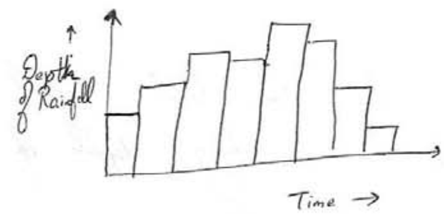
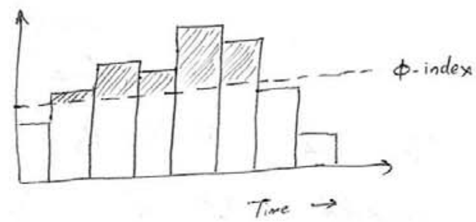
Excess Rainfall

In the last class we discussed on excess rainfall.
- → What is meant by excess rainfall
- → From a given rainfall data - how to find the excess rainfall, etc.

The method we discussed in the last class was the ϕ- index method.





Depth of excess rainfall = Depth of direct runoff

i.e. $$r_d = \sum_{i=1}^{M} (R_i - \phi \Delta t)$$

where M is the number of intervals of rainfall that actually contribute to direct runoff.

→ So now you know that in the actual rainfall depths (R_i) you need to ~~de~~ deduct some quantities to obtain the depth of rainfall (r_d).

→ One can easily say $r_d = f(R_i)$.

Runoff Coefficients

One particular method of relating r_d with rainfall depths is the use of runoff coefficients.

i.e. $r_d = C R$

where $r_d \rightarrow$ depth of runoff
$R \rightarrow$ depth of rainfall
$C \rightarrow$ runoff coefficient

Runoff coefficient $\rightarrow$ is the ratio of peak rate of direct runoff to the average intensity of rainfall in a storm.

$\rightarrow$ It is also defined as ratio of runoff to rainfall over a given time period.

e.g.: If $R_1, R_2, R_3, \ldots, R_m$ are the total rainfall recorded and if r_d is the corresponding depth of runoff, then $C = \dfrac{r_d}{\sum_{m=1}^{M} R_m}$

SCS Method

Soil Conservation Service (1972) developed a method for computing abstractions from storm rainfall.

$\rightarrow$ When you consider a storm

* You can think of depth of excess rainfall or depth of direct runoff (P_e).
* You can see that this $P_e \leq P$ (the depth of rainfall).
* Whatever rainfall occurs there will be some abstractions.

* We can suggest a depth of water that gets retained in the watershed or abstracted (F_a).
* This depth $F_a \leq S$, the depth of potential maximum retention possible.
* There can be some amount of rainfall I_a (initial abstraction) before ponding for which no runoff occurs.
* Now you can see that the potential maximum depth of runoff possible is $= P - I_a$
* SCS method suggests that the ratio of two potential quantities is equal to the ratio of their actuals.

i.e.
$$\frac{S}{P - I_a} = \frac{F_a}{P_e}$$

→ From the continuity principle, you can see in this case that the total water available here is P.

$$P = P_e + I_a + F_a$$

$$\frac{P_e}{(P_e + I_a + F_a) - I_a} = \frac{F_a}{S}$$

Rearranging, we get
$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

→ From studies on various small experimental watersheds, ~~dl~~ an empirical relation was observed

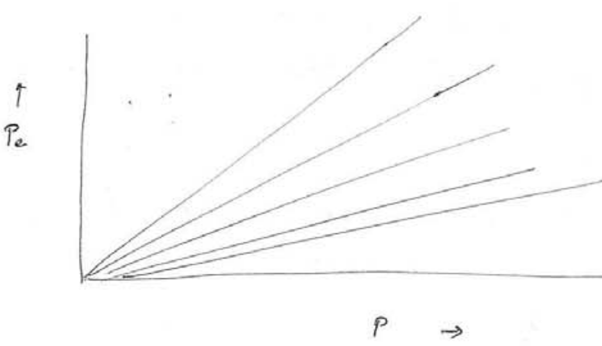
$$I_a = 0.2\,S$$

$\therefore$ Now $$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

The soil conservation service plotted data for P and P_e for many watersheds. From these plots they obtained some curves (called SCS curves or Curve Numbers).

* Curve number is a dimensionless number

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$ graphically plot this equation



$$CN = \frac{1000}{10 + S}$$

The observations and depths here are in <u>inches</u>. When you solve for your ~~cross~~ problem appropriate conversions need to be employed.

$$S = \frac{1000}{CN} - 10$$

$S \rightarrow$ in inches.

$$\therefore \quad CN = \frac{1000}{10 + S}$$

→ The curve number obtained here is for normal antecedant moisture conditions (AMC II).

→ For dry conditions (AMC I)

$$CN(I) = \frac{4.2 \; CN(II)}{10 - 0.058 \; CN(II)}$$

For wet conditions (AMC III)

$$CN(III) = \frac{23 \; CN(II)}{10 + 0.13 \; CN(II)}$$

AMC	Total 5-day antecedant rainfall (in) Dormont Season	Growing Season
I	< 0.5	< 1.4
II	0.5 to 1.1	1.4 to 2.1
III	> 1.1	> 2.1

We can define four soil groups based on SCS curve numbers:

Group A : Deep Sand, Deep loess
Group B : Sandy loam, Shallow loess
Group C : Clay loams, soils low in organic content, etc.
Group D : Heavy plastic clay, swelling clays, etc.

Example :

Compute runoff from 5-inches rainfall on a 1000 acre watershed. The hydrologic soil group is – 50% Group B and 50% Group C.
Assume AMC(II). The landuse has:

40% residential area having 30% imperviousness
12% residential area having 65% imperviousness.
18% paved roads with curbs and storm sewers
16% open land with 50% grass cover, 50% good grass cover.
14% parking lots, plazas, schools etc. (Impervious)

Solution

Total Area = 1000 Acres.
∴ Residential area ⇒ 20% Similarly others

We need to compute weighted soil curve number for the given watershed.

Land Use	Soil Group B %	CN	(% × CN)	Soil Group C %	CN	
Residential (30% Imp).	20	72	1440	20	81	1620
" (65% Imp)	6	85	510	6	90	540
Roads	9	98	882	9	98	882
Open Land grass cover	4	69	276	4	79	316
good grass cover	4	61	244	4	74	296
Parking Lot	7	98	686	7	98	686
	50		4038	50		4340

$$\therefore \text{Weighted } CN = \frac{4038 + 4340}{50 + 50} = 83.8$$

For AMC(II), $S = \frac{1000}{CN} - 10$

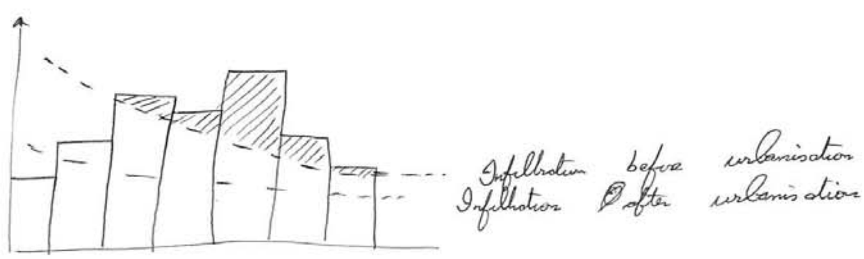
$$= \frac{1000}{83.8} - 10 = 1.93 \text{ in}$$

$$\therefore P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$= \underline{\underline{3.25 \text{ inches}}}$$

So you can see from 5-inch rainfall you have 3.25 inch runoff.

Urbanisation Effects



→ Due to urbanisation soil perviousness is reduced. Therefore there will be less water is infiltrated. Therefore there will be more surface runoff.