Example 1:

The recession limb o f a flood hydrograph is given below. The time is indicated from the arrival o f peak. Assuming the interflow component to be negligible ,estimate the base flow and surface flow recession coefficients. Also, estimate the storage at the end o f day-3.

Time from peak (day)	Discharge (m^3/s)	Time from peak (day)	Discharge (m^3/s)
0	90	4.0	3.8
0.5	66	4.5	3.0
1.0	34	5.0	2.6
1.5	20	5.5	2.2
2.0	13	6.0	1.8
2.5	9.0	6.5	1.6
3.0	6.7	7.0	1.5
3.5	5		

Solution:

The data are plotted on semi-Log paper. The flow from 4.5 to 7 days are seen to lie on straight Line AB in Fig (9). ??

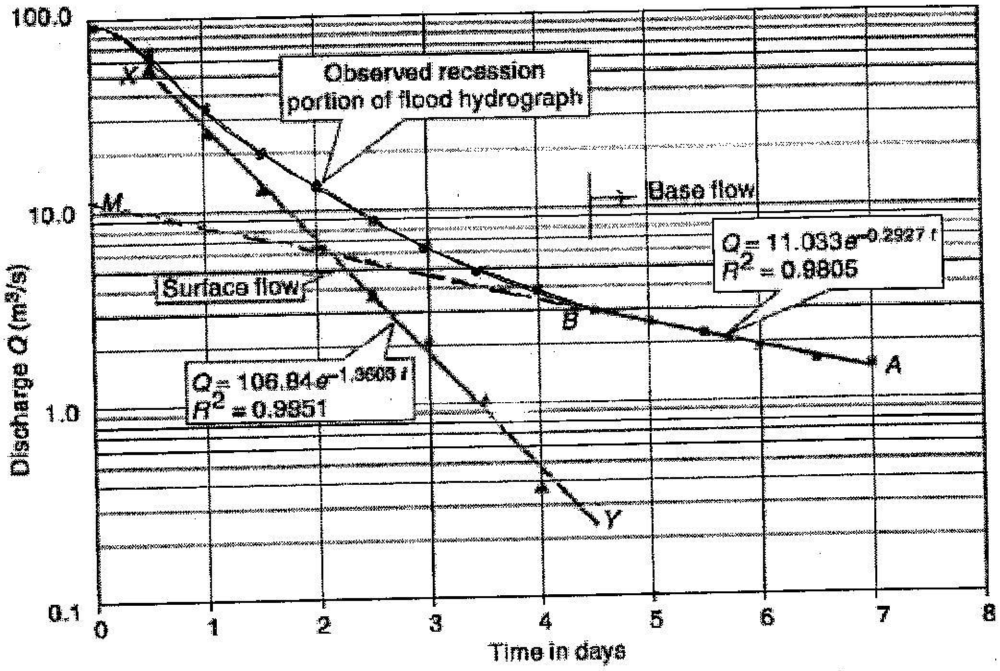

Fig. 9 Storage Recession Curve – Example 1

From eq(4): $\frac{Q_2}{Q_1} = K_r^{(t_2 - t_1)}$

$\log K_{rb} = \frac{1}{t_2 - t_1} \log\left(\frac{Q_2}{Q_1}\right)$ for base flow (Line BM).

Select: at $t_1 = 0 \rightarrow Q_b = 11$
at $t_2 = 4.5 \rightarrow Q_b = 3$ $\Bigg\} \Rightarrow \log K_{rb} = \frac{1}{4.5 - 0} \log\left(\frac{3}{11}\right)$

$K_{rb} = 0.749$ $\left[Q_b = 11\,(0.749)^t\right]$ BM

Thus; the surface runoff depletion is obtained by subtracting the base flow from the given recession limb of the hydrograph. and Apply the above procedure taking at $t_1 = 0$, $Q_s = 79$ and

$t_2 = 3$ day $\rightarrow Q_s = 2.078\ m^3/s$ $\Rightarrow K_s = 0.297$

$\Rightarrow \left[Q_s = 79\,(0.297)^t\right]$ XY

From eq (6): The storage available at end of t-days is;

$$S_b + S_s)_t = \left(\frac{Q_b}{-\ln K_b} + \frac{Q_s}{-\ln K_s}\right)$$

at period t = 3 days:

$$Q_b = 11\,(0.749)^3 = 4.622\ m^3/s$$

$$Q_s = 79\,(0.297)^3 = 2.07\ m^3/s$$

$$\Rightarrow S_3 = \frac{4.622}{-\ln 0.749} + \frac{2.07}{-\ln 0.297} = 16 + 1.7 = 17.7\ \frac{m^3}{s}\cdot day\ (\text{cumec}\cdot\text{day})$$

$$= 1.52928\ Mm^3$$

هذا الخزين المائي المؤثر ابتداءً من نهاية اليوم الثالث .

<u>H.W</u> In a stream the base flow is observed to be 30 m³/s on May 1st and 23 m³/s on May 10th. If there is no rain during May, estimate the base flow on 30th May and the volume of groundwater storage on May 1st & May 30.

Effective rainfall (ER) المطر المؤثر

Effective (المؤثر) rainfall or Excess (الزائد) rainfall (ER) is the part of rainfall that becomes direct runoff at the outlet of catchment area.

It is thus, the total rainfall from which abstractions (infiltration & initial loss) are subtracted. The DRH was correlated with so-called hyetograph of effective rainfall (ERH) shown in Fig (10).

DRH & ERH represent same quantity but in different units.

<u>ϕ-index</u>, represents the average rainfall intensity above which the rainfall volume is equal to the runoff volume.

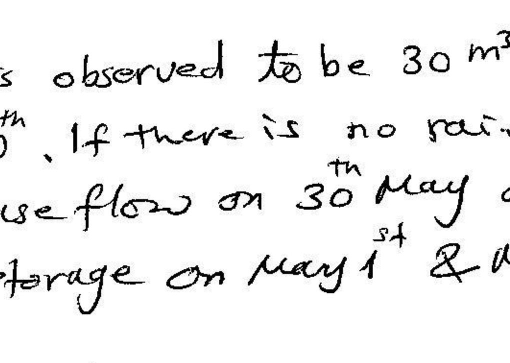

Fig. 10 Effective Rainfall Hyetograph (ERH)

<u>Example 2</u>: A storm produced a direct runoff of 5.8 cm. The data of the storm is given below. Estimate the ϕ-index.

Time (hr)	0	2	4	6	8	10	12	14	16
Acc. depth cm	0	0.4	1.3	2.8	5.1	6.9	8.5	9.5	10

Solution:

Time (hr)	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16
depth (cm)	0.4	0.9	1.5	2.3	1.8	1.6	1	0.5
Intensity(cm/hr)	0.2	0.45	0.75	1.15	0.9	0.8	0.5	0.25

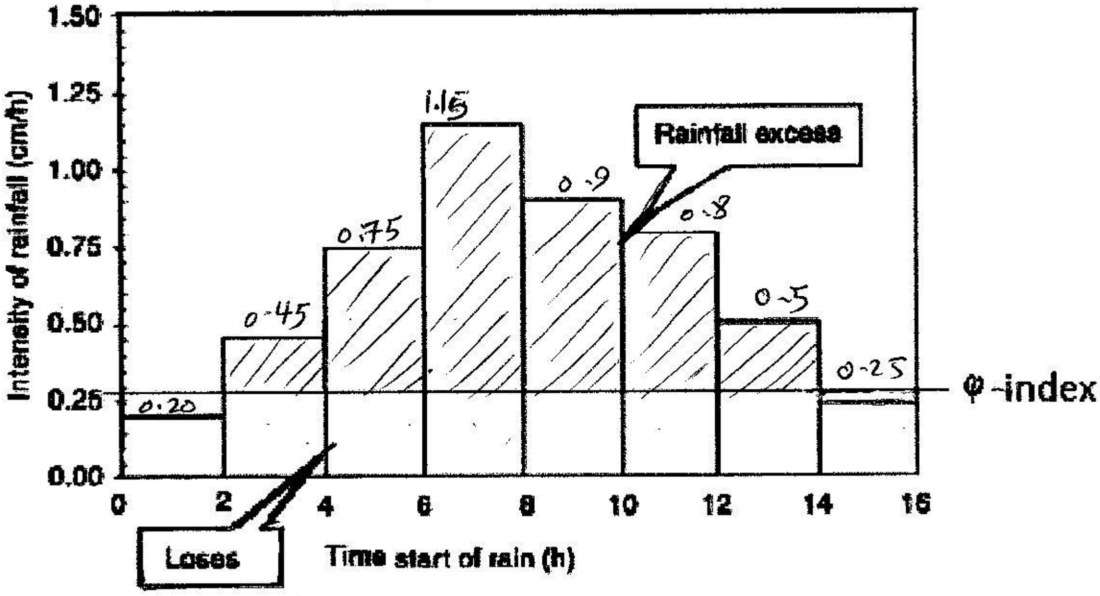

Fig. 11 Hyetograph and Rainfall Excess of the Storm – Example 2

① assume $0.45 < \phi < 0.5$ $(M = 5)$

$\sum (I_i - \phi)\Delta t = R_d$; R_d: direct Runoff

$\sum (I_i \Delta t - \phi \Delta t) = \sum_{i=1}^{5} I_i \Delta t - 5\phi\Delta t = 5.8$

$= 0.75(2) + 1.15(2) + 0.9(2) + 0.8(2) + 0.5(2) - 5\phi(2) = 5.8$

$\Rightarrow \phi = 2.4$ cm/hr (Assuming is not correct)

② assume $0.2 < \phi < 0.25$ $(M = 7)$

$\Rightarrow 5.8 = 0.45(2) + 0.75(2) + 1.15(2) + 0.9(2) + 0.8(2) + 0.5(2) + 0.25(2) - 7\phi(2)$

$\Rightarrow \phi = 0.271 > 0.25$ (Not o.k)

③ assume $0.25 < \phi < 0.45$ $(M = 6)$

$\Rightarrow 5.8 = 0.45(2) + 0.75(2) + 1.15(2) + 0.9(2) + 0.8(2) + 0.5(2) - 6\phi(2)$

$\Rightarrow \phi = 0.275$ (OK. $0.25 < \phi < 0.45$)

لاحظ أن الخوارزمية قائمة على فرضية قيمة أولية لمؤشر فاي ϕ ثم التحقق من القيمة المفروضة عبر تطبيق مفهوم المطر المؤثر هو مطابقاً لعمق السيح المباشر.

Example 3

Rainfall of magnitude 3.8 cm and 2.8 cm occurring on two consecutive 4-h durations on a catchment of area 27 km² produced the following hydrograph of flow at outlet of the catchment. Estimate the rainfall excess and ϕ index.

Time from start of rainfall (h)	–6	0	6	12	18	24	30	36	42	48	54	60	66
Observed flow (m^3/s)	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5

Solution:

The hydrograph is plotted as in Fig (12). The separation of the base flow of the storm Hydrograph was considered by using simple straight line.

However, DRH starts at $t=0$, having peak at $t=12h$ and ends at $t=48h$, i.e., 36 h from peak while this period calulated from eq (3) is;

$N = 0.83(27)^{0.2} = 1.6 \text{ days} = 38.5 h$

(which one is recommended to use?)

It abvious that the base flow has a constant value of 5 m^3/sec.

The Area under DRH curve is calculated by Trapeziodal scheme

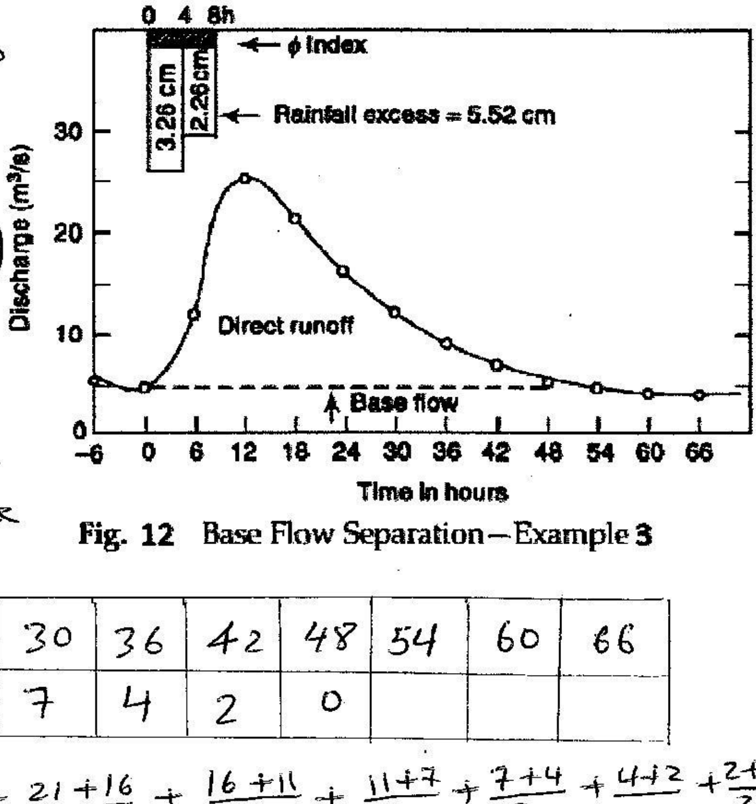

Fig. 12 Base Flow Separation—Example 3

Time (hr)	0	6	12	18	24	30	36	42	48	54	60	66
DRH m^3/sec	0	8	21	16	11	7	4	2	0			

$$\text{Area of DRH} = \Delta t\left[\frac{0+8}{2}+\frac{8+21}{2}+\frac{21+16}{2}+\frac{16+11}{2}+\frac{11+7}{2}+\frac{7+4}{2}+\frac{4+2}{2}+\frac{2+0}{2}\right]$$

$$= 6\times3600\left[8+21+16+11+7+4+2\right] = 1.4904\times10^6\ m^3$$

نلاحظ أن المساحة هي مجموع عناصر DRH مضروباً في الفترة الزمنية Δt ج التحويل.

$$\text{Runoff depth } (R_d) = \frac{\text{Volume of Runoff}}{\text{Catchment Area}} = \frac{1.4904\times10^6}{27\times10^6} = 0.0552\ m$$

$= 5.52$ cm excess rainfall

Total rainfall $= 3.8 + 2.8 = 6.6$ cm

$$\phi = \frac{6.6 - 5.52}{8} = 0.135 \text{ cm/hr}$$

$d_1 = \left[\frac{3.8}{4} - \phi\right] * 4 = 3.26$ cm ; $d_2 = \left[\frac{2.8}{4} - \phi\right] * 4 = 2.26$ cm ; $d_1 + d_2 = R_d$