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ANALYSIS OF EXISTING STORM SEWER SYSTEM – A CASE STUDY OF BAVLA TOWN

[1]Ashish Prajapati , [2]Dr. R. B. Khasiya, [3]Prof. C. N. Bhavsar

[1]PG Student, [2]Head of Department, [3]Assistant Professor

[1] Civil Engineering Department,

[1] L. D. College of Engineering, Ahmedabad, India

Abstract : An efficient storm sewer system has become a strong need of urban cities nowadays. In search of exponential growth, people are migrating to the urban area leading to haphazard densification. Impermeable Roads and floors are the major reason for flooding during the monsoon session. Characteristic of catchment area and intensity of rainfall are two major governing factors in the design of an urban storm sewer system. An inefficient system is the cause of ponding in many areas. This research paper investigates the capacity of the existing storm system by incorporating the rational method. Gumbel's method was adopted to generate the IDF curve. Historic data of 38 years were collected and analyzed. This case study of Bavla town of Ahmedabad District focuses on comparing the runoff produced and sewer capacity.

Index Terms : Rational Method, Gumbel's method, Runoff, Stormwater, IDF curve

I. INTRODUCTION

Stormwater drainage is the process of draining excess water from streets, sidewalks, roofs, buildings, and other areas. The system used to drain stormwater is often called storm drains and is also called storm sewers and drainage wells. Stormwater can be any precipitation, such as rain, snow, and sleet that falls on the surface of the earth.

Structural measures to control stormwater include storage reservoirs, flood embankments, drainage channels, anti-erosion works, channel improvement works, and detention basins and non-structural measures include flood forecasting, flood plain zoning, floodproofing, disaster preparedness, etc. In areas with natural, unaltered groundwater, about 10% of the precipitation becomes runoff and about 50% infiltrates into the soil to form or replenish groundwater and flows into streams. Evaporation and uptake by plants account for the remaining 40%. When natural conditions change due to development, land use, and other activities, this water cycle becomes altered. As the land becomes more covered with impervious surfaces, more precipitation converts into a runoff. This runoff carries the dust, other loads, and pollutants. When the development is more as much as 55% may become runoff.

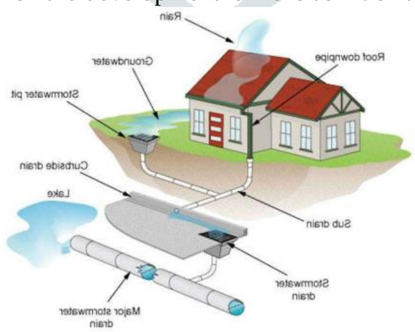

Fig 1. Storm sewer system

Storm sewers are large pipes or open channels that transport stormwater runoff from streets to natural bodies of water, to avoid street flooding. Storm drains vary in design from small residential dry wells to large municipal systems. Many storm drainage systems are designed to drain the stormwater, untreated, into rivers or streams. A combined sewer is a type of sewer system that collects sanitary sewage and stormwater runoff in a single system. Combined sewers can cause serious water pollution problems due to combined sewer overflows caused by large variations in flow between dry and wet weather. Any storm drains in the area may be discharging different quantities of water and also the type of pollutants it contributes. Since the cities become densely populated, the per-household volumes of wastewater exceed the infiltration capacity of local soils and hence require greater drainage capacity and sewer systems.

Runoff from a catchment is that fraction of precipitation that generates surface flow. It thus represents the output from the catchment corresponding to precipitation in a given unit of time. For given precipitation, initial losses due to the interception, evapotranspiration, infiltration, and detention storage requirements have to be first satisfied before the commencement of runoff. After these losses are met, the excess rainfall moves over the surface termed storm runoff. This is illustrated in the Figure given below.

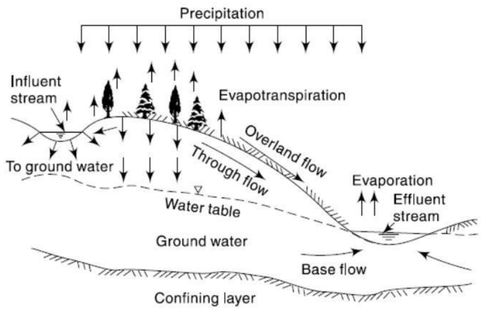

Fig 2. Hydrological cycle

Factors affecting runoff The runoff estimation is affected by the following factors of catchment hydrology:

a) Size of Catchment b) The shape of the Catchment, i.e., Fan-shaped, Fern shaped, Irregular Shaped, etc. c) Elevation of the Catchment d) Drainage Density e) Type of soil of the catchment f) Type of cover viz. paved, unpaved, vegetative, etc. g) Slope and orientation of the catchment 16 h) Topography (Depression storages/ponds/ lakes) and geology of the catchment i) Saturation of soil with water due to previous precipitation if any, including the level of groundwater table

II. LITERATURE SURVEY

Research paper on Design of Storm Water Drainage System in A Metropolitan Area by Pooja N Patel, Mr. N.N Borad , Mr. Utkarsh Nigam [1] Storm Water Drainage Design (Case Study Vijayawada) by P Sundara Kumar, T Santhi, P Manoj Srivatsav, S V Sreekanth Reddy, M Anjaneya Prasad and T V Praveen [2] Storm Water Drainage System Design – A Case Study by Shuchi Mishra, Gaurav Tanwer [3] Analysis of Drainage Capacity by Using Rational Method and Storm Water Management Model by Mi Pale Kyi, Dr. Win Win Zin [4] Storm Water Network Design of Jodhpur Tekra Area of City of Ahmedabad by Harshil H. Gajjar, Dr. M. B. Dholakia [5] To Study the Storm Water Drainage of Ahmedabad, Gandhinagar, and Vadodara City by Kanan Y. Patel Shibani Chourushi [6] Analysis of Rainfall Data and Design of Storm Water Drainage System In an Urban Area by Priyanka D. Harpalani, Dr. P. G. Agnihotri, Dr. R. B. Khasiya [7]

III. STUDY AREA AND METHODOLOGY

Bavla town of Ahmedabad District was selected as a study area to conduct this study, as this region faces ponding problems in a residential area every monsoon. 18 The town is bounded by sanad taluka to the north, bagodara to the west, and dholka and kheda to the south. It is located at 22.8365°N, 72.3628°E. Bavla is a town, and a municipality, in Ahmedabad district, in the state of Gujrat, India. As of the 2009 India census, Bavla had a population of about 45,000, with males constituting 53% and females 47%.

Bavla had a literacy rate of 69.7%, higher than the national figure of 59.5%, with 76.8% of males and 61.7% of females literate. 13% of the population was under 6 years of age. Bavla’s economy has its roots in the rice business, with an unofficial count of 135 rice mills many cotton processing factories (ginning), and a large grain market.

The Rational Method is used for runoff estimation. To find out the peak discharge, there is a requirement of the Highest daily peak of annual rainfall (mm). 38 years of rainfall data is used for analysis purposes. Gumbel’s method was used to develop the Intensity Duration Frequency curve with one in two year return period. To find out the time of concentration Kirpich Formula was used. Based upon time concentration Rainfall Intensity is found from the IDF curve. Manning’s Formula was used to find out the capacity of a sewer.

The procedure for the estimation of storm runoff by the rational method is mentioned in the following steps:

Step 1: Obtain historical rainfall data of 38 years or more for the given project area
Step 2: Select a return period as required
Step 3: Prepare the IDF curve for the above return period.
Step 4: Demarcate the catchment
Step 5: Determine the time of concentration (tc) as described below.
Step 6: Determine rainfall intensity against the time of concentration from IDF curve
Step 7: Determine runoff coefficient (C) as described in table.
Step 8: Calculate peak flow by Rational formula.

IV. DATA COLLECTION

To analyse the existing sewer system, Data such as ground elevation, sewer section, the slope of the drain, manning's co-efficient, the population of the city, and water requirement per capita are required. All the stated data were collected from Bavla Municipal office which is stated below.

IV.I GROUND ELEVATION

The study area was divided into three different zones and 15 node points are selected. The latitude, Longitude, and ElevatiNo table of figures entries found.on of each point were found with the help of google earth pro which is stated below.

Table 1 Elevation of node points

Node Points	Latitude	Longitude	Elevation (m)
1	22°50'07"	72°22'00"	28
2	22°50'00"	72°22'16"	28
3	22°49'49"	72°22'10"	27
4	22°49'49"	72°22'04"	26
5	22°50'08"	72°22'00"	28
6	22°50'01"	72°22'17"	27
7	22°50'14"	72°22'24"	29
8	22°50'12"	72°22'10"	29
9	22°50'14"	72°22'10"	29
10	22°50'16"	72°22'02"	28
11	22°50'1"	72°21'59"	29
12	22°50'1"	72°22'24"	28
13	22°49'5"	72°22'11"	29
14	22°49'5"	72°22'22"	27
15	22°50'1"	72°22'33"	29

Other data Type of Pipe:

RCC NP3 Diameter of sewer pipe: 1) 1 meter 2) 1.2 meter
Manning's coefficient of roughness: 0.011
Minimum allowable cover: 0.8 meter
Maximum allowable cover: 6.5 meter

IV.II Meteorological Data To find out the runoff produced by precipitation by Rational Method, we require rainfall intensity, area of each zone, and runoff co-efficient. Rainfall data for the past 38 years was collected which is shown below.

Table 2 Rainfall Intensity

Sr No.	Year		Highest daily peak of annual (mm)
1	1983	08-Aug	55.57
2	1984	04-Aug	83.98
3	1985	08-Oct	107.47
4	1986	23-Jun	60.91
5	1987	26-Aug	43.48
6	1988	15-Jul	43.17
7	1989	25-Jul	50.65
8	1990	18-Aug	81.91
9	1991	27-Jul	48.09
10	1992	04-Sep	55.73
11	1993	10-Jul	125.65
12	1994	08-Sep	150.33

13	1995	21-Jul	**36.19**
14	1996	07-Aug	55.43
15	1997	27-Jun	130.96
16	1998	30-Jul	73.78
17	1999	20-Jul	73.74
18	2000	13-Jul	177.71
19	2001	03-Jul	49.48
20	2002	25-Aug	39.73
21	2003	24-Aug	147.08
22	2004	30-Jul	66.72
23	2005	26-Jun	100.95
24	2006	06-Sep	62.54
25	2007	02-Jul	67.81
26	2008	12-Aug	83.22
27	2009	29-Aug	79.58
28	2010	07-Aug	136.39
29	2011	10-Jul	63.73
30	2012	03-Sep	51.93
31	2013	25-Sep	83.93
32	2014	29-Jul	163.28
33	2015	28-Jul	111.72
34	2016	09-Aug	56.33
35	2017	24-Jul	72.37
36	2018	17-Aug	51.4
37	2019	09-Aug	70.93
38	2020	4 - Sep	69.53

IV.III Runoff co-efficient

The coefficient of runoff (C), is a function of the **nature of the surface** and is assumed to be the same for all storms of all recurrence probabilities. Recommended values of C on various surface types of the catchments are given in the table below which was Adapted from ASCE and WPCF 1969. While choosing the values for C, the ultimate development of the catchment as per the master plan should be taken into consideration.

Table 3 Runoff Co-efficient

Sr. NO.	Type of Area	Runoff Coefficient
1	Commercial Area	0.70 - 0.95
2	Industrial Area	0.60 – 0.90
3	Institutional Area	0.70 – 0.95
4	Residential Area -Low Density - High Density	0.40 – 0.60 0.60 – 0.75
5	Recreational Area	0.10 – 0.25
6	Pavements Asphaltic PavementsConcrete PavementsBrick Pavements	0.70 – 0.95 0.80 – 0.95 – 0.85
7	Roof CatchmentTiles Corrugated Metal Sheet Concrete	0.80 – 0.90 0.70 – 0.90 – 0.90

IV.IV Area & Runoff co-efficient of three-zone

Table 4 Area and Runoff coefficient

Zone	Area	Runoff Coefficient
1	14.5	0.75
2	13.2	0.8
3	17.8	0.7

V. DATA ANALYSIS

IDF curve can be derived using Gumbel's method.Obtained graph is useful in finding out rainfall intensity which is further used in rational method in finding out the runoff. In this chapter results are obtained and discussion about the same is carried out to understand the problem of ponding in the study area.

Step-1. Intensity of rainfall have been found out using IDF curve for 2 year Return period for various time of concentration.

Table 5 Time of Concentration and Rainfall Intensity

zone	Length	Time of Concentration	Rainfall(mm/hr)
1	300	0.14716	110.782897
2	210	0.09372	111.079676
3	310	0.1699	110.65661

Step-2. Runoff produced by rainfall and capacity of drains of carrying discharge was evaluated using Rational and Manning's Formula Respectively.

Table 6 Runoff

Zone	Runoff coefficient	Area	Runoff= cia/360
1	0.75	14.5562	3.359537503
2	0.8	13.2952	3.281836686
3	0.7	17.8778	3.846688111

Table 7 Discharge

zone	Mannings' coefficient.	Dia of Pipe	Slope	Velocity(m/s)	Discharge (m3/sec)
1	0.011	1.2	0.00333	2.35095113	2.657515157
2	0.011	1	0.00476	2.489072024	1.953921539
3	0.011	1.2	0.00322	2.311795534	2.613253672

While analysing the combine storm sewer system it become necessary to consider sewage discharge along with runoff produced by precipitation. In order to that past 3 census population data have been collected from the local authority and population of the latest 2021 census have been found out using Arithmetic Increase Method.

Table 8 Zone wise Population

	zone 1	Avg. Arithmetical Increase	zone 2	Avg. Arithmetical Increase	zone 3	Avg. Arithmetical Increase
1991	3245		4036		2145	
2001	5769	2524	6298	2262	3564	1419
2011	6987	1218	7984	1686	4872	1308
2021	8858	1871	9958	1974	6235.5	1363.5

While designing the combine storm sewer system which carries both storm and sewage discharge, 80% of total water supply is considered to be sewage discharge in the system. Thus, 80% of the total water demand for each zone have found out and added in the runoff produced by precipitation.

Table 9 Sewage Discharge

		water demand inlpcd	Water demand in m3/sec	Sewage Discharge
zone 1	8858	1328700	0.015378472	0.012302778
zone 2	9958	1493700	0.017288194	0.013830556
zone 3	6236	935400	0.010826389	0.008661111

Step- 3. Comparison Between Actual Runoff and Capacity Of Drain

Table 10 Comparison of Discharge

Zone	Runoff (m3/sec)	Sewage Discharge	Total Discharge (m3/sec)	Capacity of Drain (m3/sec)
1	3.3595375	0.012302778	3.37184	2.657515157
2	3.28183669	0.013830556	3.295667	1.953921539
3	3.84668811	0.008661111	3.855349	2.613253672

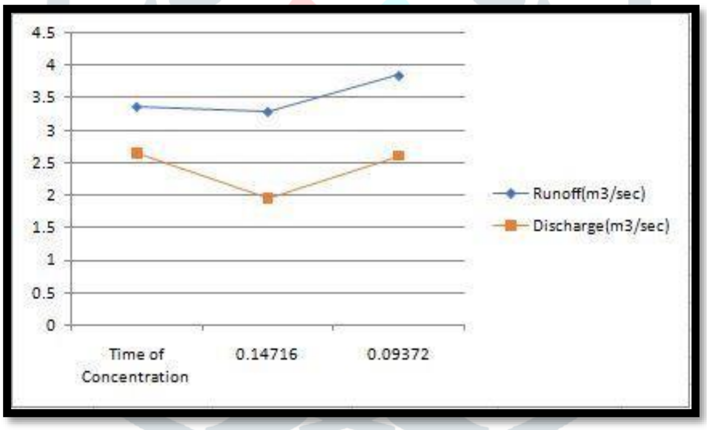

Figure 3 Comparison

V. CONCLUSIONS

Bavla is small town located in western side of Ahmedabad District, Gujarat. The rapid speed of urbanisation and migration of people from rural to urban regions in search of a better life and education has put enormous strain on urban infrastructure, aggravating urban drainage problem. Given the current state of drainage systems, which results in frequent floods and loss of property and life, it is necessary to dig deeper into the problem and come up with thoughtful planning, design, implementation, and operation and maintenance of the sewage system. This study was proposed to analyse the existing sewer system using rational method and Gumbel's Distribution method. IDF curve was developed using peak rainfall of past 38 years of the study area. Among various return period, 2 year return period was adopted and Intensity-Duration-Frequency curve was constructed. Time of concentration and rainfall intensity in mm/hour were plotted on y-axis and x-axis respectively. Based upon the catchment characteristic such as length and slope of region time of concentration was calculated. On calculation of time of concentration, rainfall intensity was found out from the graph which was further used in Rational method.

According to the topography, study area was divided in three zones. Runoff produced by precipitation was found out in each zone. Discharge carrying capacity of sewer section was found out using Manning's formula. As the city was provided with combine system, Sewage produced in the area have also been taken into account. Arithmetic Increase method is used to forecast the future population of the town.

For the design purpose it is general practise to consider 80% sewage production of total water supplied. In the brief, it can be concluded that the fluctuation of storm runoff generated and sewer capacity depends on large numbers of interdependent factors. Rational method give good and adoptable results for small areas. Existing combined storm sewer is insufficient in carrying discharge produced by Rainfall. In this approach, multiple method and conventional formula were used such as Rational method, Gumbel's Distribution method, Kirpich formula and Manning's formula. Regular Maintenance and Cleaning is required for efficient working. And Further Modification is required for proper working.

The result of this study can help water resources managers to plan future storm sewer system projects in the Bavla. The used data sets and obtained results can also be useful in future studies.

VI. ACKNOWLEDGMENT

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