrightarrow x$$

$\boxed{y = mx + c}$ type

Problem

Results of an infiltrometer test on a soil are given below. Determine the best values of the parameters of Horton's infiltration capacity equ^n for this soil.

Time since start in (min)	5	10	15	20	30	40	60	80	100
Cumulative infiltration in (mm)	21.5	37.7	52.2	65.8	78.4	89.5	101.8	112.6	12

0					
5	2.15	2.1	$\frac{2.1 \times 60}{5} = 25.8$		0.083
10	3.77	1.62	19.44		0.167
15	5.22	1.45	$\frac{1.45 \times 60}{5}$ 17.4		
20					
30					
40					
60					
80			3.69		
100			3.24		

$\rightarrow f_e = 3.24$

last value plot করব না কারণ ln(fp-fe) = ln0 = undefined হয়ে যাবে।
অথবা, fe slightly কমিয়ে ধরতে পারি।

$k = 4.1235$

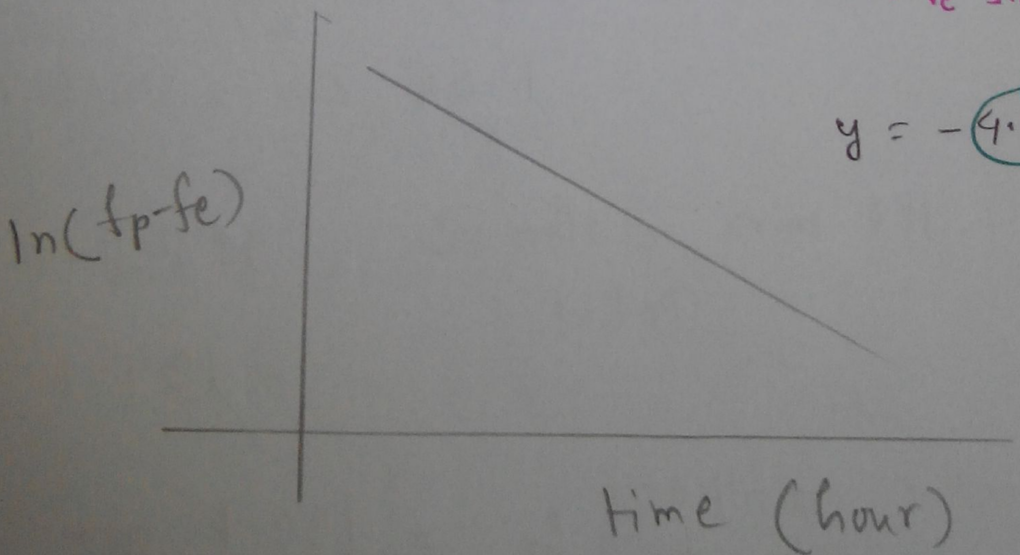
$y = -4.1235x + 3.6393$

$\rightarrow \ln(f_0 - f_e)$

$f_e = 41.3$

$f_0 - f_e = 38.06$

$f_e = 41.3$



$$f_p = 3.24 + (41.3 - 3.24)\, e^{-4.1235 \times t}$$

$\boxed{\bar{x}}$ from that equ^n,

$t = 2$ hour এ cumulative infiltration = ?

$$\boxed{\text{infiltration rate } f_p = 3.24 + 41.3\, e^{-4.1235 \times 2}}$$ → rate is varia

But integrate করলে cumulative infiltra

পাব when $\boxed{\text{rate is variable}}$

So, integration করব ।

আমরা, 100 এ const ধরেছি । (f_c = 3·

100 min এ cummulative = 123.3 ছিল .

so, last 20 min এ

total $= 3.24 \times \frac{20}{60}$

$= 1.08$ cm $= 10.8$ m

∴ 120 min or 2hr এ Total $= 123.3 + 10.8$

$= 134.1$ m

cumulative infiltration at $t = 2$ hr $= 134.1$ mm

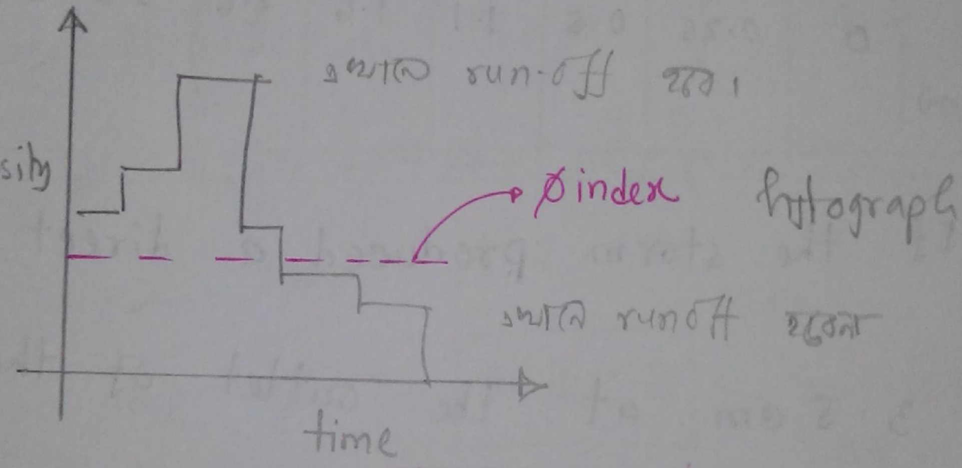
CT → ৫/১০/১৫

Lec 10 07/05/17

∅-index

→ loss estimate করার parameter

→ run-off হতে হলে Rainfall > loss হতে হবে।



problem:

ex: বই এর ∅ index এর math ( )

Solⁿ:

Run-off =?

$$loss = 10 - 5.8 = 4.2$$

$$avg\ loss = \frac{4.2}{8} = 0.53$$

1 hr এ run-off হবেনা।

2 – 7 hr এ হবে, 8 hr এ হবেনা

Time from start (hr)	0	0.5	1	1.5	2	2.5	3	3.5	4.	4.5	5
Cumulative rainfall (cm)	0	0.25	0.5	1.1	1.6	2.6	3.5	5.7	6.5	7.3	7.7
	0	0.25	0.25	0.6	0.5	1	0.9	2.2	0.8	0.8	0.4

If the storm produced a direct run off of 3.5 cm at the outlet of the watershed, estimate $\boxed{\phi\text{ - index}}$ of the storm and duration of R.F.

Soln:

Pulse number	1	2	3							
Time	0.5	0.5	0.5							
Cum rainfall	0.25	0.5	1.1							
Incremental rainfall (cm)	0.25	0.25	~~0.6~~ 0.6	0.5	1.0	0.9	2.2	0.8	0.8	0.4
Intensity (cm/hr)	0.5	0.5	1.2	1	2	1.8	4.4	1.6	1.6	0.8

let, n = 7, n = 8

7 টি pulse এ run-off আসেনি (1, 2, 10 এ আসেনি)

$$\sum_{i=1}^{10} (I_i - \phi)\Delta t = \text{Run-off } (3.5\text{ cm})$$

7 টি pulse হলে, $\sum_{i=1}^{7} (I_i - \phi)\Delta t = 3.5$ cm

$$\Rightarrow \sum_{i=1}^{7} I\Delta t - n\phi\Delta t = 3.5\text{ cm}$$

$$\Rightarrow \Delta t\left[15.4 - 7\times\phi\right] = 3.5$$

$$\Rightarrow 15.4 - 7\phi = \frac{3.5}{0.5} = 7$$

$$\Rightarrow 7\phi = 15.4 - 7$$

$$\Rightarrow \phi = \boxed{0.943}$$ → 7 টির value এর থেকে বেশী,

But n=8 এর জন্য $\phi = 0.925$. [মিলেনি]

let, n = 5. হলে, $\phi = 0.88$. [matched]

[Exam এ n এর trial 1-2 বার দিলেই হবে]

W-index

→ math করার দরকার নাই।

→ Def^n হই গেলে।

$$W = \frac{P - R - I_0}{I_e}$$

⊗ Difference bet^n w-index and ϕ-index.

Lec 11

Chapter 4

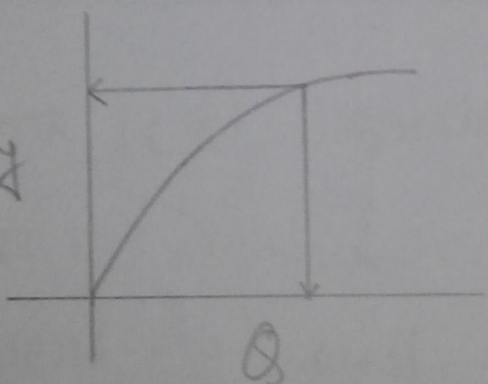
Stream Flow measurement

→ current meter দ্বারা 'v' measure করে, $Q = Av$ দ্বারা flow measure করি।

→ high flow/current থাকলে currentmeter দ্বারা measure করা tough হয়ে যায়।

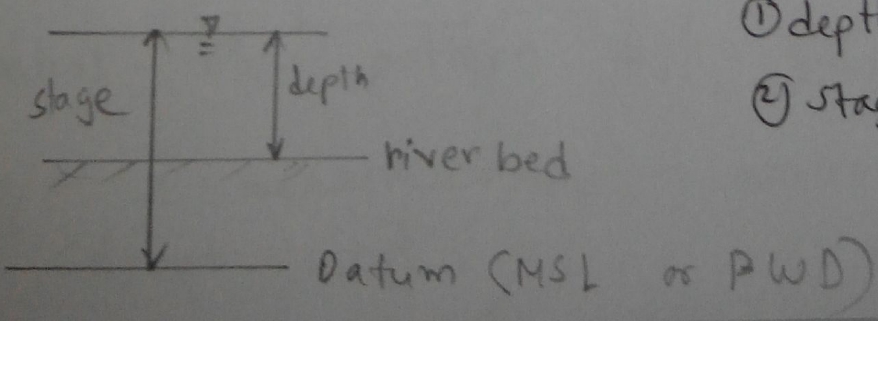
→ depth vs discharge curve /grating curve

50 days data নিয়ে



একটি graph develop করে পরে যেকোন data এর জন্য 'y' জানলে 'Q' জানতে পারব।

→

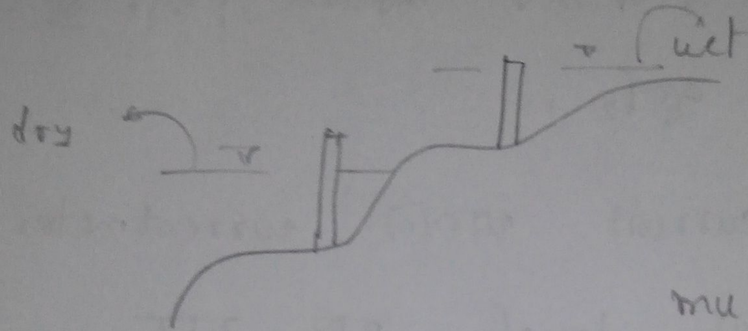


① depth

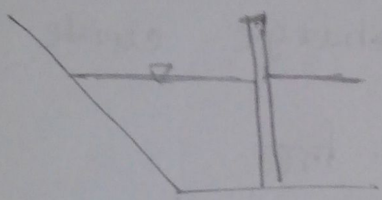
② Stage

→ Method of measurement:

staff দ্বারা measure করতে পারি।

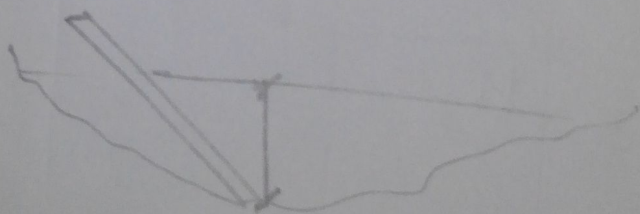


multiple staff
(when dry & wet এ WL diff]

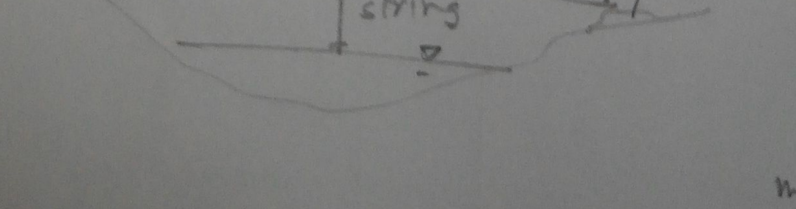


(এভাবেই হয়,

inclinded staff (ঢেউ হবার chance থাকলে)



wire gauge



→ RL জানি so, plumb bob দ্বারা string measure করতে পারি

2. Recording gauge.

(a) Float type

well dig করে, float টি পানিতে রেখে হলে pressure করে যাবে চাপের, হুলে ঘুরবে, angular movement এই characteristic হবে reading.

(b) Bubble gauge

pressure ↑ (হলে) gas এর release ↓

(এখান থেকে WL জানা যাবে)

Rules guilding location of gauges:

→ যেখানে বেশি scouring হয় সেখানে staff দিবনা।

→ bend এ staff দিলে centrifugal force এর কারণে inclined হয়ে যেতে পারে।

→ control; flow pattern diff হয় যার উপরে,

→ u/p এ measure করব as control এর effect নাই।

→ turbulence এর effect এর কারনে d/s এ set করেনা।

[*] Advantage over the float-type : (বই)

→ well খুড়া লাগেনা,

→ inlet obstruct.

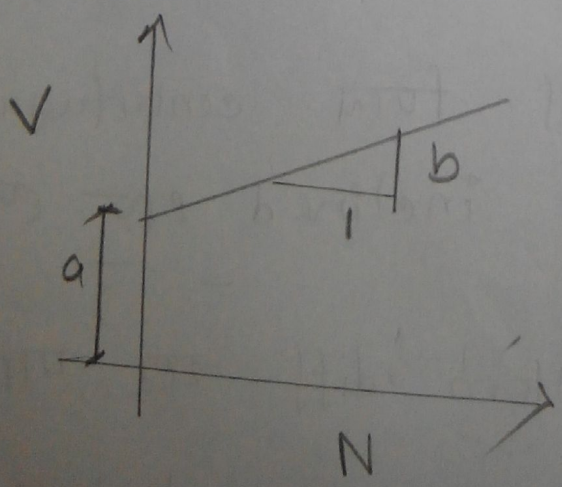
[*] vel measurement:

→ vertical axis (বই)

→ horizontal " (")

→ current meter:

$$V = a + bN$$



[*] Q_s measurement :

1. Area - velocity method

$$Q_s = V_{av} \times A$$

✓ $V_{av} = V_{0.6}$ depth < 3m (shallow depth)

✓ $V_{av} = (V_{0.8} + V_{0.2})/2$ (moderate depth)

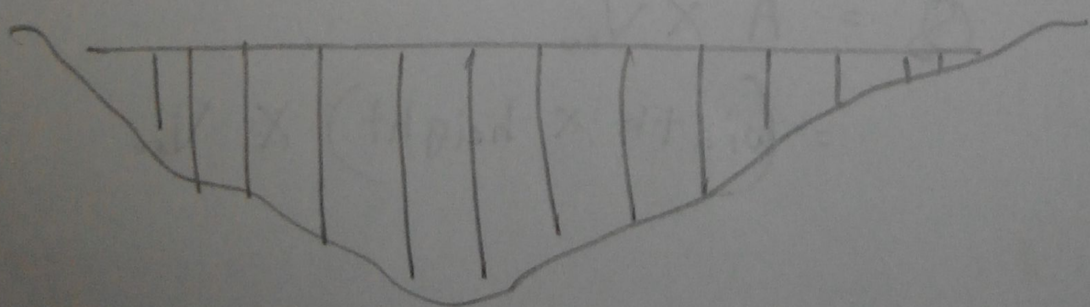
✓ $V_{av} = k \bar{V}_{0.5}$ for (deep stream - flood flow)

$$k = 0.85 - 0.95$$

vel measurement

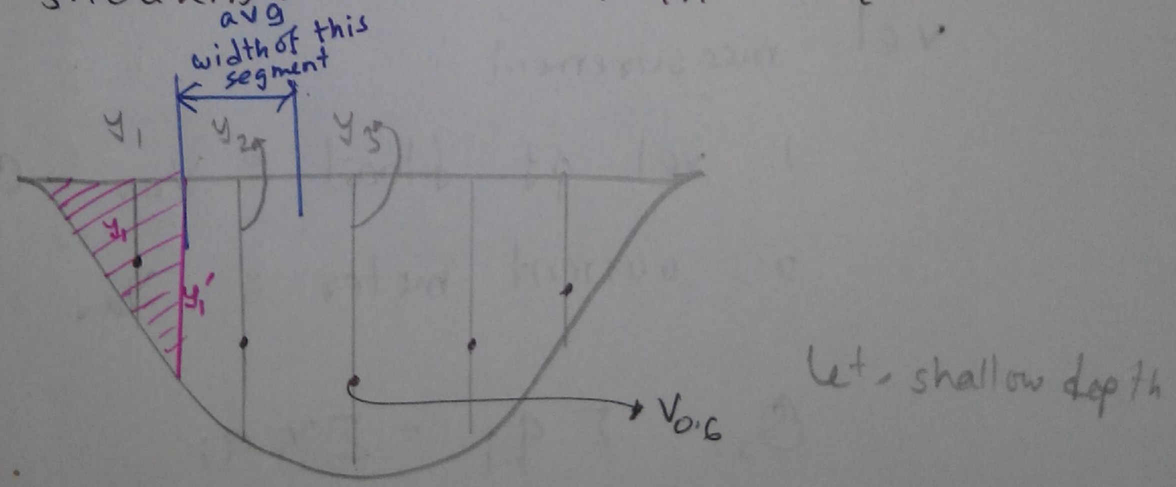
1. vel of float : $V_{av} = C V_f$
2. current meter : $V_{av} = a + bN$

$$Q_s = \Sigma q_i = \Sigma v_i a_i$$



Guidelines of choosing sec:

- The segment width shouldn't greater than $\frac{1}{15}$ to $\frac{1}{20}$ of the width of the river
- The Q in each segment shouldn't be less than 10% of the total Q.
- The diff of vel in adjacent segment shouldn't more than 20%



$$Q = A \times V_{av}$$

$$= (\text{width} \times \text{height}) \times V_{av}$$

triangle (Δ) টির জন্য

$$\frac{y_1'}{y_1} = \frac{w_1 + \frac{w_2}{2}}{w_1}$$

$$\Rightarrow y_1' = \frac{w_1 + \frac{w_2}{2}}{w_1} \times y_1$$

$$A = \frac{1}{2} \times y_1' \times \left(w_1 + \frac{w_2}{2}\right)$$

$$= \frac{1}{2} \times \frac{\left(w_1 + \frac{w_2}{2}\right)}{w_1} \times y_1 \times \left(w_1 + \frac{w_2}{2}\right)$$

$$= \boxed{\frac{1}{2} \times \frac{\left(w_1 + \frac{w_2}{2}\right)^2}{w_1}} \times y_1$$

avg width

rectangular (□) এর জন্য,

$$A = y_2 \times \boxed{\frac{w_2 + w_3}{2}}.$$

avg width

end section (Δ) এর জন্য,

$$A = \frac{1}{2} \times \frac{\left(w_N + \frac{w_{N-1}}{2}\right)^2}{w_N} \times y_n$$

Problem: 0.6 d তে নিতে বলেছে → direct বসিয়ে দিব

But যদি বলা না থাকে ($V_{0.2}$, $V_{0.6}$, $V_{0.8}$ সব দেয়া)

judgement apply করে $V_{0.6}$ দিব নাকি

$\frac{V_{0.2} + V_{0.8}}{2}$ নিব।

(*) A current meter with calibration eqn

$$V = (0.32N + 0.032) \text{ m/s}$$

N = rev/se at $V_{0.6}$

Using mid section method, calc Q

Distance from right bank (m)	0	2	4	6	9	12	15	18	20	22	23	24
Depth (m)	0	0.5	1.1	1.95	2.25	1.85	1.75	1.65	1.5	1.25	0.75	0
No. of rev	0	80	83	131	139	121	114	109	92	85	70	0
Obs. time (s)	0	180	120	120	120	120	120	120	120	120	150	0
avg width (m)	0	2.25	2	2.5	3	3	3	2.5	2	1.5	1.125	0
~~[illegible]~~ $N = \frac{N}{t}$	0	0.44	0.69	1.09	1.15	1.008	0.95	0.903	0.766	0.708	0.467	

	0	2	4	6	9	12	15	18	20	22	23	24
V	0	0.179	0.253	0.381	0.403	0.36	0.336	0.323	0.277	0.258	0.22	0
q		0.196	5566	1.85	2.72	1.998	1.764	1.33	0.831	0.484	0.186	0

$\Sigma q =$

$Q = 11.895$

CT - রবিবার (chap 5)

<u>CT ques:</u> infiltration upto 15 hr →

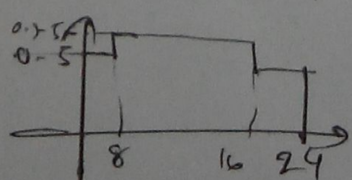
" after 15 " →

E = given

loss = given

runoff = $\boxed{\text{Precipitition}}$ − loss

hyetograph



volm = P.