# Storm Water Drainage Design Based on Hydrological Analysis at Shanmugham Road Area, Cochin, Kerala

**Ancy Genu C. George[1], Aleena Shaju[2], Ameena Rafeek[3], Namitha Binu[4], Samad Aadil M.N.[5]**

*[1]Assistant Professor, Department of Civil Engineering, Viswajyothi College of Engineering and Technology, Vazhakulam, Kerala, India*
*[2,3,4,5]Students, Department of Civil Engineering, Viswajyothy College of Engineering and Technology, Vazhakulam, Kerala, india*

---

**Abstract -** *An established drainage system to collect the running storm water is a long term ambition of the society, especially in cities. The presence of excess water within a roadway adversely affects the engineering properties of materials with which it is constructed. When it rains, a part of the rain water flows on the surface while a part of it percolates through the soil mass to reach the ground water. It is very much required that the surface water from the carriage way and shoulder should effectively be drained off from the land without allowing it to percolate to sub-grade. Also the surface water from adjoining land should not enter into the road way. The side drains in roadway should have sufficient capacity and longitudinal slope to carry away all the surface water. Thus there is the need to evaluate the hydraulic performance of the system and determine the system efficiency. The analysis is conducted on Shanmugham road area of Cochin City in Kerala, India where the excess runoff is really a threat to the area. Most of the existing storm water drains in this area are in a worst stage and not working properly with no proper maintenance. This study is mainly focused on the storm water drainage design based on hydrological analysis which includes the calculation of peak runoff by Rational Method and the slope calculation by Manning's Formula.*

***Key Words*: Storm Water, Hydrological Analysis, Rational Method, Time of Concentration, Rainfall Intensity, Manning's Formula.**

## 1.INTRODUCTION

### 1.1 General

Provision of adequate drainage is of immence important in road design. When runoff gets along the ground, it may pickup soil contaminants which include insecticides, or fertilizers that end up discharge or overland flow. Some water gets held in the pores of the soil mass and on the surface of the particles which cannot be drained by normal gravitational methods [1]. It is very much needed that the surface water from the carriage way and shoulder should effectively be drained off without allowing it to percolate to sub-grade. The surface water from adjoining land should also be restricted from entering the road way. An effective drainage system should be such that, it must be able to handle stormwater or wastewater, should effectively remove water that can cause damage to important assets, creating a safe and hazard free environment for the occupants. It should also eliminate water stagnation and associated health and safety issues. Thus it is very much important to have roadside drains with enough capacity and longitudinal slope to carry away all the surface water collected [2].

Hydrological analysis of the area is an essential element in the design of roadway drainage. This is because it supplies the required information about runoff and stream flow characteristics which are used as the basis for the hydraulic design. In this process the design flow is established by selecting the proper combination of rainfall and runoff characteristics that can be reasonably expected to occur [1]. There is also an important factor called rainfall intensity corresponding to a time of concentration within a certain frequency period which is the basis for the design [3]. The design criteria would then be the discharge capacity to be carried by the design structure with no discharge or a limited amount of discharge to be equaled or exceeded on the average of one during a design. The hydrological analysis also comprises of design of drain sections using Manning's formula. Manning's equation is a semi-empirical equation [4] and is a mostly used equation for uniform steady state flow of water in open channels. The application of this equation is restricted to small areas only.

### 1.2 Scope of the study

The urban flood vulnerability zonation [5] of the Cochin City Corporation indicates that the city is facing severe water logging problems. There is a number of places in the city suffering from water logging due to heavy rainfall during monsoon. Due to water logging, normal life and traffic movements of the city gets affected. Water logging in some roads persists for few hours, whereas in certain lowlands, it continues for few days. The main reason for the water-logging is due to improper roadside drains.

### 1.3 Objectives

- Estimation of peak runoff by Rational formula

- Determination of section of drain by Manning's formula

## 2. STUDY AREA

Cochin, also known as Kochi is called as the queen of Arabian sea, and one of the most populated city in Kerala with its total population of more than 2.1 million within an area of 440 km.sq [6][7]is under the threats of severe water logging problems that result in urban flooding due to heavy rainfall during monsoon. Cochin (Kochi), is the headquarters of Ernakulam district. Cochin Corporation having a place of 94.88 $km^2$ is positioned geographically among 76˚15'9.4"–76˚30'8.35" East longitudes and 9˚42' 3"–9˚58'9.39" North latitudes [5]. Being a coastal place, majority of the Cochin vicinity is in the lowland areas of the State. The common altitude is 7.5 m above MSL. The entire land slopes regularly from East to West.

In the vulnerability zonation [5], 1.27 % area of Cochin City Corporation falls under the category 'Very highly' at risk of city flood. The predominant places on this area consist of Kadavanthra, Mattanchery, Fort Kochi, High court area, Panchalam, Palimukku and Ravipuram. These places belong to the top areas, in which schools, markets, courtroom docket, hospitals, and different industrial establishments are positioned here. Thus, it is able to be determined that if any flood occurs in the city, it significantly have an effect on the common public, in comparison with the alternative places. Many of the above places no longer have proper drainage channels and the present channels aren't maintained properly. One main reason for the rapid urban flooding in Cochin is the unscientific construction of drains. Cochin did not have much land for open dumping of the waste.

This study was done in Shanmugham road, a major road in Cochin. It runs parallel to Cochin Backwaters and prelevantly known as Marine Drive. It is an active and a commercialized road of the city, with shopping centres and workplaces. The road starts at the High Court Junction on the North end and ends at the Ernakulam Guest House near to Broadway at the South. It further proceeds South as Park Avenue Road. It is a four lane city road which has a wide median separating the two carriageways. The region is very popular for electronic goods and cosmetics. This study on redesigning drainage is mainly centred around this area.

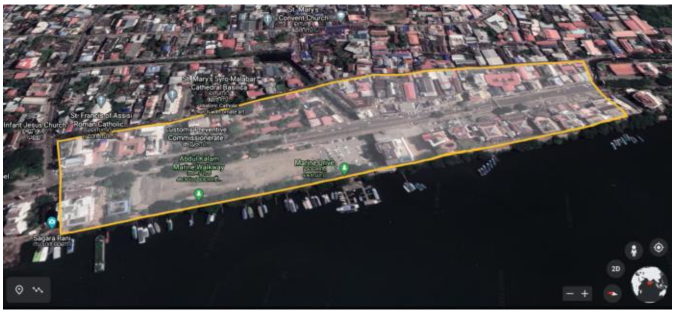


**Fig -1**: Google Earth image of Shanmugham road

## 3. METHODOLOGY

### 3.1 Determination of drainage catchment area

It is very necessary to accurately determine the area A, draining to the point under consideration in a storm water management system [1]. Drainage area information should include the landuse, percentage of imperviousness and character of soil and ground cover as they may affect the runoff coefficient. It should also include the magnitude of ground slopes which will affect the time of concentration. From google earth image, it was found that the total drainage area contributing to runoff was 15.48 hectares.


**Fig -2**: Division of catchments in Shanmugham road

**Table -1:** Area of catchments near Shanmugham Road

| SL.NO: | Sub-Catchment | Area (Ha) |
|---|---|---|
| 1 | Sub-Catchment 1 | 3.74 |
| 2 | Sub-Catchment 2 | 3.87 |
| 3 | Sub-Catchment 3 | 4.12 |
| 4 | Sub-Catchment 4 | 3.75 |

### 3.2 Determination of runoff coefficient

The runoff coefficient is expressed as a dimensionless decimal that represents the ratio of runoff to rainfall intensity. Except for precipitation, all other portions of the hydrological cycle are contained in the runoff coefficient [3]. Therefore, the runoff coefficient includes interception, infiltration, evaporation, imperviousness and groundwater flow. The variables needed to estimate runoff coefficient should include the soil type, watershed slope, degree of imperviousness, surface roughness, duration and intensity of rainfall, moisture condition, interception and surface storage.

**Table -2:** Calculation of composite C

| Catch ment | Land use | Runoff Coefficient, $C_i$ | Catchment area $A_i$ (Ha) | $C_iA_i$ |
|---|---|---|---|---|
| 1 | Builtup Areas | 0.70 | 3.74 | 2.62 |
| 2 | Playground | 0.25 | 3.87 | 0.97 |
| 3 | Builtup Areas | 0.85 | 4.12 | 3.5 |
| 4 | Builtup Areas | 0.75 | 3.75 | 2.81 |
| | | | $\sum A_i$ = 15.48 ha | $\sum C_iA_i$ = 9.9 ha |
| | | | $C = (\sum C_iA_i) / \sum A_i = 0.64$ | |

### 3.3Determination of overland flow length and elevation difference

The overland flow length and the elevation difference were calculated from Google Earth Pro. The length of overland flow from critical point to the mouth of the drain was found to be 103m and the total fall of level from the critical point to mouth of drain was found to be 2.32m.

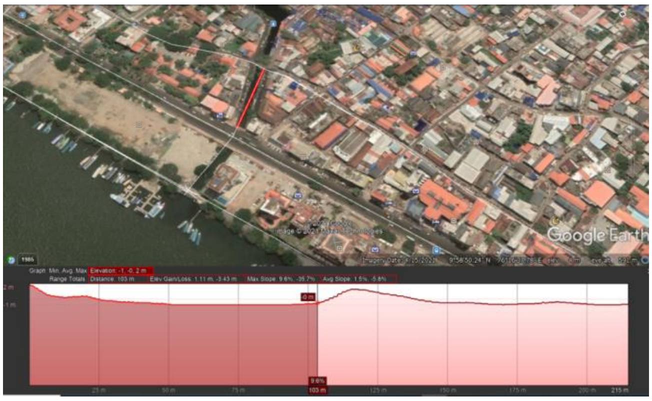


**Fig -3**: Elevation profile of Shanmugham road

### 3.4 Calculating time of concentration (Tc)

The time of concentration is equal to the sum of inlet time and travel time. Inlet time is the time required for the rain on the most remote point of the tributary area to flow across the ground surface along the natural drains to inlet of the sewer. It is given by the equation [8]

$$Ti = [0.885\ L^3/H]^{0.385} \qquad (1)$$

where,

Ti = Inlet time in hours

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

H= Total fall of level from the critical point to mouth of drain in meters

Travel time is the time required by the water to flow in the drain channel from the mouth to the point under consideration.

$$Tt = \text{Length of drain} / \text{Velocity in drain} \qquad (2)$$

After finding the overland flow length and the elevation difference, the inlet time was calculated. It was found to be 3min.The total length of the drain was 822m and the minimum velocity of 1.5 m/s was taken to ensure self-cleaning of the drain. This value of velocity was taken from IRC:SP:50-2013. The travel time was calculated as 9min. In total, the time of concentration was found to be 12min.

### 3.5 Calculation of rainfall intensity

The values of intensities for 50 year return period [8] were obtained corresponding to 1,2,3,7 and 10 days respectively. Inorder to get intensities for shorter durations, a graph is plotted with the logarithmic values of intensity on Y-axis and duration on X-axis for 50 year return period. The points are found to follow straight lines. The line is then extended inorder to get intensities for shorter durations.

**Table -3:** Values of intensity and duration corresponding to 50 year return period

| SL.NO: | Intensity (cm/hr) | Duration (days) |
|---|---|---|
| 1 | 1.025 | 1 |
| 2 | 0.746 | 2 |
| 3 | 0.65 | 3 |
| 4 | 0.446 | 7 |
| 5 | 0.35 | 10 |

Thus the rainfall intensity of the area was obtained as 112mm/hr corresponding to time of concentration of 12minutes.

### 3.6 Estimation of design discharge

Inorder to find the peak discharge of the total catchment, Rational method was used, taking the rainfall intensity as 112mm/hr. Rational method is an empirical relation between rainfall intensity and peak discharge that is widely accepted by hydraulic engineers [9]. The Rational method is usually expressed as

$$Q=CIA/360 \tag{3}$$

where; Q=Quantity of runoff (m3/s), C= Coefficient of runoff, I=Intensity or rate of rainfall (mm/h), A= Area of the watershed (Ha).

Peak discharge from the entire catchment was obtained as 3.08m$^3$/sec using the rational formula. For the purpose of determining drainage size for each of the four sub-catchments, discharge on each side of the road for all those sub-catchments were calculated as shown in table.

**Table -4:** Calculation of discharge by Rational formula

| Catchment | Area (Ha) | Cumulative Area (Ha) | C | Composite C | Total discharge (m$^3$/sec) | Discharge on each side (m$^3$/sec) |
|---|---|---|---|---|---|---|
| 1 | 3.74 | 7.61 | 0.70 | 0.47 | 2.62 | 0.55 |
| 2 | 3.87 | | 0.25 | | 0.97 | 0.55 |
| 3 | 4.12 | 7.87 | 0.85 | 0.80 | 3.5 | 0.98 |
| 4 | 3.75 | | 0.75 | | 2.81 | 0.98 |

### 3.7 Determining the size and slope of the drain

The side drainages are designed based on the principle of flow through open channels. If Q is the quantity of surface water (m$^3$/sec) to be removed by a side drainage and if V is the allowable velocity of flow (m/s) on the side drainage, the area of cross section of flow A (m$^2$) is found from the relation [9]:

$$Q=A*V \tag{4}$$

The velocity of channel must be high enough to prevent silting and it should not be too high as to cause erosion. To ensure self cleaning of the drain, a minimum velocity of 1.5m/s is taken from IRC:SP:50-2013. Thus the area of flow can be calculated. The channel section is considered to be trapezoidal section.

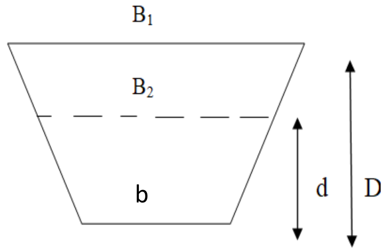



**Fig -4**: Trapezoidal section of channel

where, B1 = top width of channel section (m),

B2 = top width of flow of channel section (m),

b = bottom width of channel (m),

d = depth of water in channel (m),

D = depth of channel (m)

From IRC:SP:50-2013, the bottom width of the channel is taken as 500mm and for economical section the side slope is taken as 1:1. The minimum free board is taken as 150mm. After calculating all the parameters, hydraulic radius is determined. A channel is described as more efficient if there is a large area of water in the cross section compared with the length of the bed and banks. The efficiency is determined using hydraulic radius,

$$R=A/P \tag{5}$$

where, A = cross sectional area (m2 ),

P = wetted perimeter (m).

The slope S of the longitudinal drain of cross section and depth of flow [9] ,can be determined by using Manning's formula for the value of velocity of flow V, roughness coefficient n and hydraulic radius R.

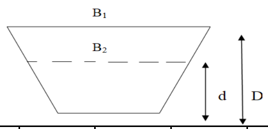
$$V=1/n*R^{2/3}*S^{1/2} \tag{6}$$

## 4. RESULTS AND DISCUSSION

First part of the study was the computation of peak discharge for the entire catchment area by Rational formula. For that, the composite runoff coefficient was calculated as 0.64. Then the intensity was traced as 112mm/hr corresponding to a time of concentration of 12minutes. Obtaining the total area of catchment from Google Earth, the peak runoff was found to be 3.08m3/sec.

The second part of the study was the computation of channel size and slope. Inorder to find it, discharge on each side of the road for those sub-catchments were found in Table 4. With certain assumptions derived from IRC:SP:50-2013, the slope of channels for those sub-catchments were calculated using Manning's equation as shown in Table 5.

**Table -5: Calculation of slope by Manning's formula**

| Parameters | | Trapezoidal Section  | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Catchment | Discharge ($m^3$/s) | Side slope H:V | $B_1$ (m) | $B_2$ (m) | b (m) | d (m) | D (m) | Slope, S |
| 1 | 0.55 | 1:1 | 1.62 | 1.32 | 0.5 | 0.41 | 0.56 | 1 in 508 |
| 2 | 0.55 | 1:1 | 1.62 | 1.32 | 0.5 | 0.41 | 0.56 | 1 in 508 |
| 3 | 0.98 | 1:1 | 1.98 | 1.68 | 0.5 | 0.59 | 0.74 | 1 in 621 |
| 4 | 0.98 | 1:1 | 1.98 | 1.68 | 0.5 | 0.59 | 0.74 | 1 in 621 |

## 5. CONCLUSION

This study was conducted to evaluate hydraulic efficiency of drainage channel. Using Rational formula and Manning's formula, the catchment peak discharge and the channel discharge were determined. The waterlogging in the study area was mainly due to the insufficient existing sections and the lack of proper slope to accommodate the runoff. Rational method has been effectively used here to design the storm water drains of the study area. The annual rainfall data of the area was used to obtain the rainfall intensity. The catchment peak discharge of the entire catchment were determined as 3.08 $m^3$/sec and channel discharge at catchment 1,2 and 3,4 were determined as 0.55 and 0.98 $m^3$/sec respectively. The slope of the drainage at 1,2 and 3,4 sections were 1 in 508 and 1 in 621 with rainfall intensity of 112 mm/h. This method of designing stormwater drains is not only limited to Cochin city, but for any other region with its own rainfall intensities and time of concentration, the procedure remains the same.

## 6. REFERENCES

[1] T.S.K. Tya and E Akoh, ''Hydraulic Evaluation Of Road Side Drainage System In Modibbo Adama University Of Technology Yola, Adamawa State, Nigeria'', Nigeria Journal of Engineering Science and Technology Research Vol. 6, No. 1, 2020(51-57)

[2] Lathif, H.W., "Drainage and Design of Drainage System", Publish in Engineering, 68p.

[3] Priyanka D. Harpalani, R.B.Khasiya, Dr.P.G.Agnihotri, "Analysis of Rainfall Data and Design of Storm Water Drainage System in an Urban Area", Volume : 2, Issue 4, April 2013 ,ISSN No 2277 - 8160

[4] Keshav Basnet, Manoj Neupane , "Storm Water Drainage Design Based On Hydrologic Analysis: A Case Study On Lamachaur Catchment Area, Pokhara, Nepal", A Journal of TUTA, Vol 5, No. 1, Issue 5, October 2018.

[5] K. Sowmya ,C. M. John, N. K. Shrivasthava, "Urban flood vulnerability zoning of Cochin City, southwest coast of India, using remote sensing and GIS", Journal of the International Society for the Prevention and Mitigation of Natural Hazards, 2014, ISSN 0921-030X

[6] Mathew S, Truck S, Henderson-Sellers A, " Kochi, India case study of climate adaptation to floods", Glob Environ Change 22(2012):308–319

[7] Hridya K K , Princy Lukose and R Rajesh, "Solid Waste Management in Cochin, India: Practices, Challenges and Solutions", Journal of Basic and Applied Engineering Research, Volume 3, Issue 9; April-June, 2016, pg. 746-751

[8] B.C. Punmia, Ashok Jain, "Wastewater Engineering (including air pollution)" , Environmental Engineering 2, 1996, ISBN : 81-7008-091-6

[9] Santosh Kumar Garg ,"Sewage Disposal and Air Pollution Engineering", Environmental Engineering Vol 2, 1979, ISBN No.: 978-81-7409-230-4.

[10] Needhidasan.S, Manoj Nallanathel, "Design of Storm Water Drains by Rational Method – an Approach to Storm Water Management for Environmental Protection", International Journal of Engineering and Technology (IJET) , 2013, Vol 5 No 4, ISSN : 0975-4024.

## 7. BIOGRAPHIES

ANCY GENU C. GEORGE
Assistant Professor
Civil Department
Viswajyothi College of Engineering and Technology,Vazhakulam, Kerala, India

ALEENA SHAJU
4th year student,
Civil Engineering
Viswajyothi College of Engineering and Technology,Vazhakulam, Kerala, India

AMEENA RAFEEK
4th year student,
Civil Engineering
Viswajyothi College of Engineering and Technology,Vazhakulam, Kerala, India

NAMITHA BINU
4th year student,
Civil Engineering
Viswajyothi College of Engineering and Technology,Vazhakulam, Kerala, India

SAMAD AADIL M.N
4th year student,
Civil Engineering
Viswajyothi College of Engineering and Technology,Vazhakulam, Kerala, India