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An Advanced GIS based Storm Water Drainage Networking Design for Bhimrad Area of Surat City (India)

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Abstract: Storm water drainage is part of the essential infrastructure of a modern city. In the new Urban area of Surat city (Gujarat, India) the lifes and properties are under the threat of flooding due to heavy rainfall within frequent time interval. The average annual rainfall of Surat city is approximately 1143 millimeters, within the three to four months. Bhimrad is a low lying area and RL of Bhimrad is 3-7 m & RL of adjoining state highway-5 is 9 m so, because of changes in level Bhimrad is more susceptible to water logging in both heavy and light rainfall. A storm water drainage system should be designed to collect and convey run-off generated within a catchment area during and after rainfall events, for safe discharge into a receiving watercourse. The magnitude of peak flows that have to be accommodated will depend primarily on the intensity of rainfall and the size, topography, soil type, configuration and land use of the catchment. GIS applications used to automate the delineation of catchments as well as produce the schematically correct drainage network attributed to basic hydrologic characteristics such as long flow paths, slopes and drainage/catchment areas for each proposed line. As well as runoff calculated with Rational method and diameter decided using Manning's formula which information about planning and investigation required for storm water drainage systems is given in the CPHEEO "Manual on Sewerage and Sewage Treatment" (2^{nd} edition), New Delhi. To overcoming water logging and flooding problems in this study area (TP- 42 & 43: Bhimrad), it is proposed to provide storm water drainage system of adequate capacity so, as to dispose of the floodwater, safely to the Mithi (Moti) khadi.

Keywords: *GIS, DEM, Flow lines in GIS, Storm Water Drainage System, Design*

1. Introduction

Apart from natural causes, human activities can also partially influence the prevalence of flooding. Examples are changes in land use resulting in an increase in runoff and depletion of flood storage; blockage of natural drainage systems by refuse, agricultural wastes or silt arising from both natural erosion and construction activities; indiscriminate land filling; and lack of comprehensive maintenance of natural water courses due to land access problems (Ref. 5). In Study area, the threat of flooding due to heavy rainfall within frequent time interval. The average annual rainfall of Surat city is about 1143 millimeters, which is spread of three to four months. In addition to the provision of a comprehensive system of storm water pipelines in the new urbanized areas. Study area (Town Planning Schemes- 42 & 43: Bhimrad) of a new urban area of the Surat Municipal Corporation, situated on the outskirts almost 10 Kms away from the main city. At present, it does not have any storm water drainage system. For overcoming of water logging and flooding problems in this area, it is proposed to provide storm water drainage system of adequate capacity; so as to dispose of the floodwater, safely to the Mithi (Moti) khadi. It is to provide a systematic underground system of storm water disposal, system. The storm water drains in place of these creeks are to be properly planned on the roads of TP Scheme. Now, as the TP-42 & 43-Bhimrad are being prepared and finalized gradually, the road networks are also finalized; which can facilitate to provide storm water drains.

A comparison of the runoff volumes generates and confirmed that runoff volume is a function of the catchment characteristics and storm depth (Ref. 2). For that same, by superimposing the existing contour of the study area in ARC GIS and prepare DEM (Digital Elevation Model), also using hydrology application in GIS containing automatically generate flow lines and the orientation of the drains as well as catchment area of each proposed drain is assessed for effectiveness (Ref. 4). To know the impervious land details land use mapping of the study area was done using ARC GIS. Finally runoff is calculated using rational method and for the engineering design of drains, the peak flows can be used with the Manning's Equation to obtain the dimensions for each drain leg (Ref. 22). This is an iterative process to ensure that the drain dimensions, and therefore its capacity can at least withstand the peak runoff determined.

1.2 Study Area

Bhimrad, is a new urban area of Surat city of Gujarat state (India), which situated at the outskirts almost 10 Kms away from the main city, with Latitude 21°8'59"N and longitude 72°47'46"E shown in Figure 1. The city of Surat is the commercial capital of the state and is of significant importance to the country, situated on the broad gauge railway track on the Mumbai -Delhi and Mumbai– Ahmadabad routes. It is also well connected by National Highway No. 8 and airways to most parts of Western India. Bhimrad lying in plane area, therefore no pothole or hills are able to notice. North side of the study area is located on the River Tapi and the Arabian Sea is to its west at a distance of about 16 kilometers by road. Reduce level of Bhimrad is 3-7 m & SH-5 is 9 m, therefore because of changes in level Bhimrad is more prone to water logging due to heavy and light Rainfall.

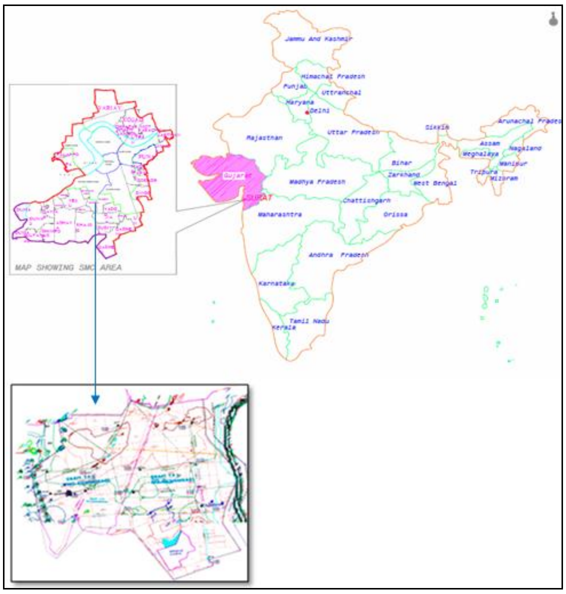

Figure 1: *Location map of Study Area in Surat city (Gujarat-India)*

2. Design Methodology

2.1 Creation of the DEM

It is a quantitative, 3-D presentation of earth's surface derived from the elevated data. It provides basic information regarding terrain characteristics. Primary attributes derived from DEM are slope, profile curvature. The surface produced was converted to a raster DEM. The next step involved filling pits or ponds, which are cells where water would accumulate when drainage patterns are being extracted. Pits are a sign of error in the DEM due to interpolation. Their frequency is affected by grid cell size. The command fell under "Hydro" in spatial analyst does this step. After filling the sinks the next step was to determine flow accumulation grid from the DEM and finally to delineate the watershed (Ref. 1).

2.2 Hydrological Assessment

To undertake an urban storm water drainage analysis, it is necessary to have basic data on rainfall intensity-duration-frequency relationships, together with adequate data on the urban storm drainage network and catchment characteristics (Ref. 12). If the drainage area is small, then the time of concentration will dictate the duration of the storm input to be used. When the catchment area is large, then the critical storm duration together with the drainage system response will dictate the peak runoff.

2.2.1 Rainfall Data and Analysis

The analysis of the frequency of storms is stated intensities of rainfall and duration; for which rainfall data have been considered in the design. The storm is occurring once in one year, i.e. 16 times in 16 years. From this data the time-intensity values for this frequency are obtained. A graph is then plotted for once a year storm, using computed values of 't' and 'I' on a log-log graph paper. From the line of best fit, the values of constants 'a' and 'n' is found out as below:

The relationship between 't' and 'i' may be expressed by a generalized mathematical formula. The commonly used one is shown as under:

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

Where,

i = Intensity of rainfall in mm / hour
t = Duration of storm in minutes
a = Constant
n = Constant

The equation can be converted into a straight line relation by taking logarithms of both sides as follows:

$$\log i = \log a - n \log t$$

or

$$\log I = - n \log t + \log a$$

The consultants 'a' and 'n' can be determined as intercept on the Y axis and the slope of the line, respectively if we have a number of pairs of values for 't' and 'i'. A straight line can then be fitted to the points.

2.2.2 Estimation of Storm Water Runoff

The Rational method for calculating storm runoff, as recommended in the Storm drainage Manual, has been considered for calculation for runoff.

2.2.3 Runoff - Rainfall Intensity Relationship

The entire precipitation over the drainage basin does not reach the drain. The characteristics of the drainage basin viz.; imperviousness, topography including depressions and water pockets, the shape of the basin and the duration of the precipitation determine the fraction of the total precipitation reaching the drain. This fraction is known as the coefficient of runoff and needs to be determined for each drainage basin. The runoff reaching the drain is expressed by

$$Q = 10\ C\ i\ A$$

Where,

Q = runoff in m3/hour
C = coefficient of runoff
i = intensity of rainfall in mm / hour

A = area of drainage basin in hectares

2.2.4 Time of concentration

The time of concentration is the time required for the rain water to flow over the ground surface from the farthest point in the drainage basin and reach the point under consideration (point of entry in the drain). Thus, the time of concentration (t_c) for a given storm water drain generally consists of two parts.

2.2.4.1 The time of inlet (t_i)

This is the time taken by the storm water, to flow overland from the critical (farthest) point up to the point; where it enters the storm water drain mouth. It may be estimated by the following equation:-

$$t_i = \left(0.885 \times \frac{L^3}{H}\right)^{0.385}$$

Where,

t_i =Inlet time in minutes
L =Length of overland flow in kilometers from the critical point of the mouth of the drain.
H =Total fall in level from the critical point of the mouth of the drain in meters

The values of 'L' and 'H' can be found from the survey, contour plan of the area and then 't_i' can be easily calculated. This inlet time (t_i) 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 and may generally vary from 5 to 30 minutes. However, for the design purpose, it is taken at 30 minutes.

2.2.4.2 Time of flow in the drain or the channel flow time (t_f)

This may be obtained by dividing the length of the drain by the flow velocity in the drain.

i.e., $t_f = \frac{\text{length of the proposed drain}}{\text{Flow velocity in the proposed drain}}$

2.2.4.3 Time of Concentration (t_c)

Thus, the total time concentration (tc) at a given point in the drain, can be easily obtained as

$$t_c = t_i + t_f$$

2.2.5 Coefficient of Runoff

The portion of runoff, which finds its way to the drain, is dependent on the imperviousness of the drainage basin, shape of the drainage basin, duration of storm water flow. This portion of runoff, reaching to the drain is known as "coefficient of runoff". It will be obvious that an accurate determination of the runoff of conditions; which will exist in the future is very difficult. The only way, therefore, will be to assume the value of the coefficient of runoff from a given area under conditions that may exist at the end of the design period. This will necessitate the approximate estimation of the equivalent percentage of the entire impervious as well as the pervious area of the drainage basin.

Thus, the coefficient of runoff will depend on the following factors:

Imperviousness of the Drainage Basin Area

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

The weighted average imperviousness of the drainage basin for the flow, concentrating on a point may be as estimated;

$$I \quad \frac{A_1I_1 + A_2I_2 + \dots\dots\dots A_nI_n}{A_1 + A_2 + \dots\dots\dots A_n}$$

Where,

I = Weighted average imperviousness of the total drainage basin
A1, A2… An = Drainage area tributary to the section of drain under consideration.
I_1, I_2… In = Imperviousness of the respective areas.

Therefore, in this research work all the T.P. Areas will be fully developed by the end of the design period, the following data adopted for the design of the storm water drainage system.

The total drainage basin under consideration is divided into 2 parts i.e.

- ✓ Built-up area = 60% of the total area; which may contain buildings, terraces, roofs, footpaths, roads etc.
- ✓ Open area= 40% of the total area; which may contain open ground, parks and gardens, lawns or any underdeveloped area.
- ✓ The imperviousness of the built-up area at the end of design period is considered as 90% i.e. impervious factor 0.9.
- ✓ Similarly, the imperviousness of the open area at the end of design period is considered as 20% i.e. impervious factor 0.2

Therefore, the total weighted average imperviousness of the area will be

$$I = \frac{0.9 \times 60 + 0.2 \times 40}{60 + 40} = \frac{54 + 8}{100} = 0.62$$

Tributary Area: For each length of storm drain, the drainage area should be clearly indicated and measured. The boundaries of each tributary are dependent on topography, land use, nature of development and shape of the drainage basin. The runoff coefficient of a larger area may have to be adjusted by dividing the area into zones of concentration and by suitably decreasing the coefficient with the distance of the zones. Although these values are applicable to the particular shape of drainage area, they also apply in a general way to the area which is usually encountered in practice. Errors due to difference in shape of drainage area are within the limits of accuracy of the rational method and of the assumptions on which it is based. The weighted average runoff coefficients for the rectangular shaped drainage area, of length 4 times the width as well as for sector shaped areas with varying percentages of impervious surfaces for different times of concentrations have been worked by Horner, as described in the CPHEEO "Manual on Sewerage and Sewage Treatment" (2nd edition), New Delhi. The values of 'c' and 'i' for the same duration time't' are determined and the value of runoff Q in m^3/hour/hector of the drainage basin is worked out from the equation,

$$Q = 10 \text{ C iA}$$

For a given time of concentration and imperviousness factor for each section of a drain, the drain is designed.

Design of Storm Drainage Lines

Design Formula

For the design of storm drainage system, Manning's formula is adopted, which is:

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

$$Q = \frac{1}{n} \times R^{\frac{5}{3}} \times S^{\frac{1}{2}} \text{ ……………… for circular sewer}$$

Where,

Q = Discharge
n =Manning's Coefficient of roughness
S =Slope of hydraulic gradient
R = Hydraulic radius in meter
=Area/Wetted Perimeter
= (π/4 D2)/ (πD)
= D/4 for circular sewer
V =Velocity

As drain surface deteriorates with age, a roughness coefficient is considered for the design period assuming fair condition in drains. The roughness coefficient `n' is assumed to be the same for all the drains and is taken as 0.013 for design.

3. Results and Discussion

3.1 Carried out a Storm Water Network and Catchment Area using Arc GIS

3.1.1 Digitizing shape file of impervious land cover

Under conventional development, urbanization tends to result in increased runoff, flooding, and pollution and decreased groundwater flow. By providing storm water drainage system can reduce both the volume and flow rate of surface water, reduce flooding, peak storm frequency and duration, and associated effects like erosion, stream siltation, and streambed scouring. To derive impervious land cover, Google image of study area (Bhimrad) was accessed through Arc Map's built-in base map function. The roads, buildings, canal, creek, water body's existing land use were obtained from digitizing google images (Ref. 10). The land use impact boundary shape file was created. Any man-made surfaces that prevent water from infiltrating the ground like Rooftops, pavement, concrete, etc. Digitized from high resolution aerial photographs for the study area and four classes identified; Buildings, roads, canal, other impervious surfaces. Also non-impervious land cover allow for infiltration of rain water into the ground reducing water runoff. Wetlands and ponds capture storm water runoff that lands digitized from high resolution aerial photographs for the study area. Shown in Figure 2.

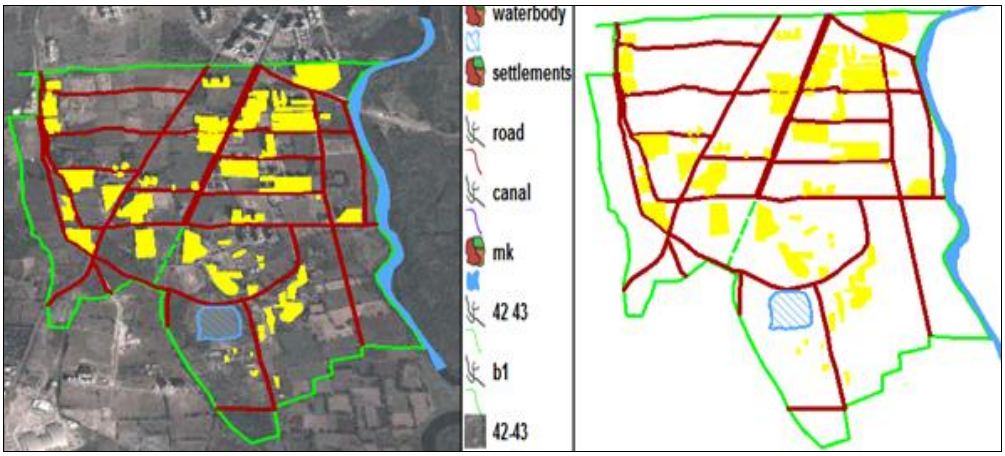

Figure 2: *Digitizing shape file of impervious land cover*

Note: *To derive impervious land cover, google image of study area (Bhimrad) was accessed through Arc Map's built-in base map function. The roads, buildings, canal, creek, water body's existing land use were obtained from digitizing google images. The land use impact boundary shape file was created.*

3.1.2 DEM and hydrology application results in ArcGIS

For the purposes of this analysis, "catchment" refers to all land that drains to a specific point (in this case, to a single stream junction), while "watershed" includes all of the catchments that drain to intermittent stream, While the Physical drainage includes numbers of recognized streams. The pathway followed by streams was found by visually comparing the storm water lines hydrography imagery GIS layers. Sections of these streams marked as "unknown" are beyond the study area (Ref. 3). The "unknown" sections are all classified as intermittent in the DEM. Without this DEM and GIS Stream shape map storm water infrastructure is not clear whether these sections flow naturally or through the man-made infrastructure. Shown in Figure 3.

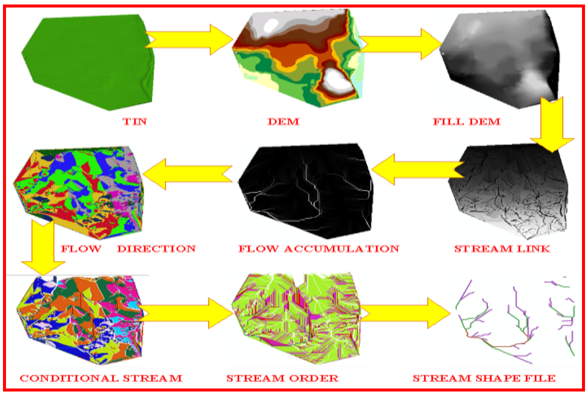

Figure 3: *DEM and hydrology application results in Arc GIS*

Note: *Catchments and pipe network were delineated based on the flow direction, flow accumulation, stream link, conditional stream, streams order and stream shape file shown in figure, which are all derived from a digital elevation model in Arc GIS.*

3.1.3 Storm water drainage network derived from DEM

Catchments and pipe network were delineated based on the flow direction, flow accumulation, stream link, conditional stream, stream order and stream shape file shown below figure, which are all derived from a digital elevation model in ArcGIS (Ref. 8). As storm water runoff from opposite sides of a stream can experience very different conditions, catchments were further subdivided by the drainage network layer, allowing land on each side to be examined separately in suitability analyses (Ref. 11). Details drawing of storm water drainage network with catchment given below. Flow direction is based on a digital elevation model (Sown Figure 4) with stream locations imposed on it. From following image, one can see the watershed's drainage pattern, including ephemeral streams. Flow accumulation values represent the number of raster cells that drains to each location, based on flow direction.

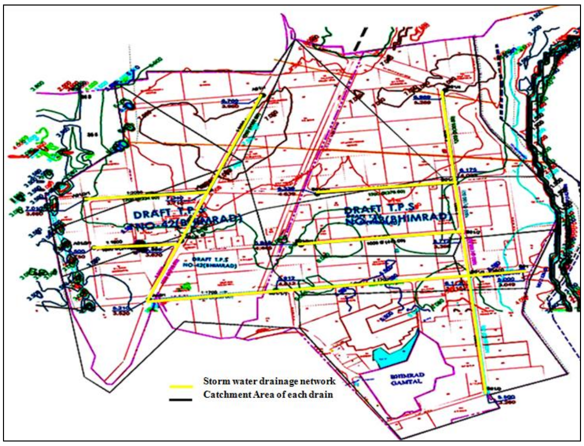

Figure 4: *Storm water drainage network derived from DEM*

Note: *From GIS models, Digital Elevation Models (DEM) are the most convenient means of representing the earth's surface, then it can judge pipe network as well as catchment of each pipe node which shown in figure.*

3.2 Rainfall Analysis

The hourly rainfall data from the year 1969 – 73, 75, 77 – 84 as well as 1982 to 1984 and 2000-2003 obtained from the IMD, Pune is analyzed as mentioned in the manual of "Sewerage and Sewage Treatment" by CPHEEO. The analysis of the frequency of storms of state intensities of rainfall and duration; for which rainfall data have been considered in the design, are carried out as shown in Figure 5.

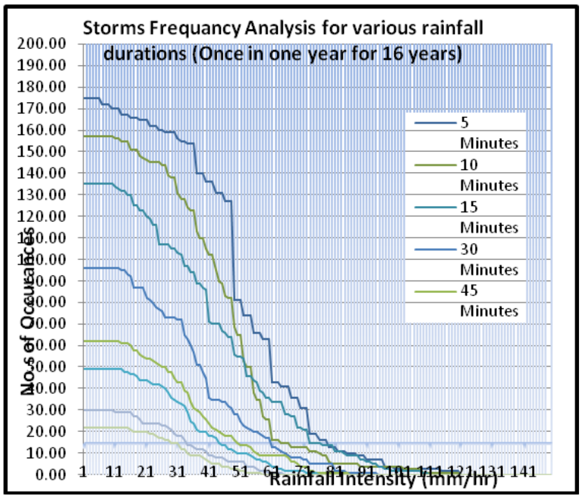

Figure 5: *Storm Frequency Analysis with different duration for Once in One year for 16 years*

The analysis of the frequency of storms of state intensities of rainfall and duration; for which rainfall data have been considered in the design, are carried out as shown in Figure.

The lines shown in Figure indicate the location of the storm occurring once in one year, i.e. 16 times in 16 years. From this data the time-intensity values for this frequency are obtained and these values are given in

Table 1. A graph is then plotted for once a year storm, using the above computed values of ‘t’ and ‘i’ from Table 1 on a log-log graph paper, as shown in Figure 5. From the line of best fit, the values of constants ‘a’ and ‘n’ is found out as below:

***Table 1:** Time Intensity values of storm in Surat*

t (minutes)	i (mm / hour)
5	78.30
10	77.15
15	76.00
30	60.50
45	50.00
60	44.00
75	33.50
90	31.00

***Note:** The relationship between‘t’ and ‘i’ may be expressed by a generalized mathematical formula. The commonly used one is shown as under: $i=a/t^n$ Where, i = intensity of rainfall in mm / hour, t = duration of storm in minutes, a = constant, n = constant.*

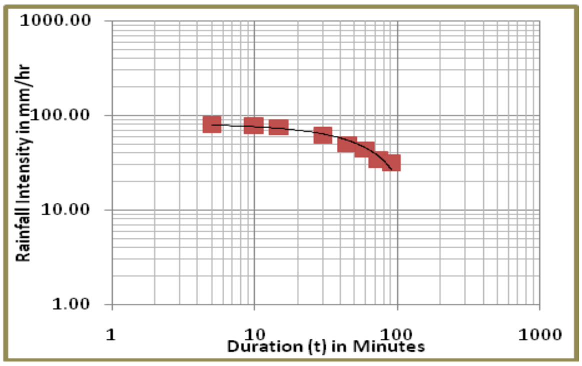

***Figure 6:** Graph of Rainfall Intensity Vs Duration*

***Note:** A graph is plotted for once a year storm, using the above computed values of ‘t’ and ‘i’ from Table 1 on a log-log graph paper, as shown in figure.*

The relationship between‘t’ and ‘i’ may be expressed by a generalized mathematical formula.

From log graph

t=	20.00		I =	70.00	And
t=	70.00		I =	40.00	
log	70.00	=	log a -	n * log	20.00
log	40.00	=	log a -	n * log	70.00
log (70/40) =			n * log (70/20)		
	=				
0.24	n *	0.54			
n =	0.45				
Now					
log	70.00	=	log a -	n * log	20.00
	1.85	=	log a -	0.58	
	log a	=	2.426		
	a	=	267		

Now, after substituting the value of “a” and “n”, the formula for counting the rainfall intensity will be,

$$i = \frac{267}{t^{0.45}}$$

Based on this formula various rainfall intensities are worked out for various rainfall durations. The majority of the values is represented in the Table 2 given below.

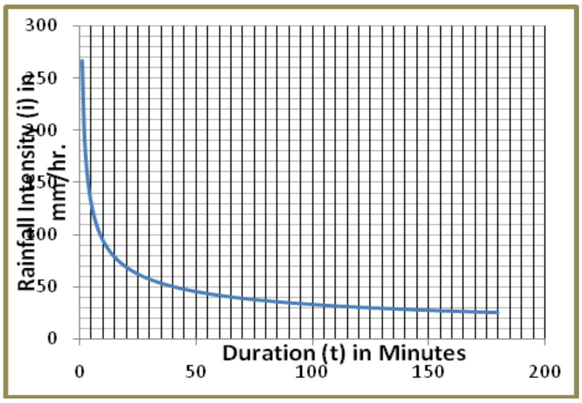

***Figure 7:** Rainfall Intensity Vs Duration*

***Note:** Based on the formula various rainfall intensities are worked out for various rainfall durations, which values are represented in the Table 2.*

***Table 2:** Rainfall Intensity Vs Duration*

t (minutes)	1	5	10	15	30	45	60	75	90	105	120	135	150	180
Rainfall Intensity (mm/hr.)	267.0	129.4	94.7	78.9	57.8	48.1	42.3	38.3	35.2	32.9	31.0	29.4	28.0	25.8

***Note:** Now, after substituting the value of “a” and “n”, the formula for counting the rainfall intensity will be, $i= 267/t^{0.45}$, based on this formula various rainfall intensities are worked out for various rainfall durations.*

3.2.1 Planning For Storm Water, Wastewater Collection and Conveyance

Considering the topography of the study area, the feasible outlet point for final disposal of the storm water is fixed. The storm water from the entire study area will be collected, transported and finally disposed of into the existing natural drain passing by and through the east side of the TP. Scheme Moti khadi. It is planned to collect the storm water from study area through a network of main and branch storm drains leading to one no. of outfalls.

***Table 3:** Planning for Storm Water collection from its Catchment Area*

Sr. no.	Name of Outlet	Catchment Area (Hectares)
1	Outlet 1	141.91

Note: *It is planned to collect the storm water from study area through a network of main and branch storm drains leading to one no. of outfalls.*

3.3 Analysis

The hydraulic analysis of storm drainage system is carried out by using computer spreadsheets.

3.3.1 Velocity Considerations

To ensure that the deposition of suspended solids does not take place in the storm drainage system, minimum self-cleansing velocities are considered in the design of sewers. A minimum partial flow velocity of 0.9 mps is considered. The assumption of minimum velocity of 0.9 MPs will not only economize the design, but will also ensure the flushing out of the settled suspended solids.

3.3.2 Minimum Size of Storm Water Drains

The minimum size of Storm Water Drain considered in the hydraulic analysis is 450mm dia.

3.3.3 Material of Construction

Alternative pipe materials are used for sewers like Glazed Stoneware (GSW), Reinforced Cement Concrete (RCC), Glass Fiber Reinforced Plastic (GRP), High Density Polyethylene (HDPE) etc. However the capital cost and durability are the major considerations in the selection of material. SMC is practicing RCC pipes and their performance is found satisfactory. Therefore, RCC NP2 / NP3 / NP4 pipes conforming to IS 458-2001 are recommended for proposed works.

3.3.4 Minimum Depth of Cover

To facilitate inlet chamber connection to storm drainage system and to provide protection to the sewers from external loads, the minimum depth of cover over the soffit is kept 0.5 meters to 1 meter.

3.3.5 Maximum Depth of Storm Water Drains

The maximum depth of storm water drain is kept above the R.L. 7.50 meters, duly considering the normal water level in the river during monsoon.

3.3.6 Storm Water Network

The hydraulic design of storm water disposal system, based on CPHEEO Manual has been incorporated. The planning for storm water collection from the areas within the study area is presented in following Table 4.

Table 4: *Design of Conventional Storm Drainage System for TP – (2 & 43 - Bhimrad, Surat (India)*

Section		Rainfall - Runoff						Proposed Drain Details					
U/S Node	D/S Node	Cum. Length of drain section	Increment	Eq. 100% Imp. Area	Estimated time of concertation (t_c) / (t_c)	Average Rainfall Intensity from Graph (I_c)	Runoff Coefficient from Graph (C)	Actual Runoff (q)	Profile Shape & Size / Dia meter	Slope of Drain	Flow Full (Q)	Velocity (V)	Actual Velocity (v)
		(mt.)	(Sq.mt.)	(Sq.mt.)	(minutes)	(mm/hr)		(m^3/s.)	mm	1 in L	(m^3/s.)	m/s	m/s
AO1/4	AO1/3	502.27	92335.92	57248.27	30.00	57.78	0.64	0.59	1200	2000	1.03	0.91	1.04
AO1/3/1	AO1/3	334.68	113262.43	70222.71	21.12	67.84	0.59	0.79	1200	2000	1.03	0.91	1.04
AO1/3	AO1/2	698.85	0.00	127470.98	40.55	50.77	0.68	1.22	1600	2000	2.22	1.10	1.26
AO1/2/1	AO1/2	245.25	93683.54	58083.79	19.81	70.97	0.58	0.67	1000	1800	0.67	0.85	0.97
AO1/2	AO1/1	933.91	0.00	185554.77	55.13	43.99	0.73	1.65	1800	2500	2.72	1.07	1.22
AO1/1	BO1/1/1	1264.22	207355.82	314115.38	72.74	38.97	0.76	2.60	1600	1700	2.41	1.20	0.86
BO1/1/1	**BO1/1**	1764.22	61910.75	352500.05	98.01	33.92	0.81	2.69	1600	1800	2.34	1.16	0.84
BO1/4	BO1/3	305.00	148100.70	91822.43	20.29	69.35	0.59	1.04	1200	1800	1.09	0.96	1.09
BO1/3/1	BO1/3	370.00	160036.76	99222.79	21.42	67.84	0.59	1.11	1200	1800	1.09	0.96	1.09
BO1/3	BO1/2	550.00	60414.93	228502.48	29.30	58.67	0.64	2.37	1600	1800	2.34	1.16	1.33
BO1/2/1	BO1/2	445.00	107632.67	66732.26	23.48	65.12	0.60	0.73	1000	1700	0.69	0.88	1.00
BO1/2	**BO1/1**	700.00	0.00	295234.74	38.57	51.95	0.67	2.87	1800	1800	3.20	1.26	1.43
BO1/0	**BO1/1**	422.03	245828.65	152413.76	21.97	67.84	0.59	1.70	1400	2000	1.55	1.01	1.46
BO1/1	BO1	1929.22	41342.09	673366.88	126.08	30.29	0.83	4.72	2000	2500	3.60	1.15	1.31

Note: *The hydraulic design of storm water disposal system, based on CPHEEO Manual has been incorporated.*

4. Conclusions and Recommendations

The Storm water drainage design is based on the fact that road side storm water drains are as important as the flood protection scheme for natural drains. Data on terrain, land-use and hydrology of the T. P. -42 & 43 - Bhimrad was converted to information for storm drainage network planning. A contour .dwg file used to gather data for DEM creation because of the fast acquisition of data. The diameter of the drains are varies from 800 mm to 2000 mm. Thereafter, RCC double ducts of 2.2 m X 1.2 m to 3.5 m X 1.2 m sizes are proposed. The design detail of the storm drainage outfall is presented in the Annexure -12C. The depth of drains at the outfall is kept above R.L. 3.0 mt. To minimize the back flooding from the drain into the drain. Thus, the purpose of providing Storm Water Drains is to carry out rainfall runoff from the terraces, paved courtyards, footpaths, roads from the developed areas so that the occurrence of flooding reduced to the acceptable frequencies. Therefore, the storm water drains are designed according to the extent and type of the tributary area to be drained and must be based on the intensities of the rainfall of the study area.

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