CHAPTER 3

Hydrologic Computation of small Urban Watershed

3.1.1 Rain fall frequency analysis

- The frequency of occurrence of rain fall of different magnitude is important for various hydrological applications:

Particularly :- **planning** & **design** engineering works that control storm run off, such as:

- **Dams**
- **Culverts**
- **Urban & agricultural drainage systems**

- This is because in most cases, **good quality flow data** of a length, adequate for the reliable estimation of flood are generally **limited or un available**, at location of interest, while extensive precipitation estimates are available.

- In general, there are two broad categories of approaches for estimating **flood from precipitation data**. These are:

1) **Statistical analysis of precipitation**
2) **Deterministic estimation (i.e. Probable Maximum Precipitation (PMP)).**

- The main objective of rain fall frequency analysis is to estimate amount of precipitation falling at a given point, over a given area, for a specified duration.

- Results of this analysis are often summarized by intensity-duration-frequency(IDF) relation ships for a given site, or are presented in the form of precipitation atlas, which provides rainfall accumulation depths, for various duration and return periods over the region of interest.

Assessment of rainfall data for frequency analysis

- Rainfall data used for frequency analysis are typically available in the form of ;

I. **Annual maximum series**

II. **Partial duration series**

- As rainfall data are collected at fixed observation times, for example clock hours, they may not provide the true maximum amounts for the selected durations.

- For example studies of thousands of station years of RF data indicates that multiplying annual maximum hourly or daily RF amounts for a single fixed observational interval of 1 to 24 hours by 1.13 will yield values close to those to be obtained from an analysis of true maxim.

- Lesser adjustments are required when maximum observed amounts are determined from 2 or more fixed observational intervals as indicated in table 3.1 (NRCC, 1981).

Table 3.1 Adjustment factors for daily observation frequencies

Number of observations / day	1	2	3-4	5-8	9-24	>24
Adjustment factor	1.13	1.04	1.03	1.02	1.01	1.00

At site frequency analysis of RF

- A frequency analysis can be preformed for a site for which sufficient rainfall data are available.

- **Similar to flood frequency analysis** rain fall frequency analysis is also based on annual maximum series or partial duration series.

- Owing to its simpler structure, the annual maximum series method is more popular.

- The partial duration analysis, however appears to be preferable for short records, or when return periods are shorter than 2 year are of interest.

- Briefly , the steps below should be followed to determine the frequency distribution of annual maximum rainfall for a given site:

a) Obtain a data sample and preform an assessment of data quality based on statistical and hydrological, procedures.

b) Select a candidate distribution model for the data & estimate the model parameters,

c) Eventually the adequacy of the assumed model in terms of the ability to present its parent distribution from which the data were drawn.

3.1.2 Storm rainfall analysis for hydrological design applications

- For **design purposes**, **precipitation** at a given site or over an area for a specified durations & return period is commonly used in the estimation of flood potential.

- The use of design precipitation to estimate flood is particularly valuable in those situations where flood records are not available or not long enough at the site of interest, or they are not homogenous due to changes of watershed characteristics such as urbanization & channelization.

- Further more, design problems usually require information on very rare hydrological events: events with return period's much longer than 100 years.

Rainfall intensity or depth-duration-frequency relationships

- In standard engineering practice, the results of point rainfall frequency analysis are often summarized by **intensity-duration-frequency** relation ships or **depth-duration-frequency relationships** for each rain gage site with sufficient rainfall records.

- These relationships are available both in tabular & graphical form for rainfall intensities or depth at time interval ranging from 5minutes to 2days and return periods ranging from 2years to 100years.

- **Empirical equations expressing intensity duration frequency and depth duration frequency relationships have been developed**.

Analysis of Rainfall Data

- Rainfall during a year or season (or a number of years) consists of several storms.
- The characteristics of a rainstorm are:

I. **Intensity (cm/hr),**

II. **Duration (min, hr, or days),**

III. **Frequency** (once in 5 years or once in 10, 20, 40, 60 or 100 years), and (iv) areal extent (i.e., area over which it is distributed).

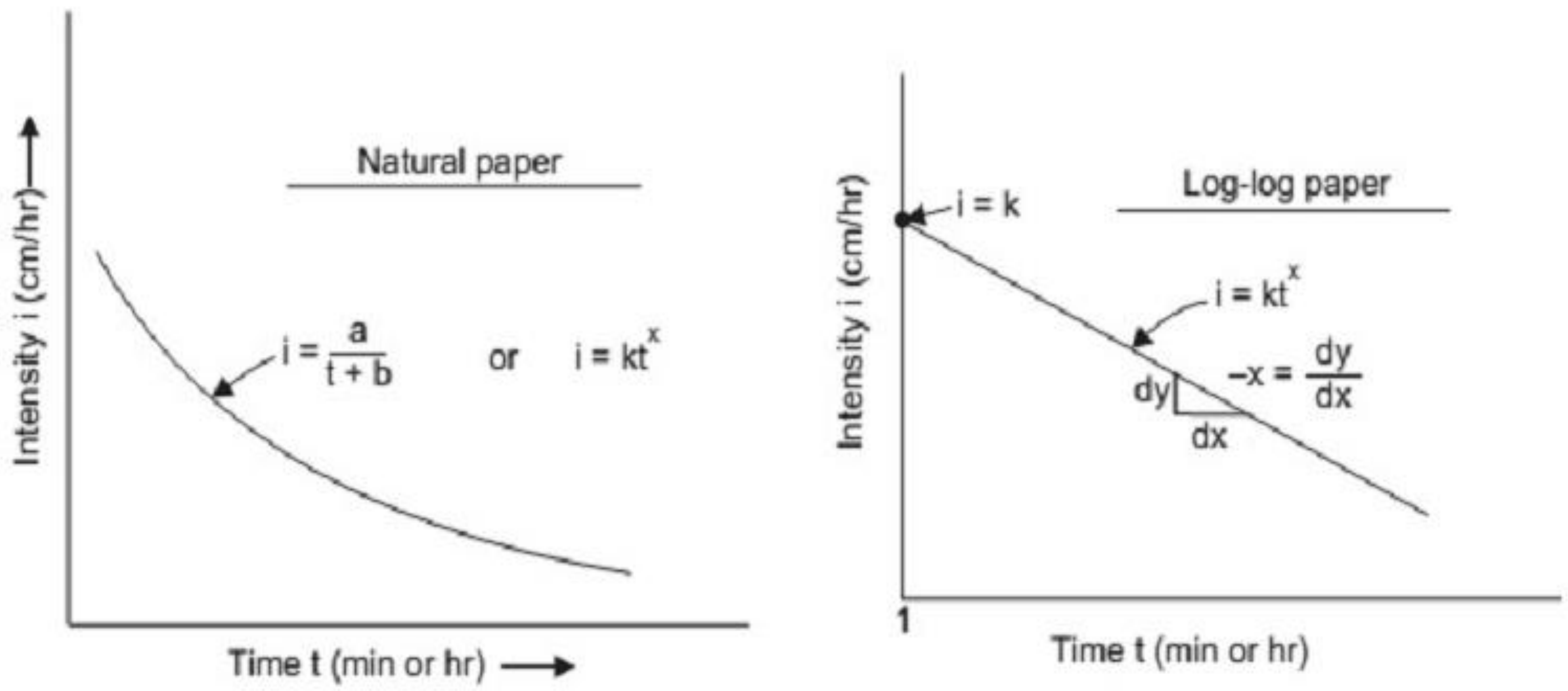
How do we correlate intensity-duration relationship ?

- If there are storms of different intensities and of various durations, then a relation may be obtained **by plotting** the intensities (i, cm/hr) against durations (t, min, or hr) of the respective storms either on:

1) **The natural graph paper, or**
2) **The double log (log-log) paper,**

- Fig. 3.1(a) and relations of the form given below may be obtained

Fig. 3.1(a) and relations of "intensity & duration" as shown on natural & log-log paper



(a) Correlation of intensity and duration of storms

- The above two graphs are obtained by the equations(relations) of the form

(a) $i = \frac{a}{t+b}$ A.N. Talbot's formula (for t = 5-120 min) 3.1

(b) $i = \frac{k}{t^n}$ 3.2

(c) $i = kt^x$ 3.3

- where t = duration of rainfall or its part, **a, b, k, n** and **x** are constants for a given region.
- Since **“x” is usually negative** Eqs. (3.1) and (3.2) are same and are applicable for durations **$t > 2$ hr**.
- By taking logarithms on both sides of Eq. (3.3),

$$\log i = \log k + x \log t$$

- Which is in the form of a straight line, i.e., if **i** and **t** are plotted on a log-log paper, the slope, of the straight line plot gives the constant **x** and the constant **k** can be determined as **i = k** when **t = 1**.
- Hence, the fitting equation for the rainfall data of the form of Eq. (3.3) can be determined and similarly of the form of Eqs. (3.1) and (3.2).

How do we correlate intensity-duration-frequency-relationship ?

- On the other hand, if there are rainfall records for **30** to **40 years**, the various storms during the period of record may be arranged in the descending order of their magnitude (of maximum depth or intensity).
- When arranged like this in the descending order, if there are a total number of **n** items and the order number or rank of any particular storm (maximum depth or intensity) is **m**, then the recurrence interval **T** (also known as the **return period**) of the storm magnitude is given by one of the following equations:

(a) California method (1923), $T = \frac{n}{m}$ (3.4)

(b) Hazen's method (1930), $T = \frac{n}{m - \frac{1}{2}}$ (3.5)

(c) Kimball's method, (Weibull, 1939) $T = \frac{n+1}{m}$ (3.6)

- If the **intensity-duration curves** are plotted for various storms, for different recurrence intervals, then a relation may be obtained of the form:

$$i = \frac{kT^x}{t^e} \quad \text{... Sherman}$$

3.7

- where **k, x** and **e** are constants.
- "**i vs. t**" plotted on a **natural graph paper** for storms of different recurrence intervals **yields curves of the form shown in Fig. 3.1(b)**, while on a **log-log paper yields straight line plots**.

- By taking logarithms on both sides of Eq. (3.7),

$$\log i = (\log k + x \log T) - e \log t$$

- which plots a straight line; **k = i**, when **T** and **t** are **equal to 1**.
- Writing for two values of T (for the same **t**) :

$$\log i_1 = (\log k + x \log T_1) - e \log t$$

$$\log i_2 = (\log k + x \log T_2) - e \log t$$

Subtracting, $\log i_1 - \log i_2 = x (\log T_1 - \log T_2)$

or, $$x = \frac{\Delta \log i}{\Delta \log T}$$

$\therefore$ **x = charge in log i per log-cycle of T (for the same value of t)**

Again writing for two values of t (for the same T):

$$\log i_1 = (\log k + x \log T) - e \log t_1$$

$$\log i_2 = (\log k + x \log T) - e \log t_2$$

Subtracting $\log i_1 - \log i_2 = -e(\log t_1 - \log t_2)$

or

$$-e = \frac{\log i}{\log t}$$

or

$$e = -\text{slope} = \frac{\Delta \log i}{\Delta \log t}$$

∴ e = change in log i per log cycle of t (for the same value of T).

- The lines obtained for different frequencies (i.e., **T** values) may be taken as roughly parallel for a particular basin though there may be variation in the slope 'e'.
- Suppose, if a **1-year recurrence interval line is required, draw a line parallel** to **10–year line**, such that the distance between them is the same as that between **5-year and 50-year line**; similarly a **100-year line can be drawn parallel to the 10-year** line keeping the same distance (i.e., distance per log cycle of **T**).
- The value of **i** where the **1-year** line intersects the unit time ordinate (i.e., **t = 1min**, say) gives the value of **k**.
- Thus all the constants of Eq. (3.7) can be determined from the log-log plot of '**i vs. t**' for different values of **T**, which requires a long record of rainfall data.

- Such a long record, will not usually be available for the specific design area and hence it becomes necessary to apply the intensity duration curves of some nearby rain gauge stations and adjust for the local differences in climate due to difference in elevation, etc.
- Generally, high intensity precipitations can be expected only for short durations, and higher the intensity of storm, the lesser is its frequency.

Example 1

In a Certain water shed, the rainfall mass curves were available for **30 (n)** consecutive years. The most severe storms for each year were picked up and arranged in the descending order (**rank m**). The mass curve for storms for three years are given below. Establish a relation of the below by plotting on log-log graph paper

$$i = \frac{kT^x}{t^e}$$

Time(min)	5	10	15	30	60	90	120
Accumulated depth (mm)							
for m = 1	9	12	14	17	22	25	30
for m = 3	7	9	11	14	17	21	23
for m = 10	4	5	6	8	11	13	14

Solution

Time t (min)	5	10	15	30	60	90	120	T-yr = $\frac{n+1}{m}$
Intensity i (mm/hr)								
for $m = 1$	$\frac{9}{5} \times 60$ = 108	$\frac{12}{10} \times 60$ = 72	56	34	22	16.6	15	$\frac{30+1}{1} \simeq 30$ yr
for $m = 3$	$\frac{7}{5} \times 60$ = 84	$\frac{9}{10} \times 60$ = 54	44	28	14	14	11.5	$\frac{30+1}{3} \simeq 10$ yr
for $m = 10$	$\frac{4}{5} \times 60$ = 48	$\frac{5}{10} \times 60$ = 30	24	16	11	8.7	7	$\frac{30+1}{10} \simeq 3$ yr

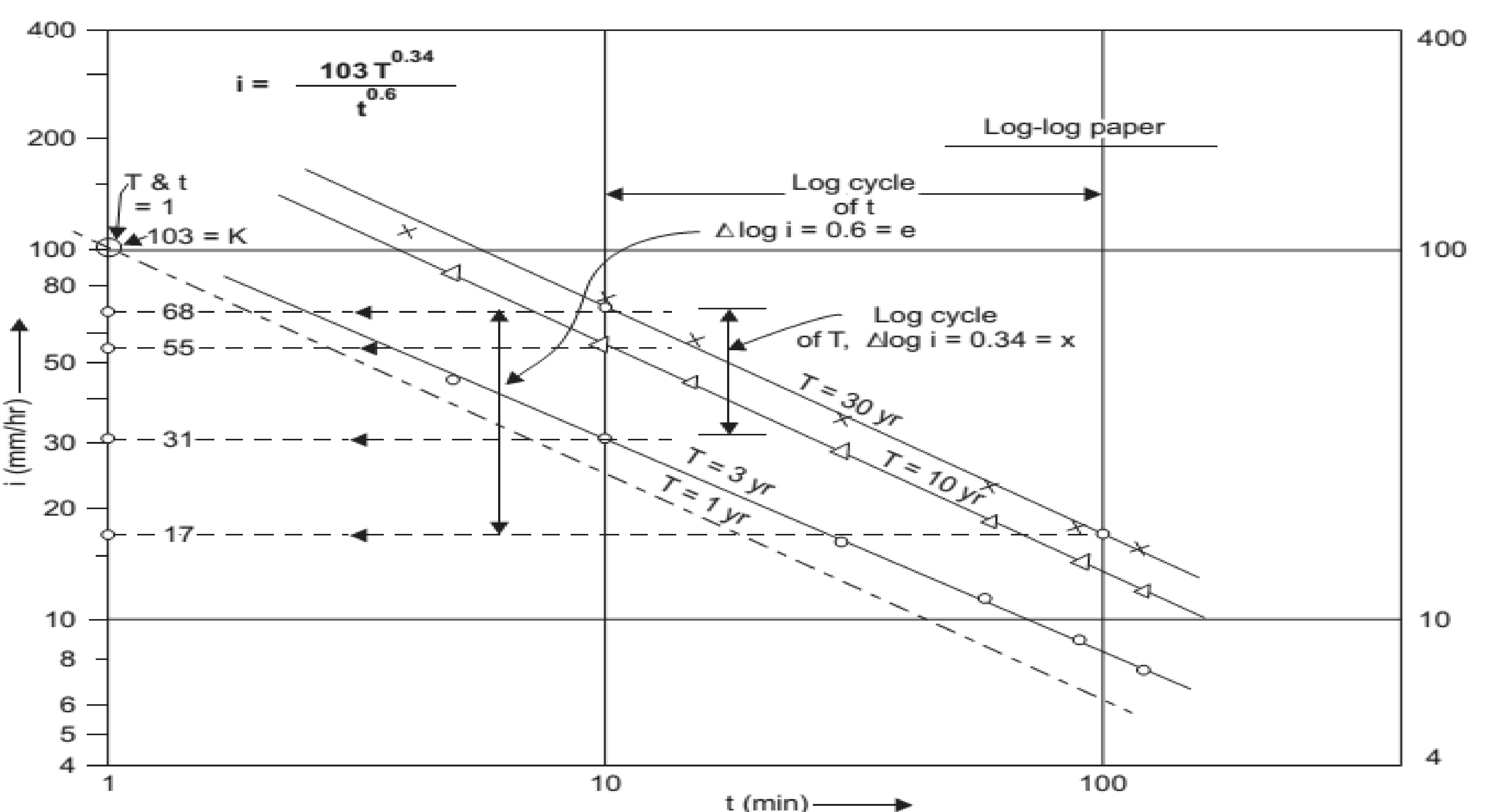
- The intensity-duration curves (lines) are plotted on log-log paper (Fig. 3.1 (c)), which yield straight lines nearby parallel.

- A straight line for **T = 1 – yr** is drawn parallel to the line **T= 10-yr** at a distance equal to that between **T = 30–yr** and **T = 3-yr**. From the graph at **T = 1-yr** and **t = 1 min, k = 103**.

- The slope of the lines, say for **T= 30-yr** is equal to the change in log i per log cycle of t, i.e., for **t= 10 min and 100 min**,

slope = log 68 – log 17 = 1.8325 – 1.2304 = 0.6021 ~ 0.6 = e

Fig. 3.1.(c) Intensity-duration relationship, (Ex. 1 (a))



- At **t = 10 min**, the change in **log i** per log cycle of **T,** i.e.

Between **T= 3–yr and 30–yr** lines(on the same vertical),

log 68 – log 31 = 1.8325 – 1.4914 = 0.3411 ~ 0.34 = x

- Hence, the intensity-duration relationship for the watershed can be established as;

$$\mathbf{i = \frac{103(T)0.34}{(t)0.6}}$$

- For illustration, for the most severe storm (**m = 1, T= 30–yr.**), at **t = 60 min**, i.e. After **1 hr** of commencement of storm,

$$i = \frac{103(T)0.34}{(t)0.6}$$

$$i = \frac{103\,(30)^{0.34}}{(60)^{0.6}} = 28\ \text{mm/hr}$$

Example 2

In a Certain water shed, the rainfall mass curves were available for **50 (n)** consecutive years. The most severe storms for each year were picked up and arranged in the descending order (**rank m**). The mass curve for storms for three years are given below. Establish a relation of the form by plotting on log-log graph paper

$$i = \frac{kT^x}{t^e}$$

Time(min)	5	10	15	30	60	90	120
RF Depth(mm)							
m = 1	11	14	16	18	20	22	26
m = 5	9	11	13	15	18	20	24
m = 10	6	8	10	13	16	18	22

A more general Intensity-Duration–Frequency (IDF) relationship is of the form

Sherman $i = \dfrac{KT^x}{(t+a)^n}$, i in cm/hr, t in min, T yr.

- Where
  - **K**,
  - **x,**
  - **a** and
  - **n**

  are **constants** for a given catchment.

- The rainfall records for about **30 to 50 years** of different intensities and durations on a basin can be analyzed with their computed recurrence interval (**T**).
- They can be plotted giving trial values of **‘a’** for the lines of best fit as

3.2 Runoff computation

- The determination of urban storm water runoff has been the concern of many engineers, for many years.
- For most part of last century, engineers used the rule of thumb approach. The rule of thumb was " **about half of rain fall would appear as runoff from urban surface**".
- Following the rule of thumb, empirical formulas became the principal mechanisms for determining the quantities of urban runoff.
- The most famous empirical equation is " the rational formula".

3.2.1 Rational formula

- The rational method provides a simple means for the assessment of the peak discharge rate for design storms, but doesn't provide reliable bases for: runoff volume, hydrograph shape, or peak discharge rates from historical(real) storms.

Limitations of Rational Method

- The use of rational method is generally not suitable for the following applications:

1) Analysis of historical storms
2) Design of detention basins
3) Catchments of unusual shape
4) Catchments with significant insolated areas of vastly different hydrologic characteristics, such as catchment with an upper forested sub-catchment and lower urbanized sub-catchments,
5) Catchments with significant, floodplain storage, detention basins, or catchment with widespread use of onsite detention system,
6) Urban catchment with an area greater than 80hectars (200acr)
7) Catchments with (t_c > 30min), where a high degree of reliability is required.

- The rational formula is given as;

$$Q = 1/Ku\ CIA$$

- where;

Q = the peak rate of flow (m^3/s (ft^3/s)

C = Dimensionless runoff coefficient assumed to be a function of the cover of the watershed

I = the average rainfall intensity during the storm duration time period in/hr.

A = the basin area

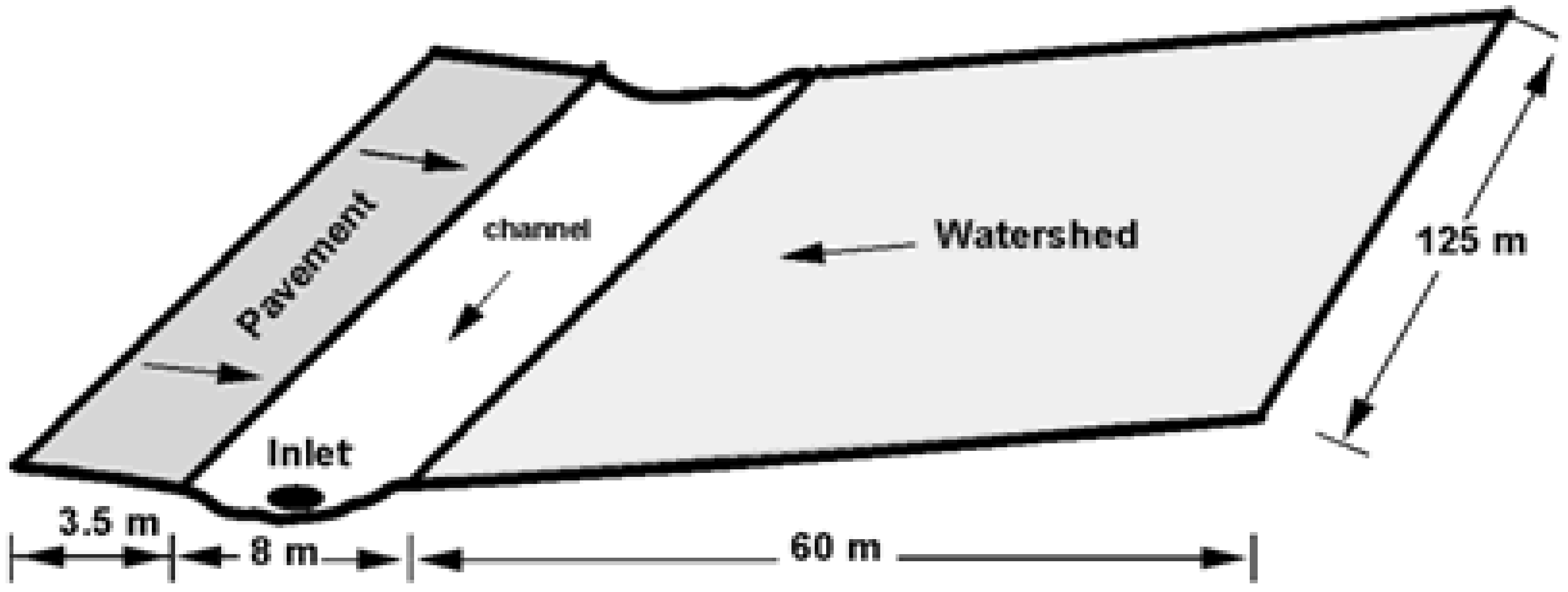
Ku = 360(1)

Runoff coefficient

- The runoff coefficient (C) in the rational formula is the ratio of the rate of runoff to the rate of rainfall at an average intensity (i) when all the drainage area is contributing.
- The runoff coefficient is tabulated as a function of land use conditions; however, the coefficient is also a function of slope, intensity of rainfall, infiltration and other abstractions.

Example 4

- Calculate the **runoff coefficient** of a toe-of-slope channel collects runoff from the roadway and an adjacent watershed. The tributary area has a fairly uniform cross section as follows: **3.5 m of concrete pavement(c = 0.95)**; **8 m grassed** channel in a sandy soil(**C = 0.10**), and back slope; **60 m** of **forested watershed (C= 0.30)**. The length of the area is **125 m.**



Solution

WC = $(\sum CA)/\sum A$

Type of Surface	**C (Table B.1)**	**Area (hectare)**	**CA (hectare)**
Concrete pavement	0.95	0.043	0.041
Grassed channel	0.10	0.100	0.010
Forested watershed	0.30	0.750	0.225
TOTAL	---	**0.90**	**0.276**

- Weighted C = **0.276/0.90** = **0.31**

3.2.2 Time of Concentration

- Time of concentration varies with the size and shape of the drainage area, the land slope, the type of surface, the intensity of rainfall, and whether flow is **overland** or **channelized**.
- Channelized flow is typically further divided into:

1) **Shallow concentrated flow and**
2) **Concentrated flow,**

resulting in the definition of three primary flow paths (**overland, shallow concentrated and concentrated**).

Various Methods of estimation of $\mathbf{t_c}$

- There are various methods of estimation o time of concentration, other than the manning's kinematic wave method, this are:
    - Kirpich’s Equation
    - FAA
    - NRCS

Total Time of Concentration

- To obtain the total time of concentration, the channel flow time must be calculated and added to the overland flow time.
- After first determining the average flow velocity in the pipe or channel, the travel time is obtained by dividing velocity into the pipe or channel length.

$$t_t = \frac{L}{(V)(60)}$$

Where:

tt= travel time, minutes

L = length which runoff must travel, m

V = estimated or calculated velocity, m/s

The total time of concentration is: $t_c = t_o + t_t$

Where:	t_C	=	total time of concentration
	t_O	=	overland flow time
	t_t	=	travel time

Kirpich’s Equation

- Kirpich’s Equation is an empirical watershed equation based on data which accounted for length, slope and soil cover. It derives from work to determine the rates of runoff from **small agricultural watersheds**.
- The Equation is considered applicable to watersheds from 1 ha to 80 ha.

$$t_C = (0.948\,(L^3)/H)^{0.385}$$

Where:

tc = time of concentration, hours

L = length of the longest waterway from the point in question to the basin divide, km

H = difference in elevation between the point in question and the basin divide (omitting drops due to gully over-falls, waterfalls, etc.), m

- Common sense dictates that this cannot occur; therefore, the Equation should be adjusted if it is used elsewhere using the following guidelines:
  - For overland flow on grassed surfaces, multiply tc by 2.0.
  - For overland flow on concrete or asphaltic surfaces, multiply tc by 0.4.
  - For flow in concrete-lined channels, multiply tc by 0.2.

- The application of Kirpich's Equation to a basin is as follows:

1) Compute the length (L) in kilometers between the basin divide and the point in question.
2) Compute the relief (H) in meters between the basin divide and the point in question.

- The elevation of the basin divide should represent **an average of the elevations in the immediate vicinity** of the termination point of the longest watercourse.
- This procedure avoids bias in the tc computation due to an isolated peak in the headwater area.
- The elevation of the site should be interpolated between successive contours crossing the stream.

- Compute the time of concentration (t_c) in hours using the equation
- Apply an adjustment factor, if applicable, based on surface type.

1) The tc produced by Step 4 is appropriate for urban areas or steep areas. For the use of Kirpich's Equation, "steep" is defined as an overall basin slope greater than 0.6% to 0.7%.
2) For other than **"urban"** areas or other than "steep" areas, the tc produced by Step 4 should be divided by 0.6.
3) Because some basins are not clearly "rural"/"urban" or "flat"/"steep," divide Kirpich's Equation by 0.8 in these cases.

Example 5

Given

L = 800 m = 0.8 km

H = 10 m Grass surface

- Find: Time of concentration (tc) using Kirpich's Equation

Solution

$$t_c = (0.948\,(0.8^3)\,/\,10\,)^{0.385}$$

$$t_c = 0.31 \text{ hours}$$

1. Using Kirpich Equation :
2. For overland flow on grassed surfaces, multiply tc by 2.0:

3. The basin slope = 10/800 = 1.25%. Therefore, this is defined as "steep" for using Kirpich's Equation and no other adjustments are necessary.

Therefore tc = 37 minutes.

Federal Aviation Administration (FAA)

- For design conditions that do not involve complex drainage conditions, the Federal Aviation Equation (FAA, 1970) can be used to estimate **overland flow time**.
- The equation was developed from airport drainage data, and it is probably best suited for small drainage areas with fairly homogeneous surfaces.

$$t_o = \frac{(1.1 - C)L^{0.5}}{1.44\, S^{0.33}}$$

- For each drainage area, the distance is determined from the inlet to the most remote point in the tributary area.
- From a topographic map, the average slope is determined for the same distance.
- Runoff Coefficients for the Rational Formula, provide values for the Rational Method runoff coefficient (C).

- Where:-

  to = overland flow travel time, minutes

  L = overland flow path length, m

  S = slope of overland flow path, decimal

  C = Rational Method runoff coefficient

Example 6

Given:

L = 45 m S = 0.02 Surface: grass

Find: Overland flow time, to

Solution:

1) Determine C from Figure
2) For lawn, heavy soil, 2% - 7% slope, use C = 0.18

$$t_o = \frac{(1.1 - 0.18)(45\ )^{0.5}}{1.44\ (0.02\ )^{0.33}}$$

$$t_o = 16 \text{ minutes}$$

NRCS Curve Number

- The Natural Resources Conservation Service (NRCS) (formerly SCS) Curve Number method may be used to estimate the total time of concentration for small rural areas of 1 ha - 800 ha (NRCS, 1989).

$$t_c = \frac{(1)^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{441\,Y^{0.5}}$$

homogeneous watershed with the same curve number:

Where:

tc = time of concentration, hours

l = length of mainstream to farthest divide, m

Y = average watershed slope, %

CN = NRCS curve number

Example 7

Given:

l = 200 m Y = 2 % CN = 77

Find: Time of concentration, tc

Solution: $t_C = \{(200)^{0.8} \text{ x } (1000/77 - 9)^{0.7}\} / (441)(2)^{0.5}$

$t_C = 0.29 \text{ hr} = 17 \text{ min}$

3.3 Estimation of Design Discharge

Example 8

An urban catchment has an area of **85 ha**. The slope of the catchment is **0.006** & the maximum length of travel of water is **950m**. The maximum depth of rainfall with **25year return period** is as below: If a culvert for drainage at the outlet of this area is to be designed for a return period of **25yrs**, estimate the required peak flow rate, by assuming the runoff coefficient as **0.3.**

Duration in (min)	**5**	**10**	**20**	**30**	**40**	**60**
Depth of RF (mm)	**17**	**26**	**40**	**50**	**57**	**62**

Solution

- Time of concentration is obtained by Kirpich's formula as:

$$t_c = 0.01947 * (950)^{0.77} * (0.006)^{-0.385} = \mathbf{27.4min}$$

- by interpolation maximum depth of RF for 27.4 min duration

$$= ((50-40)/(10)) * 7.4 + 40 = \mathbf{47.4mm}$$

Average intensity = i = (47.4mm)/(27.4min))* 60 = **103.8mm/hr**

$$\mathbf{Q_p} = (0.3*103.8*0.85)/(3.6) = \underline{\underline{\mathbf{7.35m^3/s}}}$$

- Although different countries local agencies might have developed standards that specify the return period design requirement for storm water conveyance facilities with their jurisdiction, typical return period design criteria for storm water conveyance & control structures are given in (table 3.5) and also it is common in some countries and agencies to have used the modified IDF curves set up with large factor of safety for establishing the design of flow.

Type of structure	Return period used for design (years)
Highway culverts	
Low traffic	5 -10
High traffic	10 - 25
Intermediate traffic	50 - 100
Highway bridges	
Secondary system	10 -50
Primary system	50 - 100
Urban drainages	
Storm sewers in small cities	2 - 25
Storm sewers in large cities	25 - 50

Farm drainage	
Culverts	5 - 50
Ditches	5 - 50
Airfields	
Low traffic	5 - 10
intermediate traffic	10 – 25
High traffic	50 – 100
Levees	
On farms	25 – 50
Around cities	50 - 200

Dams with no likely hood of loss of life	
Small Dams	50 – 100
Intermediate Dams	100+
Large Dams	--

Example 9

A 500ha of watershed has the land use/cover and corresponding runoff coefficient as given below:

Land use/cover	Area(ha)	Runoff coefficient
Forest	250	0.10
Pasture	50	0.11
Cultivated land	200	0.30

- The maximum length of travel of water in the watershed is about **3000m** and the elevation difference between the highest and outlet points of the water shade is **25m**. The maximum intensity duration frequency relationship of the water shade is given by

$$\mathbf{i} = \frac{6.311\ \mathbf{T}^{\mathbf{0.1523}}}{(D + 0.5)^{\mathbf{0.945}}}$$

- Where: i = intensity in cm/hr, T= return period in years and D = duration of RF in hours. Estimate;

a) 25year peak runoff from the watershed &

b) The 25year peak runoff if the forest cover has decreased to **50ha** and the cultivated land has encroached up on the pasture and forest lands have a total coverage of **450ha**.

Solution

a) The equivalent runoff coefficient;

$$C_e = (\sum \boldsymbol{CA})/\sum \boldsymbol{A}$$

$$= ((0.1 * 250) + (0.11*50) + (0.3*200))/(500) = \mathbf{0.181}$$

➢ Since, the slop is not given, time of concentration is obtained by the modified Kirpich equation:

$$\mathbf{t_c} = 0.01947(K)^{\mathbf{0.77}}, \text{ where } K = \sqrt{\frac{\mathbf{L^3}}{\mathbf{\Delta H}}}$$

Thus;

$$L = 3000m \; \& \; \Delta H = 25m$$

$$\mathbf{K} = \sqrt{\frac{(3000)^3}{25}}$$

$$\mathbf{D} = t_c = 0.01947(32863)^{0.77} = \mathbf{58.5\ min = 0.975h} \quad \mathbf{and\ T = 25yr}$$

$$\mathbf{i} = \frac{6.311(25)^{0.1523}}{(0.975 + 0.5)^{0.945}} = 10.304/1.447 = 7.123cm/h = \mathbf{71.23mm/h}$$

Peak flow by $\mathbf{Q_p}$ =1/(3.6)*(C_e iA)

$\mathbf{Q_p}$ = (0.181*71.23*(500/100))/(3.6) = **64.46m³/s**

- Here equivalent C = C_e = ((0.1*50) + (0.3*450))/(500) = **0.28**

i = 71.23mm/h and A= 500ha

Q_p = (0.28*71.23*(500/100))/(3.6) = **$99.27 m^3/s$**