Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 5, May-2016

"ANALYSIS OF RAINFALL DATA AND DESIGN OF STORM WATER DRAINAGE SYSTEM IN AN URBAN AREA"

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Abstract: *Rainfall data of past available in minute form is analyzed and new data from year 2001-2015 is analyzed. The new minute data is obtained by co-relating the previous minute data which is available to us . After co-relating flood frequency is being found out .As new data are available in hourly form and old data in minute . Rational method is used for estimating runoff from catchment. Different curves of intensity vs duration, runoff coefficient vs duration, 10CI vs duration are derived for city of surat and design of drain is carried out by manning's chart in study area.*

Key words*: *Rainfall, Runoff, Storm-water, Rainfall intensity, Flood frequency

I. INTRODUCTION

Different methods to find runoff and is as under

1. Rational Method

2. SCS curve no. method

3. Annual Maxima Method

4. Empirical formula method

5. Rainfall runoff coefficient

6. Hydrograph method

We will use Rational method suggested by Central public health engineering and environmental organization

The storm sewers are not designed for the peak flow of rare occurrence such as once in 100 years more but it is necessary to provide sufficient capacity to avoid too frequent a flooding of drainage area. There may be some flooding when the precipitation exceeds the design value which has to be permitted. The frequency of such permissible flooding may vary from- place to place, depending on the importance of the area. Flooding at any area, however, causes inconvenience to citizens but they may accept it once in a while considering the savings affected in storm drainage coats. Commercial and industrial areas should be subject to less frequent flooding than the Residential areas. Manuals on sewerage and sewage treatment has suggested following frequency of flooding in different areas.

II. STUDY AREA AND DATA COLLECTION

Vadod area of surat city Tp. No 63 has insufficient capacity of storm drainage facility and some where no storm water drainage facility is available . such area is being selected as there is frequent flooding due to inadequate capacity of rainfall .Vadod area of surat city lies in south zone of surat district . It is developing area as per new developing scheme . the study area lies in residential area so our design will be done as per guided by CPHEEO manual.

III. METHODOLOGY

A). Estimation of runoff

As we know precipation as a whole does not forms runoff , for runoff impervious factor plays a vital role. impervious for diffenernt area may be different . so impervious factor is taken as per the developing area characteristics of that area .That area lies in the urban residential area .

Q= 10CIA.

1. Frequency of storm

Manual of CHPEEO has suggested following storm flood frequency .

Table. 1 Frequency of flooding in different areas

	Residential areas	
	(i) peripheral area	year
	(ii) Central and comparatively area	once a year
	and high priced areas	once in 2 years

Our area of design is residential areas part (ii) central and comparatively high priced area so our design will be once in a year .

2. Intensity of Precipitation

Intensity of the rainfall decreases with the duration. Analysis of past records over a period of years of the observed data on intensity duration of rainfall in the area is necessary to arrive at a fair estimate of intensity duration for given frequencies. The longer the record available more dependable is the forecast.

The relationship may be expressed by suitable mathematical formula given in CPHEEO.

The following equation is commonly used

$i = \frac{a}{t^n}$

where ,

i = intensity of rainfall (mm/hr)

t = duration of storm (minutes) and a, b and n are constant.

The available data on i and t are plotted are called rainfall intensity duration curve. The values of intensity, (i) can then be determined for any given time of concentration, (t_c).

3. Time of concentration

It is the time required for the rain water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. Time of concentration (t_c) is equal to inlet time (t_i) plus time of flow in sewer (t_f). The inlet time is dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin. It is the time required for the rain water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. Time of concentration (t_c) is equal to inlet time (t_i) plus time of flow in sewer (t_f). The inlet time is dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin.

The time of inlet can be obtained from the formula as suggested by IRC which is given below:

$$t_i = (0.87 \frac{L^3}{H})^{0.385}$$

Where t_i - time of entry in hours.

L - Length of critical point of catchment area to starting of the section in Kms.

H - fall in level from critical point to starting of section in meter .

And time of flow can be obtained from the single relation as given below:

$$t_f = \frac{L}{V*60}$$

Where,

L - length of drain proceeding the section under consideration in meters.

V - velocity in meter per sec.

4. Coefficient of runoff

Pondage in depressions, evaporation, absorption, and other factors reduce the runoff, so that not all the rainfall, even on impervious surfaces, reaches the sewer inlets. The longer the storm duration, larger may be the percentage of rainfall runoff.

The proportion of pervious and imperious areas probably affects the runoff as much as any other factor. In designing practical procedure includes a reasonable estimate of the probable future percentage of impervious area. Different factor used for computation of runoff coefficient is discussed in following paragraphs

(A) Imperviousness:

Estimates of the relative proportion of pervious and impervious area can be made by considering the present development of a number of typical areas in the more completely developed sections of the city for which sewers are to be designed and comparing these with the anticipated future development of the districts to be sewered.

Manual on sewerage and sewage treatment has recommended the values of percent imperviousness for different areas as given in Table-2 below:

Table.2 Guidelines for imperviousness factors of drainage area

No.	Type of Area	Percentage of imperviousness
1	Commercial and industrial area	70 to 90
2	Residential area	
	(a) High density	60 to 75
	(b) Low density	35 to 60
3	Parks and other undeveloped area	10 to 20

The weighted average imperviousness of drainage basin for the flow concentrating at a point may be estimated as:

$$I = \frac{A_1 I_1 + A_2 I_2 + ..}{A_1 + A_2 + ..}$$

Where,

I = Weighted average imperviousness of the total drainage basin

A_1, A_2, …An = Drainage area tributary to the section of drain under consideration.

I_1, I_2, …… In = Imperviousness of the respective areas.

(B) Computation of runoff coefficient :

The weighted average run-off coefficient for rectangular areas of length four times the width as well as for sector shape areas with varying percentage of impervious surface for different time of concentration are calculated from Horner Table given in CPHEEO . Although these are applicable to particular shapes of area , they also apply in general way to areas which are usually encountered in practice.

1. Self Cleansing Velocity

It is necessary to maintain a minimum velocity or "self cleansing velocity" in sewer to ensure that suspended solids do not deposit and cause nuisance. Manual on sewerage and sewage treatment has recommended 0.8 mps at design peak flow.

2. Velocity at Minimum Flow

To avoid steeper gradient which will require deeper excavations it is a practice to design storm drains for self cleansing velocity at peak flow as calculated from rational method. This is done on the assumption that although silting might occur at minimum flow, the silt would be flushed out during the peak flows.

3. Erosion and Maximum velocity

Erosion of sewers is caused by sand and other gritty material in the sewer and also by excessive velocity, velocity in a sewer is recommended not to exceed 3.0 mps as recommended by manual on sewerage and sewage treatment.

4. Minimum Size

Manual on sewerage and sewage treatment has recommenced minimum diameter of sewer shall be 200 mm. Minimum size for hilly areas where extreme slopes are prevalent may be 100 mm.

5. Hydraulic Formulae

Usually sewers are considered as open channels in the selection of hydraulic formulae. The Kutter and Manning's formula have been widely used in designing slope and diameter of sewer line to carry the design flow at a stated velocity for open channel flow condition. The Manning formula has increased use in recent years because of its simplified form and relative ease of use and more commonly used . Hence manning's formula is used for designing.

6. Depth of flow

Storm sewers are generally designed to run full. But from considerations of ventilation in waste water flow the sewers should not be designed to run full.

IV. ANALYSIS OF RAINFALL DATA

The flooding of the Vadod area, Surat is quite common during the monsoon. This part of area gets flooded even when there is rainfall for one hour. This area is yet not considered for design of storm water drainage by Surat Municipal Corporation, this area falls in TP Scheme 63. Therefore, Vadod area of the Surat has been selected for design of storm water drainage system. Data collection analysis are presented here.

Analysis of maximum rainfall intensity for 5,10,15,30,45,60,75 and 90 minute duration for the period of 1969 to 1983 for the city of Surat are calculated

Analysis of maximum rainfall intensity for 60 minute duration for the period of 2001 to 2015 for the city of Surat are done and new rainfall pattern is obtained by correlating old data because only hourly data are available nowadays.

Table :- 3 Analysis of frequency of storm of stated intensities and duration for period of 15 year (1969 to 1983)

Duration in min	No. of storms of stated intensity in mm/hr												
	25	30	35	40	45	50	60	70	75	80	90	100	120
5							63	31	19	13	9	3	2
10						65	26	22	20	10	4	4	1
15						55	36	22	15	14	7	2	
30				45	33	28	17	8	5	5	1		
45				26	19	15	9	4	1	1			
60			25	20	14	10	5	2					
75		19	14	11	8	6	1						
90	17	15	9	7	4	3							

Table 3 and Table 5 gives the analysis of the frequency of storms of stated intensities and durations during 1969 to 1983 (15 year) and 2001 to 2015 (15 year) for which rainfall data are available for the city of Surat respectively.

The storm occurring once in a year i.e. 15 times in 15 years has been found. The time intensity value for this frequency has been obtained by interpolation and given in Table 4 and Table 6

Table :- 4 Time intensity values for one year flood frequency for year 1969 to 1983

Duration ‘t’ in minutes	**Intensity ‘i’ in mm/hr**
5	78.33
10	77.43
15	75.00
30	62.22
45	50.00
60	44.16
75	34.00
90	30.00

The above data are plotted on graph paper (fig.1) known as rainfall intensity duration curve for one year flood frequency is obtained.

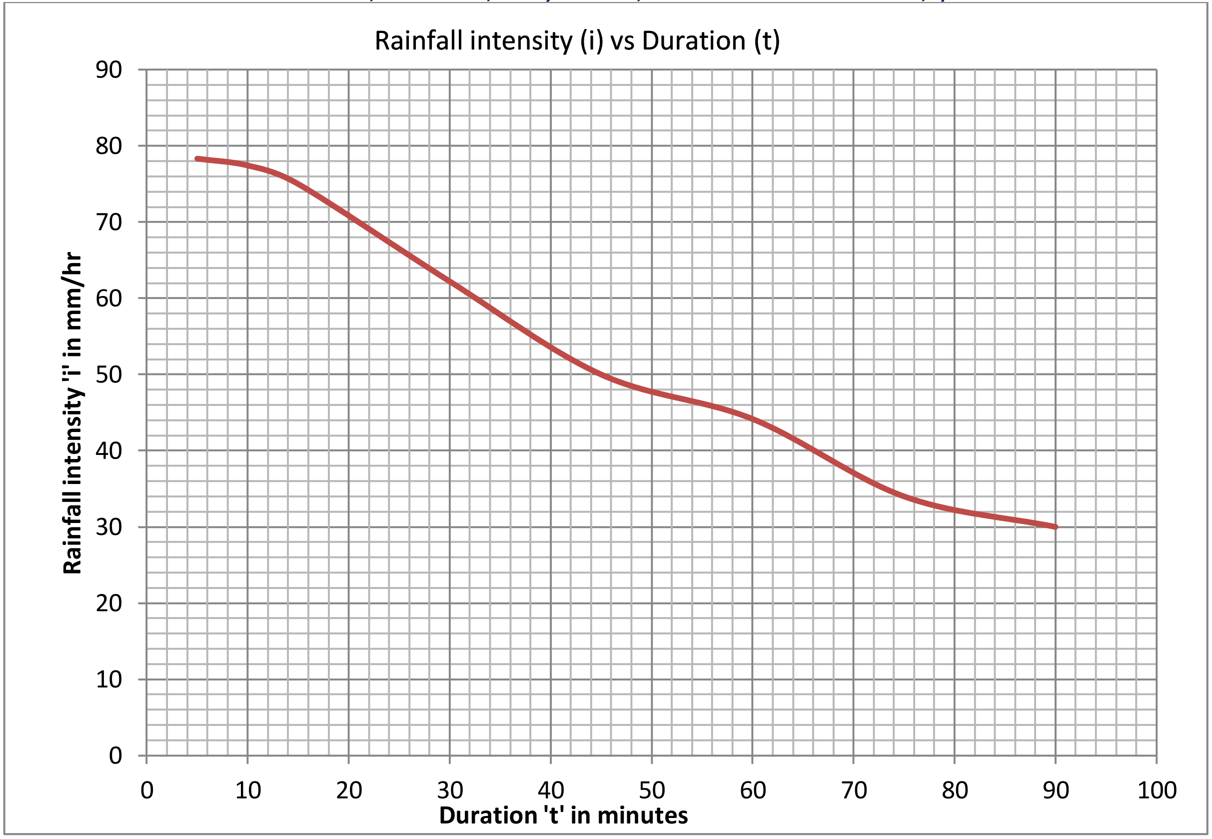

Fig 1 Rainfall intensity duration curve for one year flood frequency for year 1969 to 1983

Table. 5 Analysis of frequency of storm of stated intensities and 60 minute duration for period of 15 year (2001 to 2015)

Duration	No. of storms of stated intensity											
	25	30	35	40	45	50	60	70	75	80	90	100	120
60	85	61	46	37	22	19	8	4	4	3	3	1	0

Table.6 Time intensity values for one year flood frequency for year 2001 to 2015

Duration 't' in minutes	Intensity 'i' in mm/hr (2001 to 2010)
5	103.39
10	102.20
15	99
30	82.13
45	66
60	58.18
75	44.88
90	39.6

Volume 3, Issue 5, May 2016, e-ISSN: 2393-9877, print-ISSN: 2394-2444

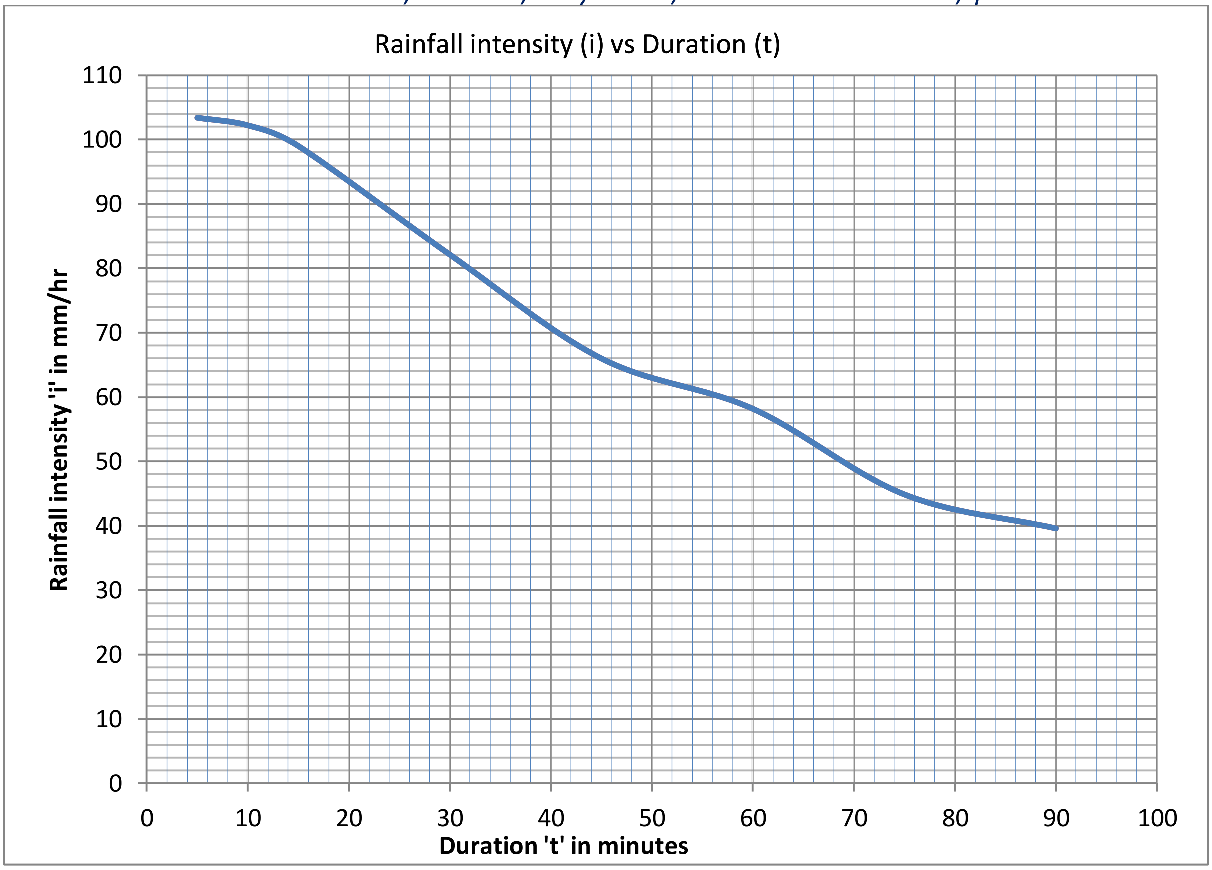

Fig 2 Rainfall intensity duration curve for one year flood frequency for or year 2001 to 2015

Table.7 Comparison of Time intensity values for one year flood frequency for year (2001 to 2015) to (1969 to 1983)

Duration 't' in minutes	**Intensity 'i' in mm/hr (2001 to 2010)**	**Intensity 'i' in mm/hr (1969 to 1983)**
5	103.39	78.33
10	102.20	77.43
15	99	75.00
30	82.13	62.22
45	66	50.00
60	58.18	44.16
75	44.88	34.00
90	39.6	30.00

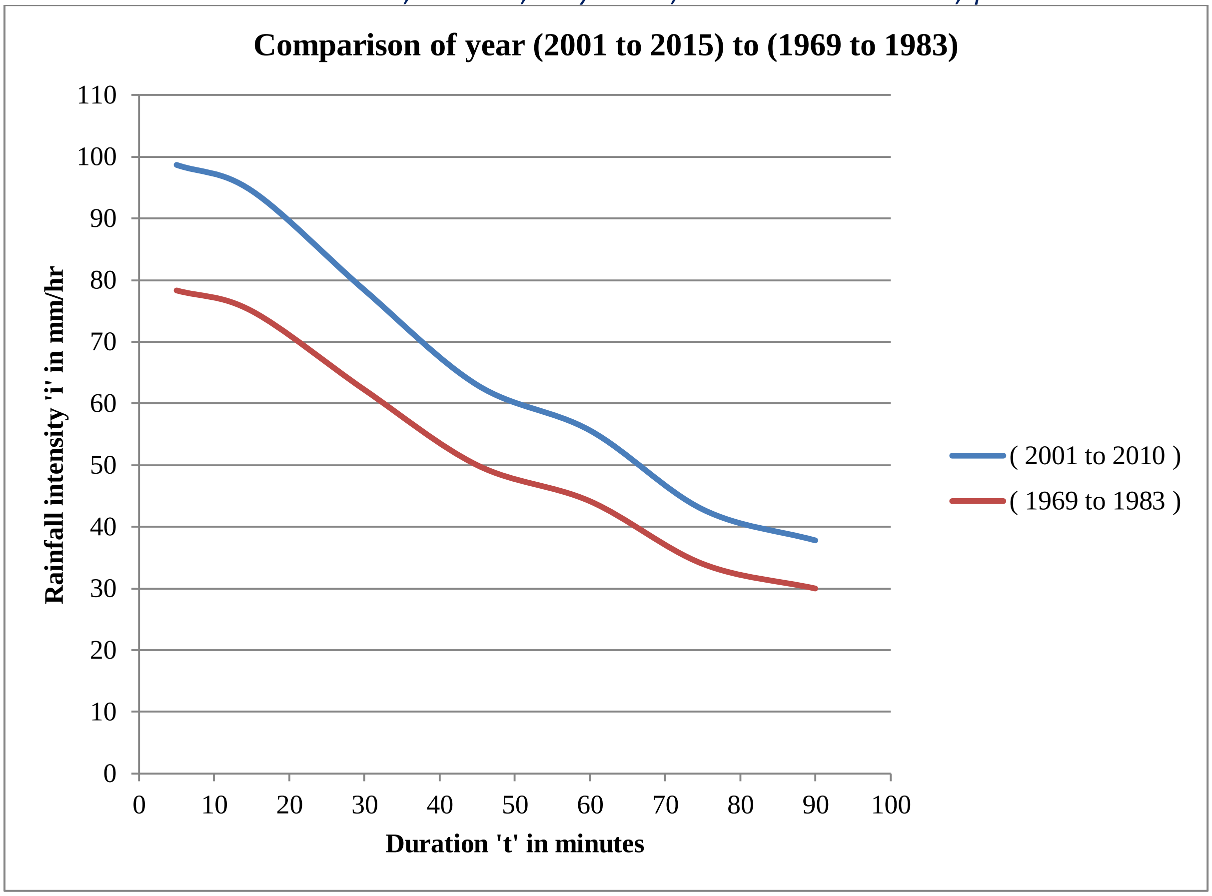

Fig 3 Comparison of Rainfall intensity duration curve for one year flood frequency for year (2001 to 2015) to (1969 to 1983)

1. Computation of Constants for Equation of Rainfall Intensity Curve suggested by CPHEEO

The constant a and n in the rainfall equation $i = \frac{a}{t^n}$, where a and n are constants and t is the duration of storm has been computed in Appendix-E. Logarithm graph is prepared considering the values of intensity (2001 to 2015).

Constants are calculated by putting values of rainfall intensity in log equation .

log 82 = log a – (n × log 30) …..1 t = 30 → i = 82

log 66 = log a – (n × log 45) …..2 t = 45 → i = 66

0.09496 = n × 0.17604

n = 0.53

Putting the value of 'n' in above equation 1

1.91 = log a – 0.53 × 1.477

log a = 2.71 , a= 514

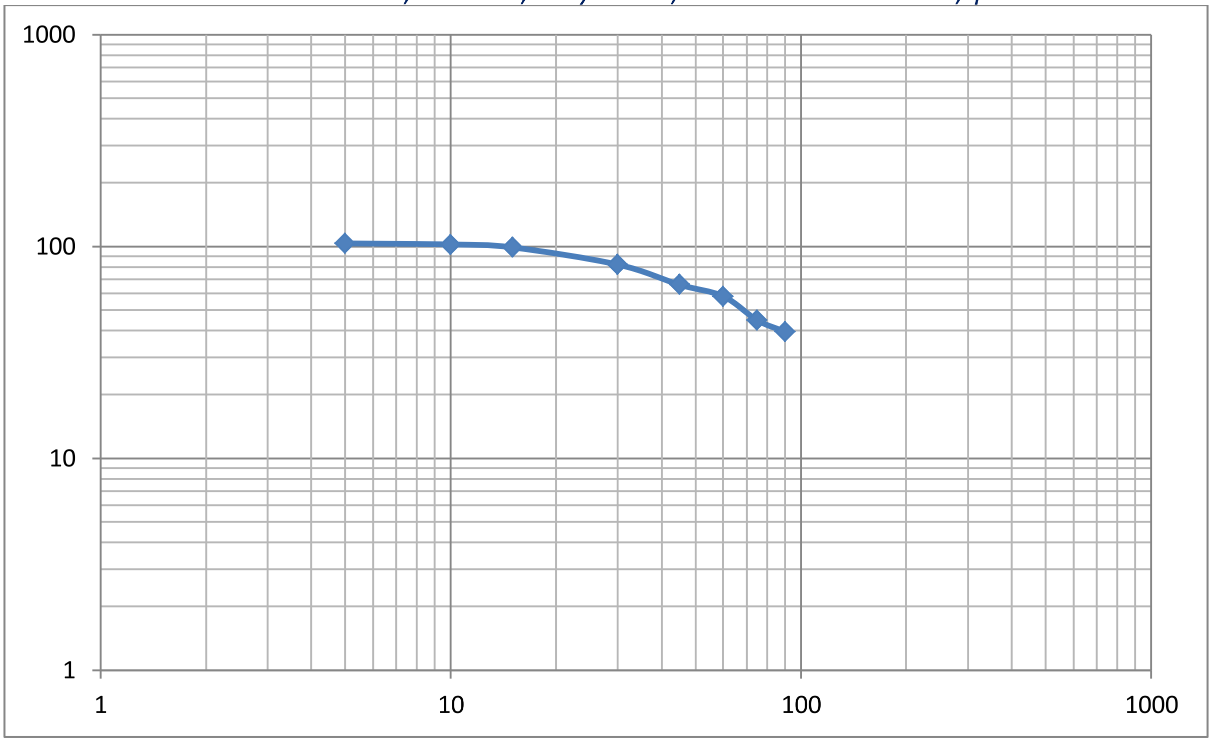

Fig 4 Logarithm Graph of Rainfall intensity duration curve for one year flood frequency for year (2001 to 2015)

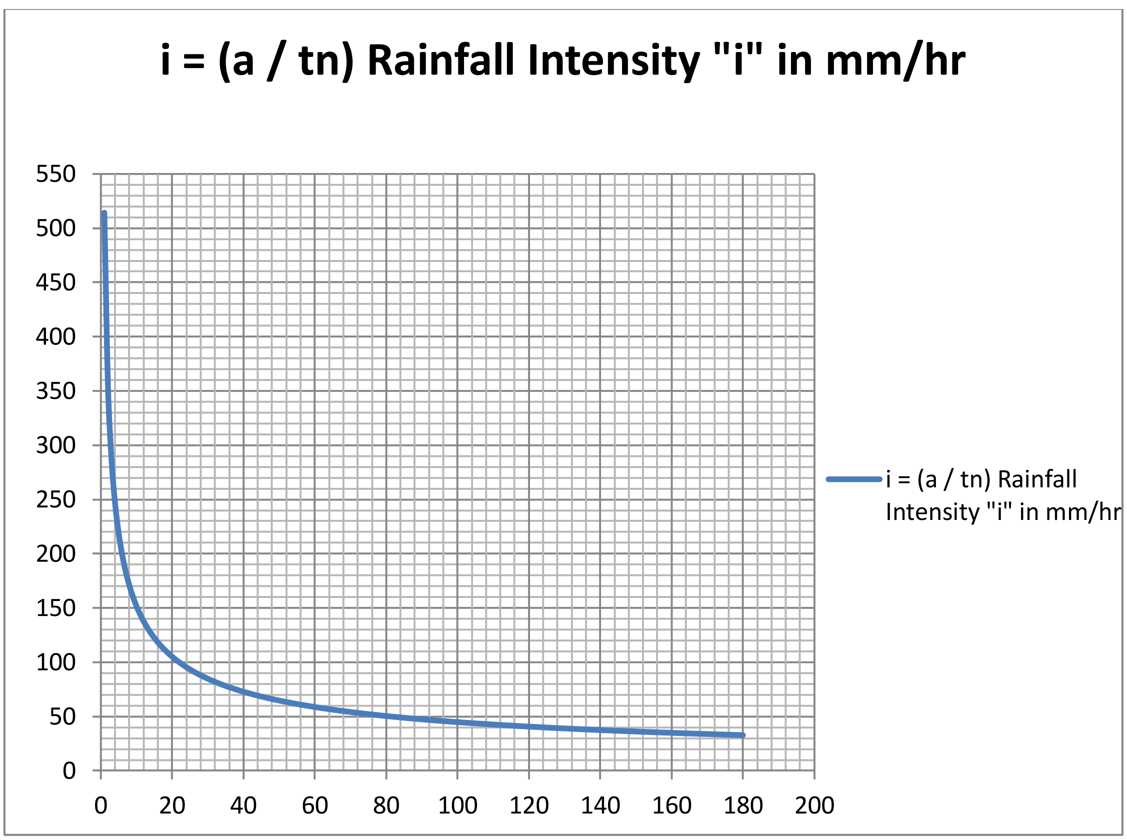

Fig 5 Rainfall intensity duration curve for one year flood frequency using Logarithm Graph for year (2001 to 2015)

2. Calculation of Runoff Coefficient

Graph (Fig.6) of runoff coefficient 'C' Vs duration time 't' is plotted as per values given in Table-6.

These curves is useful in getting rate of runoff per hectare of area for different duration of storm. The runoff coefficient increases as duration increases and runoff coefficient decreases as percent imperviousness decreases

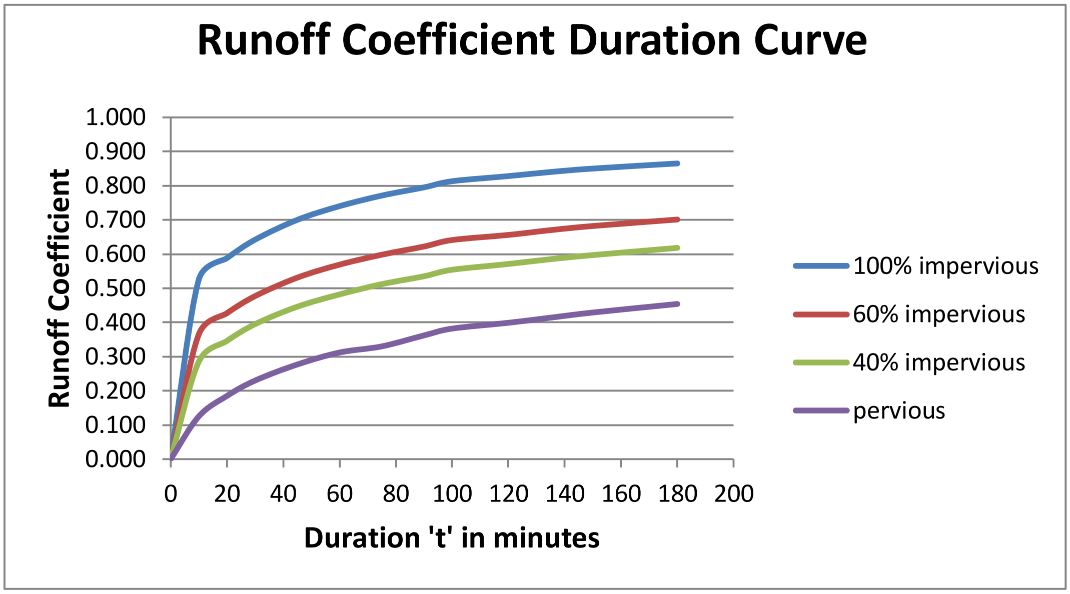

Fig 6 Graph is obtained of Runoff Coefficient Vs Duration curve with different curves of Pervious , 40% impervious , 60% impervious , 100% impervious with help of Horner'sTable.

2. Calculation of 10CI

Runoff coefficient vs. duration plotted by multiplying runoff coefficient with rainfall intensity. The values obtained by multiplying is presented in Table 8 and from this table curve is plotted. This curves is usefull in getting rate of runoff per hectare of area, for different duration of storm. The runoff coefficient increases as duration increases and runoff coefficient decreases as duration decreases .

Table.8 Values of 10 Ci (Rate of runoff in m^3/hr/ha for different duration of time)

Duration	Values of 10Ci in m^3/hr/ha			
	100 % Impervious	60 % Impervious	40 % Impervious	Pervious
10	536.55	373.03	291.27	127.75

20	549.02	398.69	323.06	172.73
30	527.27	391.76	324.41	188.90
45	462.00	350.46	294.36	182.82
60	430.53	331.04	280.43	181.52
75	346.02	268.38	229.79	148.10
90	314.82	246.31	211.86	143.35

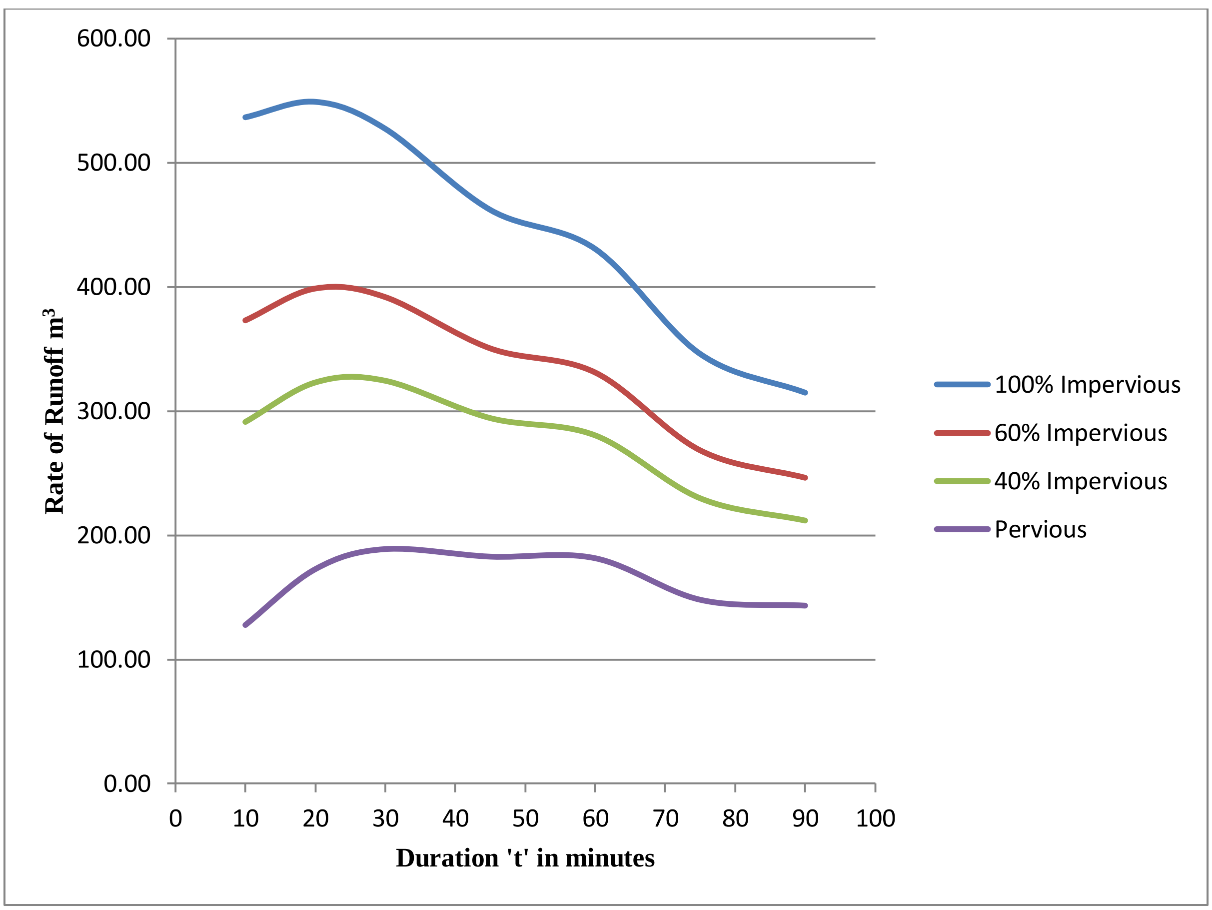

Fig 7 10Ci Chart

3. Computation of Imperviousness factor

The percentage of impervious of the drainage basin area can be obtained from the records of a particular district or zone. However, in absence of such data, the following may serve as a guide, as per CPHEEO "Manual on Sewerage and Sewage Treatment" (2nd edition), New Delhi. These are reproduced in Table

Table. 9 Guidelines for imperviousness factors of drainage area

No.	Type of Area	Percentage of imperviousness
1	Commercial and industrial area	70 to 90
2	Residential area	
	(a) High density	60 to 75
	(b) Low density	35 to 60
3	Parks and other undeveloped area	10 to 20

Table.10 Percentage of impervious for different types of surfaces

No.	Type of surface	Percentage of impervious
(a)	Water tight roof surfaces	90
(b)	C.C / Asphalt pavement in good order	80
(c)	Parks , open space lawn's meadows etc.	15

In area under Town Planning scheme, it is considered that 50 % area is covered with water tight roof surface, 15 % area is covered with C.C pavement in good order and 35 % area is covered with parks , open spaces lawns and meadows etc.

-The impervious for water tight roof surfaces at the end of design period is considered as 90% , i.e impervious 0.9.
-The impervious for C.C road pavements at the end of design period is considered as 80% , i.e impervious 0.8
-The impervious for parks, open lawns and meadows at the end of design period is considered as 15% , i.e impervious 0.15

Therefore, total weighted average imperviousness of the area will be

$$I = \frac{0.5\times90+0.8\times15+0.15\times35}{0.5+0.15+0.35} = \frac{45+12+5.25}{1} = 0.62$$

V. DESIGN OF DRAINS

The Vadod area of Surat has been considered for design storm water drainage system of T.P scheme 63 . The design is based on the rational formula for the estimation of peak runoff. Following assumptions have been made

Imperviousness factor = 0.62

minimum velocity in sewer = 1.0 mps

Rainfall Intensity is based on the one year storm flood frequency, as the area is central and comparatively low priced area. Quantity of storm water runoff is calculated using rational formula given

Q = 10 CiA

Where,

Q is the runoff in m^3 /hr

C is the coefficient of runoff

i is the intensity of rainfall in mm / hour, and

A is the area of drainage district in hectares.

Storm water runoff is determined in the following manner

(i) From rainfall records of last 15 year (1969 to 1983) and number of storm of various intensity for various time duration have been listed in Table- 3. The storm occurring once in a year i.e. 15 times in 15 years, the time intensity values for this frequency has been obtained by interpolation and are given in Table 4

(ii) From rainfall records of 15 years (2001 to 2015)and number of storm of various intensity for various time duration have been listed in Table-5. By correlating old data we obtain the storm occurring once in a year i.e. 15 times in 15 years, the time intensity values for this frequency has been obtained by interpolation and are given in Table 6.

Generalised formula adopted far intensity and duration is.
$i = \frac{a}{t^n}$

where
i = intensity of rainfall (mm/hr)
t = duration of storm (minutes) and
a and n are constants.

A logarithm Graph is obtained (Fig.5.4) for once in year rainfall intensity curve of year (2001 to 2015) and values of constant a and n for different time duration has been computed .

Another graph (Fig.6) of runoff coefficient 'C' vs duration time 't' is plotted as per values given in Horner Table in CHPEEO. From above graphs the values of c and i for the same duration time t are determined and the curves for 10 ci vs t for the various values of imperviousness are plotted (fig.7) with the help of Table-8. The value of 10 ci gives the rate of runoff in m^3 /hr per hectare of the tributary area. These curves ultimately used in calculating the runoff from the tributary areas for a given time of concentration and imperviousness factor.

VI. RESULTS AND DISCUSSION

(i)In the rainfall intensity equation $i = \frac{a}{t^n}$ the values of constants a and n are computed for different rainfall intensity duration, from the rainfall data available for the city of Surat, the value of constants a and n for different rainfall intensity duration are given

a = 514.27

n = 0.53

Using these constants a and n, the rainfall intensity for any duration can be computed.

(ii) Plot between rainfall intensity and duration is generated (Fig.2) The values of rainfall intensity can be read directly for different duration of storm from this graph.
(iii) Plots between runoff coefficient and duration are given in Fig.6. The values of runoff coefficient for different duration and for 100%, 60%, 40% and 20%. Imperviousness may be directly read from these graphs.
(iv) Plots between rate of runoff and duration are given in Fig.7. The value o f rate of runoff per hectare of area for different duration and for 100%, 60%, 40% and 20%. Imperviousness may be directly read from these curves.
(v) Design diameter, slope and profile of the storm water drains are calculated from manning's chart.
(vi) Curves generated are useful in the design of storm water drainage system. These curves are further used in design of storm water drainage system in area in Surat City or area of equivalent storm conditions.

VI. REFERENCES

[1] Dr.S.Akliandeswari and A.Julie, "Estimation of Biological Oxygen Demand Through Anfis Modeling" Global research analysis,2(10),pp.90-92,year 2013
[1] Paolo S. Calabro, "Design Storms and Water Quality Control", ASCE, J. Hydrol. Eng,9(1): 28-34,year 2004

[2] Fauzi Bin Baharudin, "A Study on rainfall-runoff characteristics of urban catchment of ungai kerayong"

[3] Ismail Abustan, Ahmad Husaini Sulaiman, Nabsiah Abdul Wahid and Fauzi Baharudin, "Determination of Rainfall-Runoff Characteristics in An Urban Area: Sungai Kerayong Catchment, Kuala Lumpur". 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK,year 2008

[4] Mahesh R. Gautam, Kumud Acharya and Mark Stone, "Best Management Practices for Stormwater Management in the Desert Southwest", year 2007

[5] Otunga robert okoth, "Rainfall-runoff corelation related to land use in nyando river basin",year 2010

[6] Qianqian Zhou, "A Review of Sustainable Urban Drainage Systems Considering the Climate Change and Urbanization Impacts",year 2014.

[7] Kim, Seung-Hyun, "Green Infrastructure as Water Sensitive Urban Design Strategy for Sustainable Stormwater Management ",year2015.

[8] Sankion,"Developing stormwater management through research and practice experiences from a Finnish pilot programme", year 2015.