Module 6: Quantity Estimation of Storm Water

Lecture 6: Quantity Estimation of Storm Water

6.0 QUANTITY ESTIMATION OF STORM WATER

6.1 Factors Affecting the Quantity of Storm Water

The surface run-off resulting after precipitation contributes to the storm water. The quantity of storm water reaching to the sewers or drains is very large as compared with sanitary sewage. The factors affecting the quantity of storm water flow are as below:

i. Area of the catchment
ii. Slope and shape of the catchment area
iii. Porosity of the soil
iv. Obstruction in the flow of water as trees, fields, gardens, etc.
v. Initial state of catchment area with respect to wetness.
vi. Intensity and duration of rainfall
vii. Atmospheric temperature and humidity
viii. Number and size of ditches present in the area

6.2 Measurement of Rainfall

The rainfall intensity could be measured by using rain gauges and recording the amount of rain falling in unit time. The rainfall intensity is usually expressed as mm/hour or cm/hour. The rain gauges used can be manual recording type or automatic recording rain gauges.

6.3 Methods for Estimation of Quantity of Storm Water

1. Rational Method
2. Empirical formulae method

In both the above methods, the quantity of storm water is considered as function of intensity of rainfall and coefficient of runoff.

Time of Concentration: The period after which the entire catchment area will start contributing to the runoff is called as the time of concentration.

- The rainfall with duration lesser than the time of concentration will not produce maximum discharge.
- The runoff may not be maximum, even when the duration of the rain is more than the time of concentration. This is because in such case the intensity of rain reduces with the increase in its duration.

- The runoff will be maximum, when the duration of rainfall is equal to the time of concentration and is called as *critical rainfall duration*. The time of concentration is equal to sum of inlet time and time of travel.

Time of concentration = Inlet time + time of travel

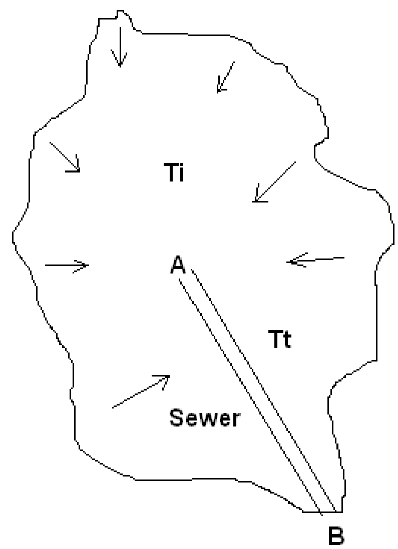

Figure 6.1 Runoff from a given catchment

Inlet Time: The time required for the rain in falling on the most remote point of the tributary area to flow across the ground surface along the natural drains or gutters up to inlet of sewer is called inlet time (Figure 6.1). The inlet time 'Ti' can be estimated using relationships similar to following. This coefficients will have different values for different catchments.

$$Ti = [\ 0.885\ L^3/H]^{0.385}$$

Where,

Ti = Time of inlet, time

L = Length of overland flow in Kilometer from critical point to mouth of drain

H = Total fall of level from the critical point to mouth of drain, meter

Time of Travel: The time required by the water to flow in the drain channel from the mouth to the point under consideration or the point of concentration is called as time of travel.

Time of Travel (Tt) = Length of drain/ velocity in drain

Runoff Coefficient: The total precipitation falling on any area is dispersed as percolation, evaporation, storage in ponds or reservoir and surface runoff. The runoff coefficient can be defined as a fraction, which is multiplied with the quantity of total rainfall to determine the quantity of rain water, which will reach the sewers. The runoff coefficient depends upon the porosity of soil cover, wetness and ground cover. The overall runoff coefficient for the catchment area can be worked out as follows:

Overall runoff coefficient, $C = [A_1.C_1 + A_2.C_2 + \ldots + A_n.C_n] / [A_1 + A_2 + \ldots + A_n]$

Where, A_1, A_2, …. are types of area with C_1, C_2, …. as their coefficient of runoff, respectively.

The typical runoff coefficient for the different ground cover is provided in the Table 6.1.

Table 6.1 Runoff coefficient for different type of cover in catchment

Type of Cover	Coefficient of runoff
Business areas	0.70 – 0.90
Apartment areas	0.50 – 0.70
Single family area	0.30 – 0.50
Parks, Playgrounds, Lawns	0.10 – 0.25
Paved Streets	0.80 –0.90
Water tight roofs	0.70 – 0.95

6.3.1 Rational method

Storm water quantity can be estimated by rational method as below:

Storm water quantity, $Q = C.I.A / 360$

Where,

Q = Quantity of storm water, m^3/sec

C = Coefficient of runoff

I = intensity of rainfall, mm/hour, and

A = Drainage area in hectares

OR

$Q = 0.278\ C.I.A$

Where, Q is m^3/sec; I is mm/hour, and A is area in square kilometer

6.3.2 Empirical Formulae

Empirical formulae are used for determination of runoff from very large area. Various empirical relationships are developed based on the past observations on specific site conditions suiting a particular region. These empirical formulae can be used for prediction of storm water runoff for that particular catchment.

A] Burkli – Zeiglar formula

B] Mc Math formula (used in USA)

C] Fuller's formula

$$Q = \frac{C.M^{0.8}}{13.23}$$

(Where, S- Slope of the are, M- drainage area in sq. km., A – drainage area in hect.)

6.3.3 Empirical formulae for rainfall intensities

These relationships between rainfall intensity and duration are developed based on long experience in field (Figure 6.2). Under Indian conditions, intensity of rainfall in design is usually in the range 12 mm/h to 20 mm/h. In general, the empirical relationship has the following forms:

$I = a/(t + b)$ OR $I = b / t^n$

Where, a, b, and n are constants.

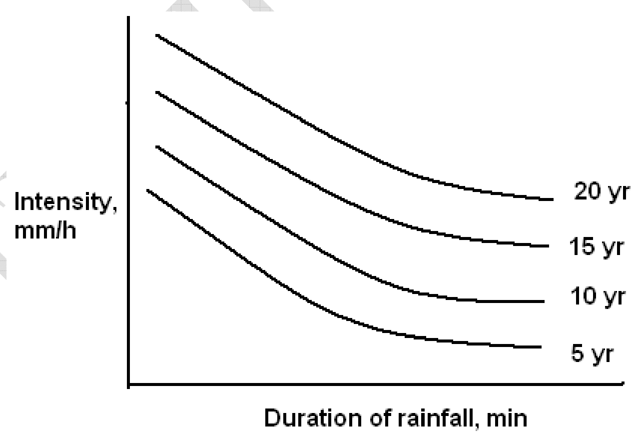

Figure 6.2 Relationship of rainfall duration and intensity

British Ministry of Health formula

$I = 760 / (t + 10)$ (for storm duration of 5 to 20 minutes)

$I = 1020 / (t + 10)$ (for storm duration of 20 to 100 minutes)

Where, I is intensity of rainfall, mm/h and t is duration of storm, minutes.

6.4 Examples

1. Determine designed discharge for a combined system serving population of 50000 with rate of water supply of 135 LPCD. The catchment area is 100 hectares and the average coefficient of runoff is 0.60. The time of concentration for the design rainfall is 30 min and the relation between intensity of rainfall and duration is I = 1000/(t + 20).

Solution

Estimation of sewage quantity

Considering 80% of the water supplied will result in wastewater generation,

the quantity of sanitary sewage = 50000 x 135 x 0.80 = 5400 m^3/day = 0.0625 m^3/sec

Considering peak factor of 2.5, the design discharge for sanitary sewage = 0.0625 x 2.5

= 0.156 m^3/sec

Estimation of storm water discharge

Intensity of rainfall, I = 1000/(t + 20)

Therefore, I = 1000/(30 + 20) = 20 mm/h

Hence, storm water runoff, Q = C.I.A/360

= 0.6 x 20 x 100/(360) = 3.33 m^3/sec

Therefore, design discharge for combined sewer = 3.33 + 0.156 = 3.49 m^3/sec

2. The catchment area is of 300 hectares. The surface cover in the catchment can be classified as given below:

Type of cover	Coefficient of runoff	Percentage
Roofs	0.90	15
Pavements and yards	0.80	15
Lawns and gardens	0.15	25
Roads	0.40	20
Open ground	0.10	15
Single family dwelling	0.50	10

Calculate the runoff coefficient and quantity of storm water runoff, if intensity of rainfall is 30 mm/h for rain with duration equal to time of concentration. If population density in the area is 350 persons per hectare and rate of water supply is 200 LPCD, calculate design discharge for separate system, partially separate system, and combined system.

Solution

Estimation of storm water discharge for storm water drain of separate system

Overall runoff coefficient C = $[A_1.C_1 + A_2.C_2 + \ldots + A_n.C_n] / [A_1 + A_2 + \ldots + A_n]$

$$= \frac{(0.15 \times 0.90 + 0.15 \times 0.80 + 0.25 \times 0.15 + 0.20 \times 0.4 + 0.15 \times 0.1 + 0.10 \times 0.5)}{0.15 + 0.15 + 0.25 + 0.20 + 0.15 + 0.10}$$

= 0.44

Therefore quantity of storm water, Q = C.I.A/360

= 0.44 x 30 x 300/360

= 11 m^3/sec

Estimation of sewage discharge for separate system sanitary sewer

Quantity of sanitary sewage = 300 x 350 x 200 x 0.80 = 16800 m^3/day = 0.194 m^3/sec

Considering peak factor of 2, the design discharge for sanitary sewers = 0.194 x 2

= 0.389 m^3/sec

Estimation of discharge for partially separate system

Storm water discharge falling on roofs and paved courtyards will be added to the sanitary sewer. This quantity can be estimated as:

Average coefficient of runoff = (0.90 x 45 + 0.80 x 45) / 90 = 0.85

Discharge = 0.85 x 30 x 90 / 360 = 6.375 m^3/sec

Therefore total discharge in the sanitary sewer of partially separate system = 6.375 + 0.389 = 6.764 m^3/sec and the discharge in storm water drains = 11 – 6.375 = 4.625 m^3/sec

Questions

1. Explain the factors affecting the storm water discharge.
2. What is time of concentration? What is its role in determination of the storm water runoff?
3. Explain critical rainfall duration. Why rainfall of this duration will generate maximum runoff?
4. Write short notes on the estimation of storm water runoff.
5. What is coefficient of runoff?
6. A catchment is having total area of 60 hectares. The rainfall intensity relation with duration for this catchment is given by the relation I = 100/(t+20), where I is in cm/h and t is duration of rain in min. (A) Draw the graph of rainfall intensity relation with duration at 10 min interval? (B) What will be the storm water runoff from this catchment if the average imperviousness factor is 0.63, and time of concentration is 35

min? (C) If population density of the area is 350 persons per hectare and water consumption is 170 LPCD, what will be the design discharge for separate system and combined system?