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DESIGN OF DRAINAGE NEWTORK USING SWMM FOR NMIT CAMPUS

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Abstract — *Storm water is water that originates during precipitation events and snow/ice melt. Storm water can soak into the soil (infiltrate), be held on the surface and evaporate, or runoff and end up in nearby streams, rivers, or other water bodies (surface water). In natural landscapes such as forests, the soil absorbs much of the storm water and plants help hold storm water close to where it falls. Storm water is also a resource and important as the world's human population demand exceeds the availability of readily available water. Techniques of storm water harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water. The importance of urban storm water modelling is constantly increasing due to three global trends: urbanization, population growth, and climate change. The storm water management becomes more challenging due to urbanization & population growth while at the same time a rising number of people is affected by the harmful effects of storm water on the environment. SWMM is a dynamic hydrology-hydraulic water quality simulation model. It is used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component operates on a collection of sub catchment areas that receive precipitation and generate runoff and pollutant loads. EPA's Storm Water Management Model (SWMM) is used throughout the world for planning, analysis and design related to storm water runoff, combined and sanitary sewers, and other drainage systems in urban areas. The study aims to simulate the rainfall-runoff process and design off drainage for urban catchment, the main objectives of this study are setting up the SWMM (Storm water management model, including relevant data preparation for SWMM), to Study the rainfall characteristics, to estimate the runoff of study area, to check the adequacy of existing drainage system and also prescribe the smart & sustainable storm water management techniques.*

Keywords- *Storm1; Precipitation2; Infiltrate3; Urbanization4; Runoff5; Simulation6; Catchment7; Smart8; Sustainable9*

1. INTRODUCTION

1.1 GENERAL

Storm water is water generated on the land surface, originating from rainfall or melting snow or ice (Durrans, 2003). The importance of urban storm water modelling is constantly increasing due to three global trends: urbanization, population growth, and climate change. The first two trends induce a rapid growth of area, making storm water management ever more challenging while at the same time a rising number of people is affected by the harmful effects of storm water on the environment. In many areas, these effects are expected to be amplified in the future due to climate change and associated higher frequencies of extreme weather events. The concept of storm water is strongly related to urban areas storm water also is interesting regarding the urban water balance. The expansion of impervious land-cover implies both larger storm water runoff volumes and peak flows and consequently reduces other components of the hydrologic cycle, e.g. infiltration and evapotranspiration [1]. The global runoff damage and the increasing risk of runoff both in river basins and in urban areas are more. Then, the objectives of runoff management are discovered, where emphasis is given to urban runoff control. Storm water runoff occurs when precipitation from rain or snowmelt flows over the land surface. The addition of roads, driveways, parking lots, rooftops and other surfaces that prevent water from soaking into the ground to our landscape greatly increases the runoff volume created during storms. This runoff is swiftly carried to our local streams, lakes, wetlands and rivers and can cause flooding and erosion, and wash away important habitat for critters that live in the stream. Storm water runoff also picks up and carries with it many different pollutants that are found on paved surfaces such as sediment, nitrogen, phosphorus, bacteria, oil and grease, trash, pesticides and metals. It comes as no surprise then that storm water runoff is the number one cause of stream impairment in urban areas.

1.2 STUDY OBJECTIVES

One major assumption in the traditional approach of designing infrastructure is that the statistical parameters of the hydrological variables remain constant over time, without major fluctuations or long term trends. However if climate change contributes to an increase in precipitation intensity, this assumption of stationary becomes erroneous, this raises important question. Will hydraulic infrastructures designed for pre climate change conditions are able to sustain future higher discharge [11]. Relatively few studies have looked at climate change from that perspective. Pioneering work by Niemczynowicz (1989) looked at the impacts of climate change on the sewerage system for the city of Lund, Sweden.

This study aims to simulate the rainfall-runoff process and design off drainage for urban catchment, the main objectives of this study are:

- Setting up the SWMM (Storm water management model, including relevant data

- preparation for SWMM).
- To Study the rainfall characteristics.
- To estimate the runoff of study area.
- To check the adequacy of existing drainage system.
- Suggesting Smart Storm water management techniques
- Sustainable Drainage system

1.3STUDY BACKGROUND: RAINFALL – RUNOFF RELATED PROBLEMS

Water is the necessity of life. It has decided the economic basis for most of the societies. However, it can also be a threat to those who really on it when its excessive force invades inhabited areas. Therefore, water not only provides for life, but also turns out to be the source of catastrophes. Compared with the other natural disasters, runoffs are regarded as the most frequent events and cause the most economic losses. Problems associated with management of runoff in densely populated areas are as old as many human settlement themselves Since availability of water supply has been a decisive factor in the search for adequate settlement locations throughout history, river banks and lake sides have become preferred living spaces . However, the cost for such favorable locations is an increased runoff risk [30]. Runoffs are triggered by many causes. Heavy rainfall, tropical storms, snow or ice melt, dam break, mudslide, insufficient capacity of transportation and storage are all among the major runoff origins, geographically, there are three main types of runoff. Revering flooding happens when extreme rainfall attacks a river basin [2]. Urban Runoff is triggered when surface runoff exceeds the capacity of drainage systems, which happens when heavy rainfall pours on sewers with the limited capacity, or even medium rainfall falls on poorly planned or operated drainage systems coastal runoff takes place when heavy rainfall on inland encounters storm surges from the sea. Therefore, runoff control has to do with different situations. In addition, many runoffs have been caused by combined causes. Therefore, there is a need for preparation to withstand such runoff if the possibility exists [1].

1.4 FACTORS AFFECTING THE RUNOFF

Runoff rate and volume from an area mainly influenced by following two factors they are:

(i) Climatic factors like types of precipitation, rainfall Intensity, duration of rainfall and rainfall distribution.

(ii) Catchment characteristics: it includes both the watershed and channel characteristics, which are as follows, Slope of watershed, Land Use, Soil moisture, Soil type, Topographic characteristics and Drainage Density.

1.5 SIGNIFICANCE OF URBAN RUNOFF

Urban runoff is significantly different from rural runoff as urbanization leads to increased impervious area, which increases the runoff peaks from 1.8 to 8 times and runoff volumes by up to 6 times [30]. Consequently, runoff occurs very quickly due faster flow times (in a matter of minutes). Runoff in Mumbai on July, 2005 can be taken as examples of such events, When an unprecedented extreme rainfall strands one of the largest cities in the world for weeks and at least 5000 people died because of runoff and its after – effects. The runoff was caused by the eight highest ever recorded 24-hour rainfall figures of 994 mm (39.1 inches) which lashed the metropolis on 26 July 2005, and intermittently continued for the next day, 644 mm (25.4 inches) was received within the 12-hour period between 8 am to 8 pm [21]. As cities and towns started growing uncontrollably, the land use pattern changed drastically with the more area got impervious due to constructions, carpeted roads etc. Urbanization significantly alters the way water flows in a watershed. In natural areas most rainfall soaks into the ground to replenish groundwater or is absorbed or transpired by plants, and a significantly smaller amount runs directly into rivers [10] . In urbanized areas, water flows rapidly off of the hard “impervious surface” of buildings, streets and sidewalks and it is piped into streams and rivers or discharged underground. Even lawns can contribute to urban runoff because their soil has been completed. In many cases of urban runoff it is found that one of the major reasons of runoff was inadequacy of sewer system (Schmit et al., 2004: Chen et al., 2009; Jacobson, 2011; Singhand Singh, 2011).

3. STUDY AREA

3.1 GENERAL

The proposed project comes The proposed project site lies in **Govindapura, Golahalli village** 3 km from Baglur cross, on the way to Devanahalli airport on Hyderabad Bangalore NH 7 and it is 25 km from Centre of Bangalore . The total area of the study is about **23-acre** (93,000 m^2). The latitude and longitude of the project are **13°7ˈ42ˈˈN** and **77°35ˈ14ˈˈ E** respectively. The type of soil is deep lateritic clayey soil.

3.1.1. CLIMATE

The study area climate is the free from moderate, from March to June is dry, July to October is the monsoon & from November to February winter season [47].

3.1.2. RAINFALL

The amount of rainfall is measured from Golahalli stations. The normal annual rainfall in that station is 1347 mm; December to March is the very low rainfall months, September is the wettest month with monthly rainfall in excess of 254 mm, the rainfall occurs in nearly 48 days in a year [47].

3.1.3. TEMPERATURE

The temperatures start rising from January to a peak of around 39°C in April, the hottest month in the district, Thereafter it declines during the monsoon period and December is coldest month and the temperatures dips down to 9°C. The humidity is lowest during the dry season and highest during the monsoon period, the winds are predominantly south westerly during the summer monsoon and north easterly during the winter monsoon [47] .

4. METHODOLOGY AND DATA PREPARATION

4.1 GENERAL

There are number of methods for estimate of runoff on bases of empirical equation water balance equation, CN methods and effective models like SCS curve number, SHETRAN model, SWAT by those methods algorithms for infiltration, surface runoff, flow routing, impoundments, and lagging of surface runoff have been modified to allow flow simulations with a sub-hourly and hydrologic simulation program- Fortran (HSPF) with a commonly used GIS etc [23] . For all those number of methods they have some limitation and advantages but for our objectives the SWMM model is preferred for estimation of urban runoff. SWMM is a dynamic rainfall-runoff simulation model that computes runoff quality from primary urban areas [23] .

4.2 RUNOFF SIMULATION BY SWMM MODEL

The Environmental protection Agency (EPA) Storm Water Management Model (SWMM) is a dynamic rainfall- runoff simulation model that computes runoff quantity and quality from primarily urban areas [8] . SWMM was first developed in 1971 and since then has undergone several major upgrades, It continues to be widely used throughout the world for planning, analysis, and design related to storm-water runoff, combined sewers, and other drainage systems in urban areas and has also been used for modelling non-urban areas . The latest version of the current implementation of the model is 5.0 which is released in 2015. SWMM model need some basic parameters like, elevation, slope, soil characteristics, infiltration rate, percents of impervious cover, percents of pervious cover, land use/cover type, etc. Except for land use/cover and percent of pervious and impervious cover, all other parameters were obtained through filed work shown in fig.4.1

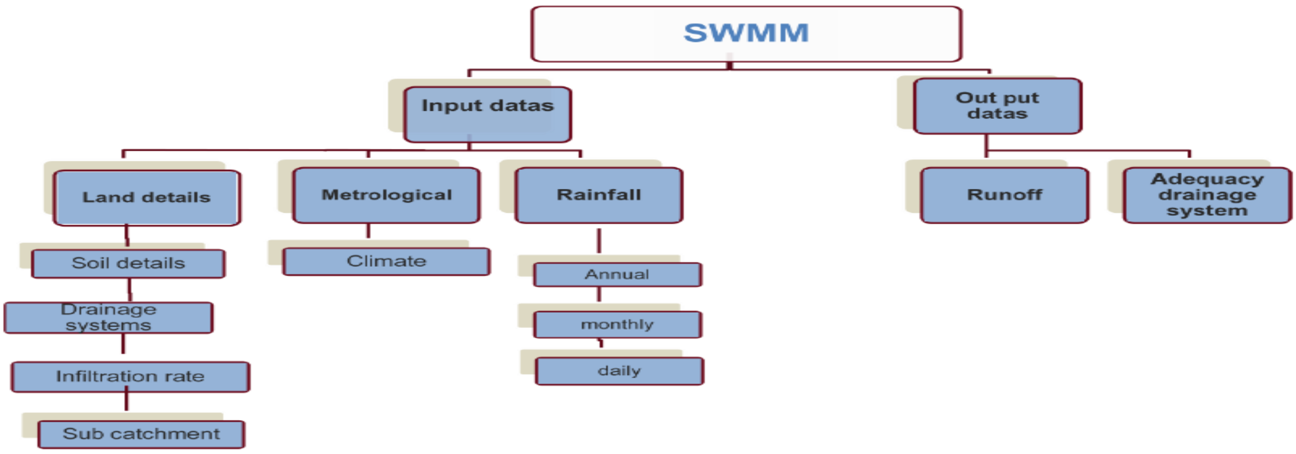

Figure4.1: Work flow diagram of SWMM

4.2.1 SLOPE

Slope of catchment: It has extreme effect. It regulates the overland flow and time of concentration of rainfall. E.g. sloppy watershed results in high runoff due to greater runoff velocity and vice-versa. Slope of the study area was calculated by using data from Google image.

4.2.2 RAINFALL CHARACTERISTICS

1. Types of Precipitation: It has great effect on the runoff. E.g. A precipitation which occurs in the form of rainfall starts immediately as surface runoff depending upon rainfall intensity while precipitation in the form of snow does not result in surface runoff .

2. Rainfall Intensity: If the rainfall intensity is greater than infiltration rate soil then runoff starts immediately after rainfall, while in case of low intensity runoff starts later, thus high intensities of rainfall yield higher runoff.

3. Duration of Rainfall: It is directly related to the volume of runoff because infiltration rate of soil decreases with duration of rainfall. Therefore medium intensity rainfall even results in considerable amount of runoff if duration is longer.

4. Rainfall Distribution: Runoff from a watershed depends very much on the distribution of rainfall . It is also expressed as “distribution coefficient” mean ratio of maximum rainfall at a point to the mean rainfall of watershed [10]**.**

4.3 METHODS FOR INFILTRATION

Infiltration is a component of the general mass balance hydrologic budget; there are several ways to estimate the volume and/ or the rate of water into a soil . 3 estimation methods to calculate the infiltration in SWMM are the green-Ampt methods, SCS methods and Horton’s method.

Infiltration rate	Average maximum Infiltration rate(mm/hr)	Average minimum Infiltration rate (mm/hr)
HIGH	60	40
MEDIUM	25	10
LOW	10	5

4.5 PERCENTS OF IMPERVIOUS COVER

For calculation of percent of impervious cover by using GIS software, maps of study area are taken from Google Earth and upload in GIS. By using GIS in the map the each building each road area is found and it is deducted by total study area. The percent of impervious cover for sub-catchments comes between 35-50% from both Auto CAD and GIS software. Therefore 35% and 45% of impervious cover was used in simulation and runoff was estimated for 60% of impervious cover for future expansions.

4.6 MANNING’S EQUATION

The Manning formula is also known as the Gauckler–Manning formula, or Gauckler– Manning–Strickler formula, The Manning formula is an empirical formula evaluating the velocity of a liquid flowing in a conduit that does not completely enclose the liquid, (i.e., open channel flow) . The discharge formula, $Q = A\ V$, can be used to manipulate Gauckler–Manning's equation by substitution for V, Solving for Q then allows an estimate of the volumetric flow rate (discharge) without knowing the limiting or actual flow velocity . The Gauckler–Manning formula is used to estimate the average velocity of water flowing in an open channel in locations where it is not practical to construct a weir or flume to measure flow with greater accuracy.

Figure 4.2: Existing Square Drainage channel

The Gauckler–Manning formula states:

$$V = \frac{k}{n} {R_h}^{2/3} \, S^{1/2} \quad \text{.........4.3}$$

$$R = \frac{(T - yz)\, y}{T + 2y\left(\sqrt{1+z^2} \;- z\right)} \quad \text{.........4.4}$$

Where:

V is the cross-sectional average velocity (m/s), n is the Gauckler–Manning coefficient, Rh is the hydraulic radius (m), S is the slope of the hydraulic grade line or the linear hydraulic head loss, k is a conversion factor between SI and English units. It can be left out if consistent units are used throughout. However it is standard practice to use k=1, Rh is the hydraulic radius (L).

Table 4.2 Manning's coefficient (n)

CONCRETE	CONSTANT(n)
With rough joints	0.016-0.017
Dry mix, rough forms	0.015-0.016
Wet mix, stall forms	0.012-0.014
Very moth finished	0.011-0.012

4.7CATCHMENT CHARACTERISTICS

4.7.1 LAND USE: Land use and land management practices have great effect on the runoff yield, for example if an area with forest cover or thick layer of mulch of leaves and grasses contribute less runoff because water is absorbed more into soil [45] . GIS map of site can be referred and can be predicted the soil type of this area is Deep lateritic clayey soil at Golahalli village.

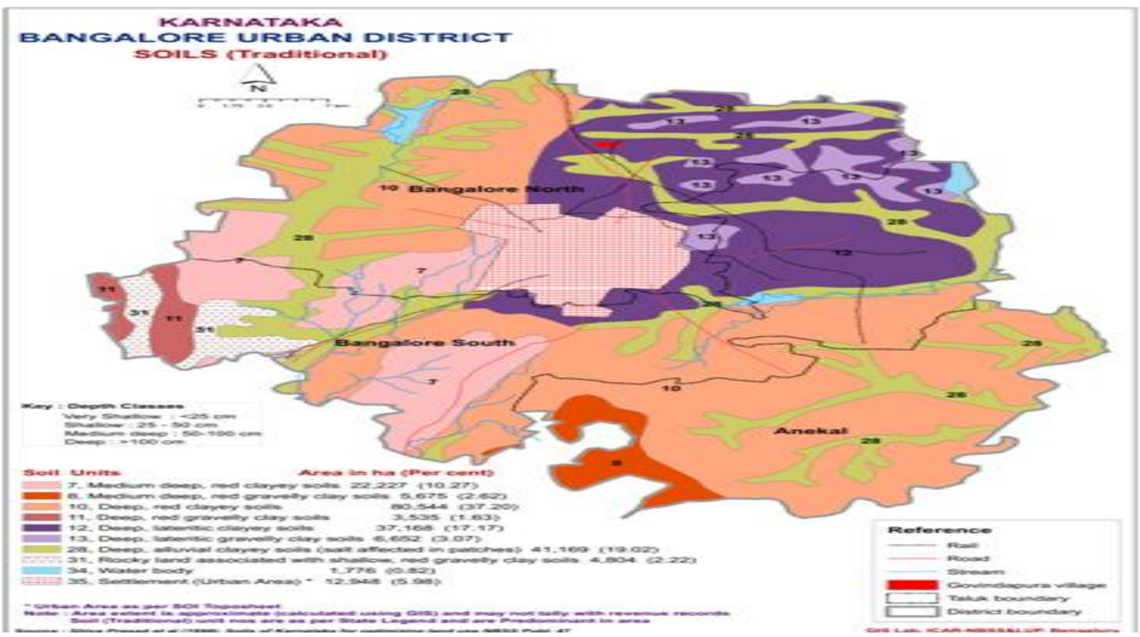

Figure 4.3(a): Study area GIS Map

a) Map of study area

The land-use and land-cover map was derived from AUTOCAD MAP, obtained from Project Department Office of NMIT Bangalore.

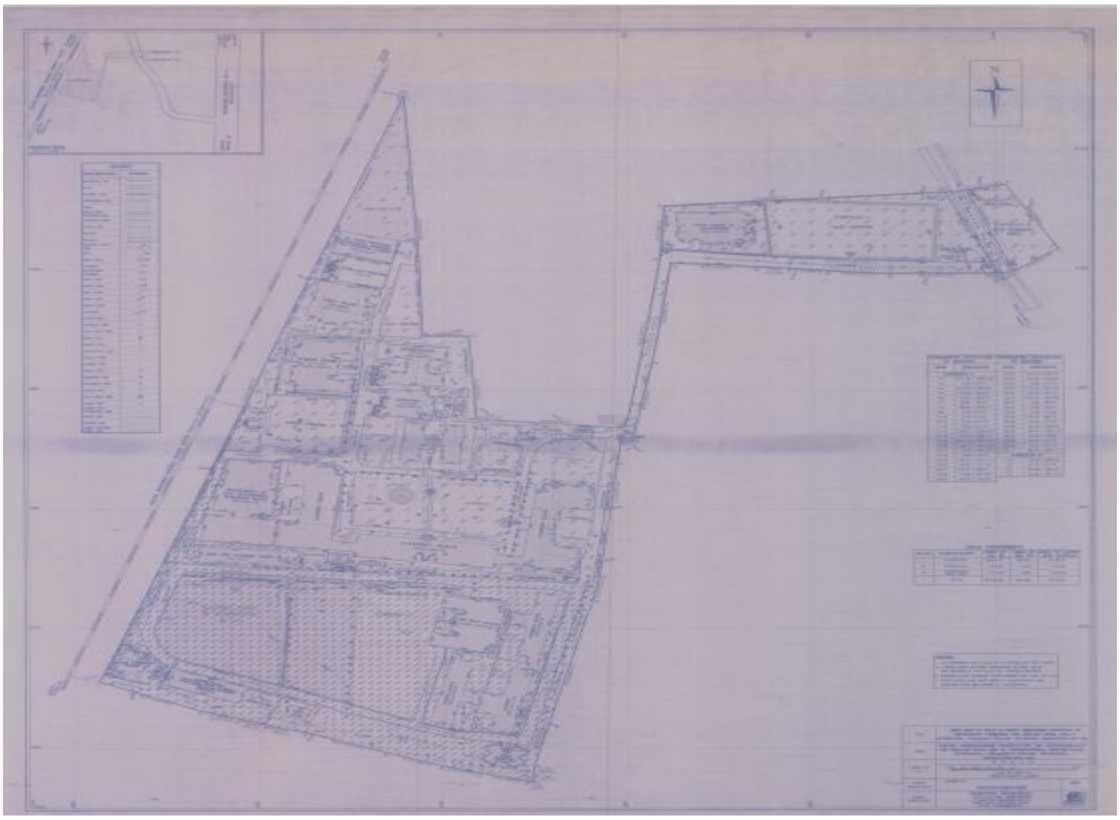

Figure 4.3(b.): Study area AUTOCAD Layout Map

4.7.2 TOPOGRAPHIC CHARACTERISTICS: It contents the topographic features which will affects on the runoff. Undulate land has greater runoff than flat land because runoff water gets additional energy [Velocity] due to slope and little time to infiltrate [27].

a) Characteristics of the study area

To perform the rainfall-runoff simulation in the catchment was divided into six sub catchments. Physical characteristics of each catchment are presented in table 4.3 and illustrated in figure.4.4

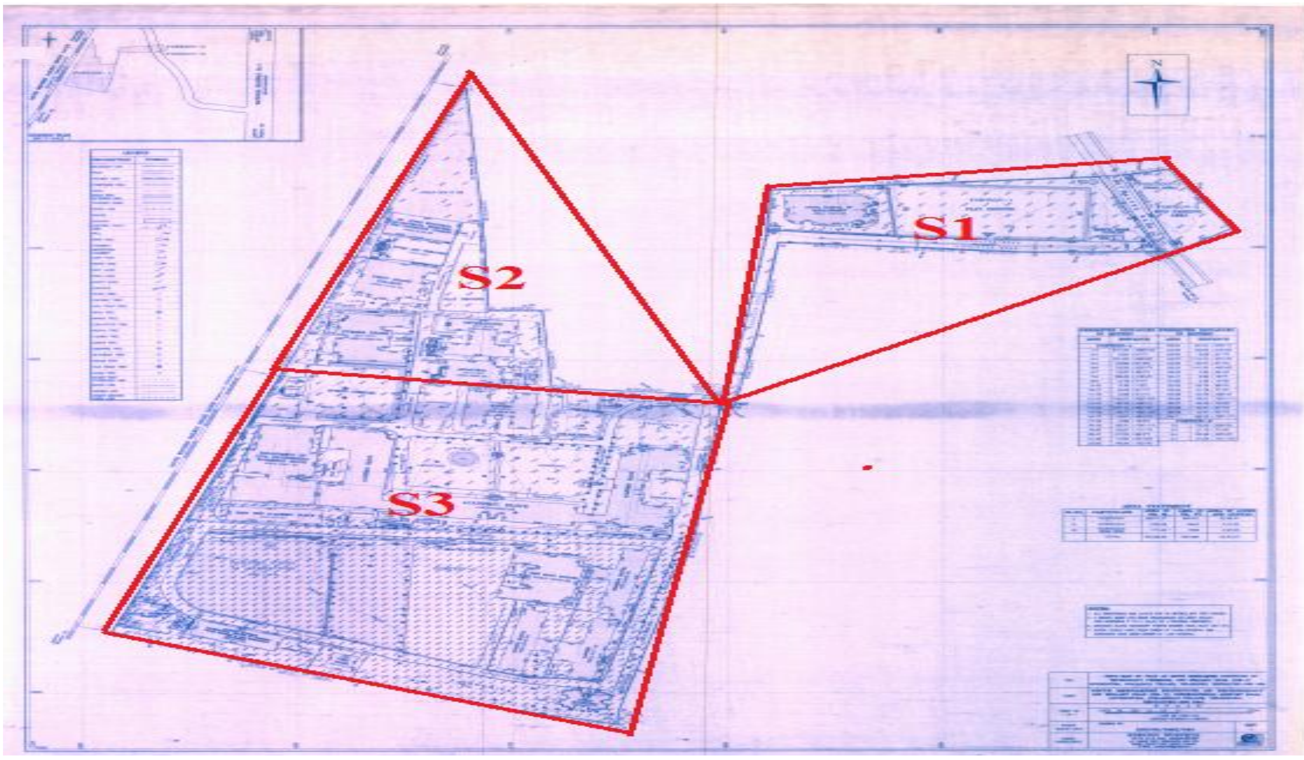

Figure 4.4: Sub catchments used in the present study area

Table 4.3 Physical characteristics of sub catchments

Catchments	Area	Impervious area (Acres)	
		Roads	Buildings
Sub-catchment 1	1 acre	0.15	0.24
Sub-catchment 2	8 acre	0.017	1.20
Sub-catchment 3	14 acre	0.75	3.62

Table 4.4 Sub-catchments impervious details

Physical Parameters	Basin		
	Sub- catchment 1	Sub-catchment 2	Sub- catchment 3
Area(m^2)	4046.85	32374.8	56655.9
Maximum Elevation(m)	865	856	859
Minimum Elevation (m)	859	853	850
Avg. slope of the basin (m/m)	0.06	0.03	0.09
Impervious area (%)	40-50	20-30	30-40

b) Drainage Characteristics of study area

To check the existing drainage design capacity, drainage characteristics like drainage width, length and drainage depth of the catchment has been collected through physical measurement of all surface drainage in the entire catchment. Manning's equation of velocity method was used to calculate the design capacity of the existing drainage system. The width, length and depth of drainage of sub-catchment are survey for future scope of study for this study area drainages are checked for existing drainage all survey points are given below.

Table.4.5 Drainage details of NMIT campus

SL.NO	DRAINAGE USED IN STUDY AREA	WIDTH(cm)	DEPTH(cm)
1.	Sadanand Gate to PGDM block	60.96	67.5
2.	PGDM to security	60.96	61.9
3.	Security to Right BBC Junction	60.96	65.19
4.	PUC To BBC	60.96	62.66
5.	Security To Straight (left) Staff quarter	60.96	63.54
6.	BBC Junction to 1st year block	60.96	62.45
7.	Staff quarter to Solid waste management building	60.96	63.66
8.	Solid waste management building to Back gate	60.96	61.4
9.	BBC to Back gate	60.96	62.15
10.	Hostel areas	60.96	63.66

NOTE: Red colored lines in the figure 4.5 represents the existing covered drains while black colored is uncovered and blue colored line represents the proposed drainage.

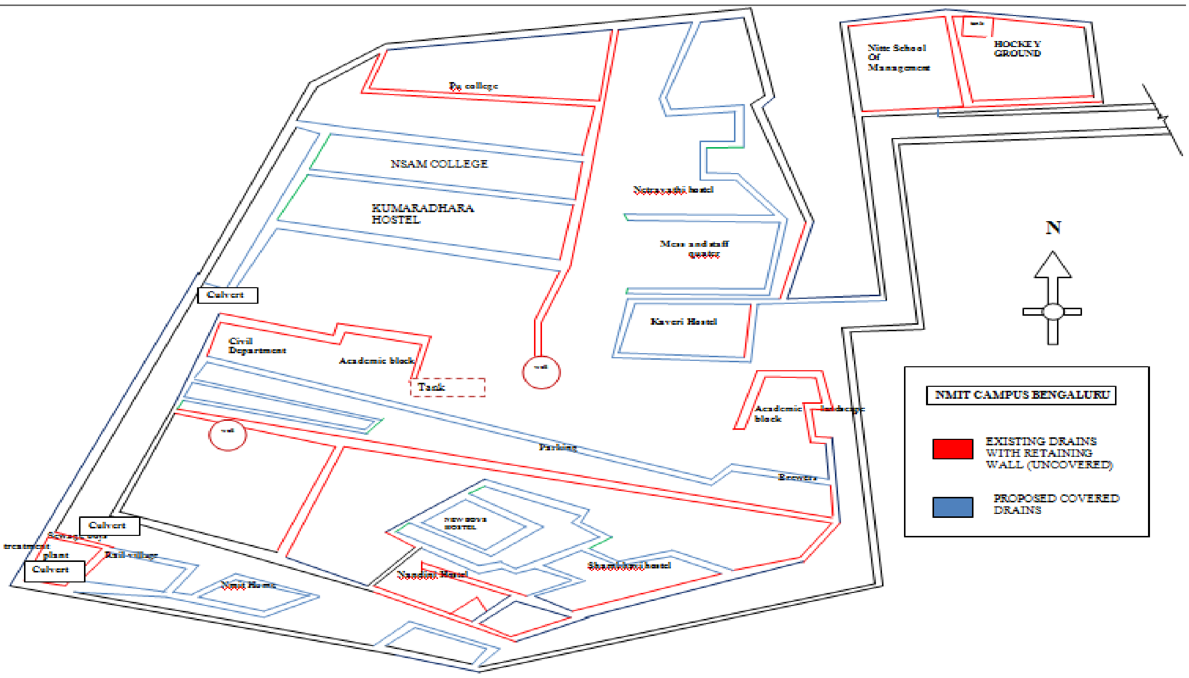

Figure 4.5 Drainage details map

5. RESULT AND DISCUSSIONS

5.1 GENERAL

Due to urbanizations the impervious area gets changed in the impervious area runoff will increase. Understanding the rainfall-runoff process in urban catchment is very essential to design the drainage network. In urban areas, surface runoff mainly depends upon rainfall, infiltration, slope, percent of imperviousness and land use. But land use and rainfall are two major factors which influence the runoff process greatly. The results obtained from SWMM model and manning's equation are presented. For the simulation the rainfall the rainfall-runoff by SWMM model catchment and climate characteristics required like, rainfall, slope, impervious area, infiltration rate. It is very important to understand the rainfall pattern distribution over the study area and to check the adequacy of existing drainage Manning's equation is used. This chapter deals with the results obtained from the methodology adopted.

5.2 SIMULATED RUNOFF FROM SWMM MODEL

5.2.1 SLOPE OF STUDY AREA

For slope calculation DEM (Digital Elevation Mode) is used. For Rainfall-runoff simulation in SWMM model average slope of sub catchment was considered. The average slope of sub catchment area show in table 4.3 for calculation of average slope highest and lowest elevation of sub-catchment was considered [3].

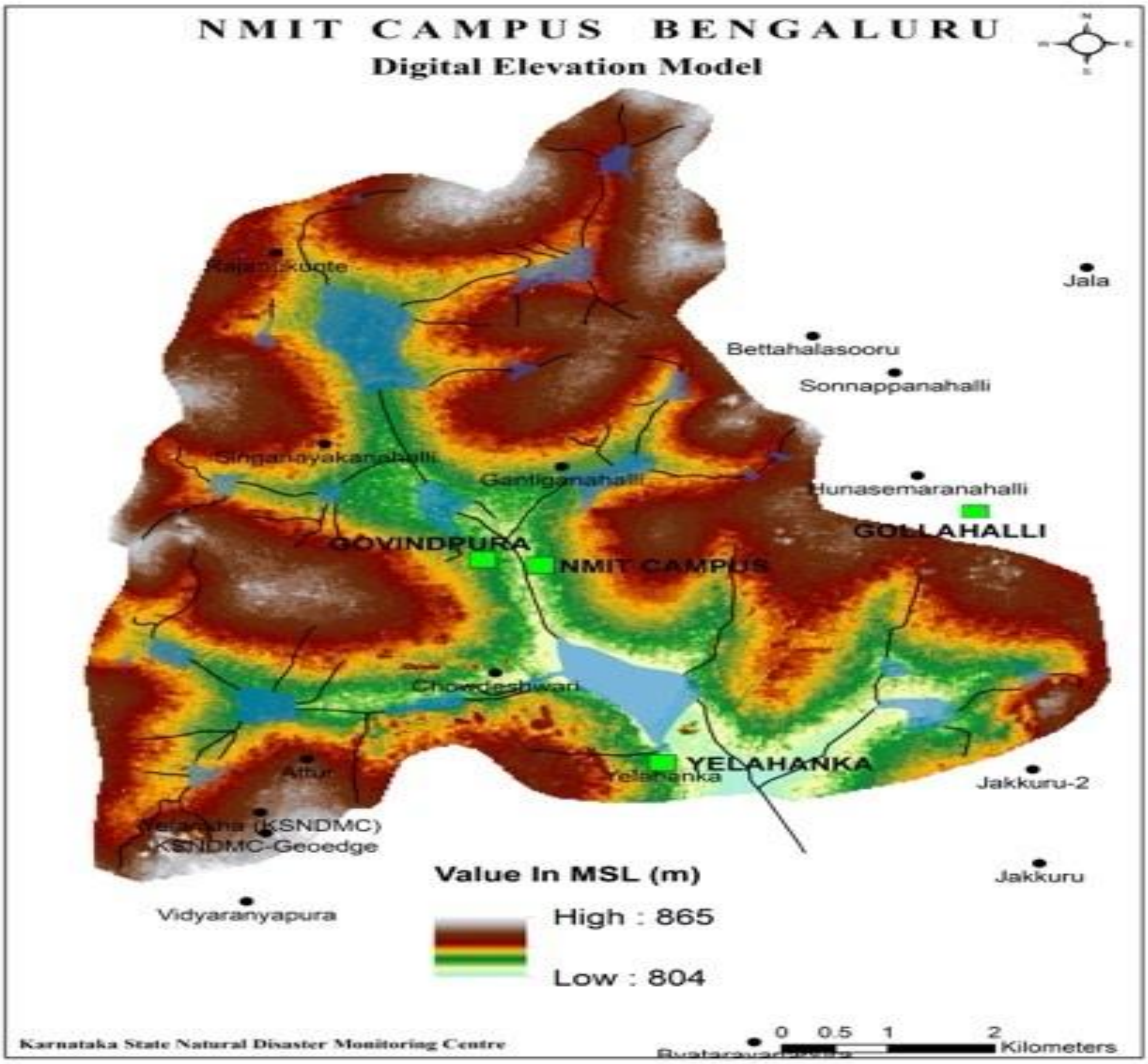

Figure5.1 Profile Digital Elevation Model of Study Area

5.2.2 RAINFALL CHARACTERISTICS

1. Rainfall Intensity: The study area comes under rain gauge station and there will be maximum rainfall intensity for 1hr Maximum rainfall intensity is 102.5 mm, 2hr maximum rainfall intensity is 102.5 mm and so on from 3hr to 24hr as shown in table 5.1 and for 24hr maximum rainfall intensity is 107.02 mm.

2. Duration of Rainfall: For 24 hr duration of rainfall maximum rainfall intensity is 120 mm.

3. Rainfall Distribution: Distribution of rainfall in study area varies over a day it will be maximum of 102.5 mm/hr rainfall, minimum of 1 mm/hr rainfall and average rainfall distribution between 102.5 to 1 mm/hr.

5.2.2.1 RAINFALL DATA USED TO IN SWMM MODEL

(1) For maximum rainfall value of 1hr duration, the maximum 1hr rainfall in a year is considered. For maximum values of 2hr to 24hr rainfall duration, the maximum rainfall in a year is considered.

(2) The total duration of this rainfall event was 24hr. Total daily rainfall on 07-09-2015was 120 mm .For considering the highest rainfall value during 07-09-2015, for this 24hr duration, total rainfall depth was 107 mm. (table5.1 and figure5.2)

Table 5.1 One day Maximum Rainfall Time Series

Rainfall Duration	Rainfall	Year 2015	1 day max rainfall (mm)
1 hr max	Intensity(mm)	100.2	100.2
2 hr max	Intensity(mm)	100.4	100.4
3 hr max	Intensity(mm)	101.3	101.3
4 hr max	Intensity(mm)	101.5	101.5
5 hr max	Intensity(mm)	102.2	102.2
6 hr max	Intensity(mm)	101.2	101.2
7 hr max	Intensity(mm)	101.3	101.3
8 hr max	Intensity(mm)	101.3	101.3
9 hr max	Intensity(mm)	95.6	95.6
10 hr max	Intensity(mm)	90.5	90.5
11 hr max	Intensity(mm)	90.5	90.5
12 hr max	Intensity(mm)	90.5	90.5
13 hr max	Intensity(mm)	90.5	90.5
14 hr max	Intensity(mm)	90.5	90.5
15 hr max	Intensity(mm)	90.5	90.5
16 hr max	Intensity(mm)	90.5	90.5
17 hr max	Intensity(mm)	90.5	90.5
18 hr max	Intensity(mm)	90.5	90.5
19 hr max	Intensity(mm)	90.5	90.5
20 hr max	Intensity(mm)	90.5	90.5
21 hr max	Intensity(mm)	90.5	90.5
22 hr max	Intensity(mm)	90.5	90.5
23 hr max	Intensity(mm)	90.5	90.5
24 hr max	Intensity(mm)	90.5	90.5

5.2.2.2 IMPORTANCE OF HOURLY DATA

For 24 hr duration total rainfall depth was 107 mm (Table 5.1). Due to this rainfall 107 mm there will be more runoff at this rang of time. (Figure 5.2)

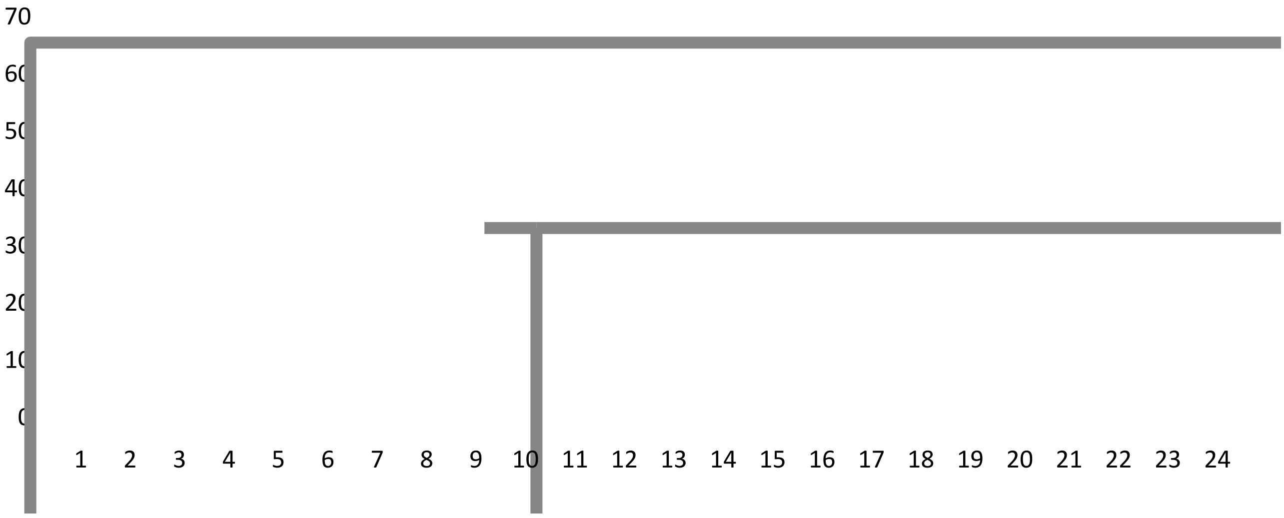

Figure 5.2 Rainfall Distribution of Selected Rainfall Event

The figure 5.3 shows the annual maximum one day rainfall of 2015. The maximum rainfall occur on 7th September 2016 i.e. 101.5 mm.

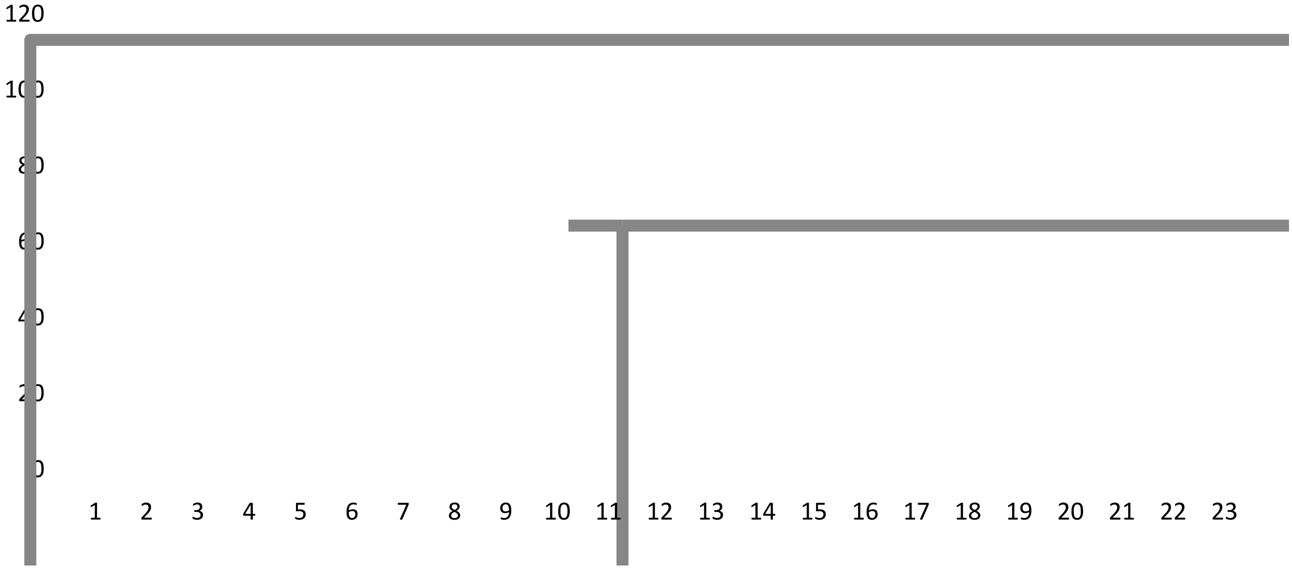

Figure 5.3: Annual maximum 1 day Rainfall Distribution

5.3EFFECT OF DIFFERENT RAINFALL ON RUNOFF

5.3.1 SUB- CATCHMENT 1

For estimate of rainfall-runoff for sub-catchment 1, 24 hr duration rainfall is considered. (Table 5.1)

Estimated runoff for maximum rainfall of 24 hr duration for 2015 (table 5.1) varies from 0 .43 to 0.71 CMS. (Table 5.2)

Table 5.2 Runoff for rainfall event of 2015

SUBCATCHMENT-1-2015										
Rainfall Duration N(hr)	Flow (CMS)	Infiltration rate 10-5(mm)			Infiltration rate 25-10(mm)			Infiltration rate 60-40(mm)		
		35	45	60	35	45	60	35	45	60
1 hr	Runoff	0.43	0.45	0.54	0.40	0.43	0.52	0.40	0.45	0.50
2 hr	Runoff	0.43	0.45	0.54	0.40	0.43	0.52	0.40	0.45	0.50
3 hr	Runoff	0.44	0.50	0.61	0.42	0.48	0.59	0.41	0.50	0.55
6 hr	Runoff	0.44	0.51	0.61	0.42	0.49	0.59	0.41	0.50	0.67
12 hr	Runoff	0.44	0.51	0.71	0.42	0.49	0.69	0.41	0.50	0.67
24 hr	Runoff	0.44	0.52	0.71	0.42	0.49	0.69	0.41	0.50	0.67

5.3.2SUB-CATCHMENT 2

For estimate of rainfall-runoff for sub-catchment 2, 24 hr duration rainfall is considered. (Table 5.1)
Estimated runoff for maximum rainfall of 24 hr duration for 2015 (table 5.1) varies from 0.43 to 0.71CMS. (Table 5.4)

Table 5.3 Runoff for rainfall event of 2015

SUBCATCHMENT-2-2015										
Rainfall Duration N(hr)	Flow (CMS)	Infiltration rate 10-5(mm)			Infiltration rate 25-10(mm)			Infiltration rate 60-40(mm)		
		35	45	60	35	45	60	35	45	60
1 hr	Runoff	0.20	0.21	0.20	0.20	0.21	0.20	0.20	0.21	0.20
2 hr	Runoff	0.20	0.21	0.20	0.20	0.21	0.20	0.20	0.21	0.20
3 hr	Runoff	0.36	0.40	0.45	0.36	0.40	0.45	0.36	0.40	0.45

6 hr	Runoff	0.36	0.40	0.45	0.36	0.40	0.45	0.36	0.40	0.45
12 hr	Runoff	0.36	0.40	0.45	0.36	0.40	0.45	0.36	0.40	0.45
24 hr	Runoff	0.36	0.40	0.45	0.36	0.40	0.45	0.36	0.40	0.45

5.3.3 SUB-CATCHMENT 3

For estimate of rainfall-runoff for sub-catchment 3, 24 hr duration rainfall is considered. (Table 5.1)
Estimated runoff for maximum rainfall of 24 hr duration for 2015 (Table 5.1) varies from 0.43 to 0.71CMS. (Table 5.3)

Table 5.4 Runoff for rainfall event of 2015

SUBCATCHMENT-3-2015										
Rainfall Duration N(hr)	Flow (CMS)	Infiltration rate 10-5(mm)			Infiltration rate 25-10(mm)			Infiltration rate 60-40(mm)		
		35	45	60	35	45	60	35	45	60
1 hr	Runoff	0.35	0.42	0.47	0.35	0.42	0.47	0.35	0.42	0.47
2 hr	Runoff	0.35	0.42	0.51	0.35	0.42	0.51	0.35	0.42	0.51
3 hr	Runoff	0.44	0.55	0.71	0.44	0.52	0.69	0.44	0.52	0.69
6 hr	Runoff	0.44	0.55	0.71	0.44	0.52	0.69	0.44	0.52	0.69
12 hr	Runoff	0.44	0.55	0.71	0.44	0.52	0.69	0.44	0.52	0.69
24 hr	Runoff	0.44	0.55	0.71	0.44	0.52	0.69	0.44	0.52	0.69

5.4 EFFECT OF DIFFERENT RAINFALL ON PEAK RUNOFF FROM SWMM MODEL

For sub-catchment 1 from Table 5.2 to 5.4 shows the variation of runoff for corresponding rainfall. For 1 hr and 2hr rainfall peak runoff is 0.54CMS, for 3 hr rainfall peak runoff is 0.71CMS and for 12hr and 24 hr peak runoff is 0.71CMS. From 1 hr rainfall the peak runoff occurs, after 2 hr runoff will decreases till 4 hr 30 min there will be no runoff. From 2 hr rainfall the peak runoff occurs after 2 hr and 3 hr rainfall duration, after 3 hr runoff will decreases till 5 hr 50 min after 5 hr 50 min there will be no runoff. From 3 hr rainfall the peak runoffs occurs after 2 hr, 3 hr and 4hr rainfall duration, after 4hr runoff will decreases till 6 hr after 6 hr there will be no runoff, From 6 hr rainfall the peak runoff occurs after 2 hr, 3hr, 4hr and 7 hr rainfall duration, after 7 hr runoff will decreases till 9 hr 50 min after will be no runoff. From 12 hr rainfall the peak runoff occurs after 4 hr, 5 hr 30 min, 6 hr 30 min and 10 hr rainfall duration, after 10 hr runoff will decreases till 14 hr 30 min after 14 hr 30 min there will be runoff. From 24 hr rainfall the peak runoff occurs after 5 hr, 7 hr, and 10 hr rainfall duration, after 10 hr runoff will decreases till 25 hr 30 min after 25 hr 30 min there will be no runoff. In between 15 hr 20 hr in this 5 hr duration the runoff is less. In the same way the time is estimated for all the three sub catchments and if required graph for rainfall-runoff is plotted.

5.5 EFFECT INFILTRATION RATE ON RUNOFF

Table 5.5 Effect infiltration rate on runoff

Year 2015						
Sub Catchments	Runoff for infiltration rate@10 to 5 min (cms)		Runoff for infiltration rate@25 to 10 mm		Runoff for infiltration rate@60 to 40 mm (CMS)	
Sub catchment 1	0.46	0.59	0.40	0.52	0.40	0.52
Sub Catchment 2	0.49	0.59	0.40	0.52	0.40	0.52
Sub Catchment 3	0.49	0.62	0.45	0.58	0.52	0.58

5.6 EFFECT OF PERCENTS OF IMPERVIOUS COVERS ON RUNOFF

Table 5.6 Effect of percents of impervious covers on runoff

Year 2015			
Sub Catchments	Impervious cover 35%	Impervious Cover 45 %	Impervious Cover 65%
Sub Catchment 1	0.42	0.51	0.68
Sub catchment 2	0.52	0.54	0.69
Sub catchment 3	0.58	0.58	0.71

5.7 EFFECT OF DIFFERENT IMPERVIOUS COVER ON RUNOFF FROM SWMM MODEL

From table 5.5. and 5.6 shows the variation of runoff for corresponding impervious cover. For impervious cover 35 % peak runoff is 0.58CMS, for impervious cover 45 % peak runoff is 0.58CMS, for impervious cover 60 % peak runoff is 0.71 CMS. For impervious cover 35% the peak runoff occurs after 2 hr, 7hr and 10 hr rainfall duration, after 10 hr runoff will decreases till 25 hr 50 min after 25 hr 50 min there will be no runoff. For impervious cover 45 % the peak runoff occurs after 2 hr, 7hr and 10hr rainfall duration, after 10 hr runoff will decrease till 25 hr 50 min after 25 hr 50 min there will be no runoff. For impervious cover 60% the peak runoffs occurs 2 hr, 7hr and 10 hr rainfall duration, after 10 hr runoff will decrease till 25 hr 50 min after 25 hr 50 min there will be no runoff. Hence if required graph for runoff of impervious cover can be plotted.

5.8 CALIBRATION

Pearson's correlation coefficient (r) and coefficient of determination (R2): Pearson's correlation coefficient (r) and coefficient of determination (R**2**) describe the degree of co linearity between simulated and measured data . The correlation coefficient, which ranges from −1 to 1, is an index of the degree of linear relationship between observed and simulated data, If r = 0, no linear relationship exists, If r = 1 or −1, a perfect positive or negative linear relationship exists . Similarly, R**2** describes the proportion of the variance in measured data explained by the model. R**2** ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi et al., 2001, Van Liew et al., 2003) . Although r and R**2** have been widely used for model evaluation, these statistics are oversensitive to high extreme values (outliers) and insensitive to additive and proportional differences between model predictions and measured data (Legates and McCabe, 1999) [48] .

Nash-Sutcliffe efficiency (NSE): The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliffe, 1970) . NSE indicates how well the plot of observed versus simulated data fits the 1:1 line.

RMSE-observations standard deviation ratio (RSR): RMSE is one of the commonly used error index statistics (Chu and Shirmohammadi, 2004; Singh et al., 2004; Vasquez- Amábile and Engel,2005) . Although it is commonly accepted that the lower the RMSE the better the model performance, only Singh et al. (2004) have published a guideline to qualify what is considered a low RMSE based on the observations standard deviation. Based on the recommendation by Singh et al. (2004), a model evaluation statistic, named the RMSE-observations standard deviation ratio (RSR), was developed. RSR standardizes.

5.9 RUNOFF ESTIMATION FROM MANNING'S EQUATION

To check the existing drainage adequacy, peak discharge were computed by using manning roughness coefficient. Manning equation gives the value of velocity of liquid in the channel if the cross section area of channel is known discharge can be computed by multiplying the velocity into cross sectional area. For calculation of velocity, Manning coefficient constant n=0.012 is used since the channel surface is very rough is very rough so high value of manning roughness coefficient was adapted for three sub-catchments. For sub-catchment 1 the width and depth of the channel was 0.6 m and0.67 m respectively. The calculated discharge for adopted sub-catchment from equation was found to be 0.71 CMS. The peak discharge for SWMM model is 0.55 CMS which is less than 0.71 CMS. For sub-catchment 2 the width and depth of the channel was 0.60 m and 0.62 m respectively. The calculated discharge for adopted sub-catchment from equation was found to be 0.71 CMS. The Peak discharge for SWMM model is 0.57 CMS which is less than 0.82 CMS. For Sub catchment 3 the width and depth of the channel was 0.6 m and 0.61 m respectively. The calculated discharge for adopted sub catchment from equation was found to be 0.82 CMS. The Peak discharge for SWMM model is 0.63 CMS which is less than 0.71 CMS.

Results	SWMM Model runoff	Manning's equation Runoff
Sub Catchment 1	0.55	0.71
Sub Catchment 2	0.57	0.71
Sub Catchment 3	0.63	0.71

5.10 APPLICATION OF LOW IMPACT DEVELOPEMNET

Already LID application is implicated to the study area but in comparison with the result at present condition it can handle the runoff, as the impervious area developed by 60% over year return period of rainfall that time it's not sufficient to handle it so for that changes should be made.

5.11 IMPLEMENTING SMART & SUSTAINABLE STORM WATER DRAINAGE CONCEPT

Communities across the country are adopting smart growth strategies to achieve environmental, community, and economic goals. Development strategies that use compact development forms, a mix of uses, better use of existing infrastructure, and preservation of critical environmental areas can protect water quality. While the water quality and storm water benefits of smart growth are widely acknowledged, there has been little explicit regulatory recognition of these benefits to date. Regulations under the National Pollutant Discharge Elimination System (NPDES) storm water program offer a structure for considering the water quality benefits associated with smart growth techniques.

Using Smart Growth Techniques as Storm water Best Management Practices (2005) can help communities that have adopted smart growth policies and plans recognize the water benefits of those smart growth techniques and integrate those policies into storm water planning and compliance. Taking credit for the work a community is already doing can be a low-cost and practical approach to meeting water quality goals and regulatory commitments. Examples of smart growth techniques and approaches covered in this publication include:

- Regional planning.
- Infill development.
- Redevelopment policies.
- Special development districts (e.g., transit oriented development and brown fields redevelopment).
- Tree and canopy programs.
- Parking policies to reduce the number of spaces needed or the footprint of the lot.
- "Fix It First" infrastructure policies.
- Smart growth street designs.
- Storm water utilities.

5.11.1 A STORM WATER MANAGEMENT PLAN (SWMP) OR STORM WATER POLLUTION PREVENTION PLAN (SWPP)

The SWMP should include strategies and BMPs for those measures:

‣ Outreach ‣ Education ‣ Construction ‣ Post-Construction ‣ Illicit Discharges Elimination ‣ Pollution Prevention

Under the new rules, MS4s need to include measurable goals, and show how the SWMP relates to water quality goals. The minimum measures listed above were not part of the original permit structure for Phase I permits, though the general tasks were required. In reissuing storm water permits, many permitting authorities are modifying the permits to more closely dovetail Phase I and Phase II requirements to make it easier for these communities to work together.

5.11.2 STORM WATER MANAGEMENT AND RESTORATION TRACKER (SMART)

Storm water remains one of the most difficult and expensive sources of Chesapeake Bay pollution to control. While a great deal of attention and resources have been committed to wide scale adoption of Agricultural Best Management Practices (BMPs), many counties and towns receive a large volume of storm water from smaller scale residential and private properties. Actions on these smaller properties, such as the installation of rain barrels, rain gardens, green roofs, or changing of lawn fertilization practices on an individual property, when considered in aggregate, can show significant nutrient and sediment reductions.

5.11.3. INFILL DEVELOPMENT

Infill can reduce potential runoff by ensuring that growth does not create additional impervious surfaces on the developed fringe and in environmentally sensitive areas. The impacts of such development can be considerable. Growth on the undeveloped fringe results in less groundwater flow into streams and less aquifer recharge as water runs over the surface. A modeling study conducted by Purdue University estimated that placing a hypothetical low-density development at the Chicago fringe area would produce 10 times more runoff than a mixed-use development in the urban core. In Virginia, a Chesapeake Bay Foundation study found that clustered development across the state would convert 75 percent less land, create 42 percent less impervious cover, and produce 41 percent less runoff. In addition, infill development can make use of existing infrastructure. Guiding development to existing areas also increases the economic activity and tax base needed to support the maintenance, repair, and/or expansion of the water infrastructure in place.

5.11.4. TMDL (TOTAL MAXIMUM DAILY LOAD)

A process typically follows to identify major sources (e.g., agriculture, urban runoff) and allocate a portion of the pollutant load to each source. The goal of a TMDL program is to restore a waterway by reducing pollutant sources. Thus, sources often face reductions in how much pollutant they contribute. Storm water can be a major contributor to impairments due to the heat, nutrients, metals, and other pollutants carried in runoff. Thus, reducing storm water runoff in areas with impaired water-bodies is often at the center of the TMDL process.

5.11.5. TREE AND CANOPY PROGRAMS

A well maintained tree canopy can provide a variety of environmental benefits. Trees provide erosion control and help reduce the costs of structural storm water management, including land acquisition costs and construction of storm water retention facilities. Strategically preserving or planting trees along urban rivers, streams, and creeks can reduce water temperatures. Increased temperatures affect certain native aquatic species, can increase nuisance algae populations, and impact commercial activities that rely on stable water temperatures for recreation, industrial use, or aesthetics. Tree canopy intercepts rainwater, which provides for gradual release of rainwater into streams, thereby preventing flooding, filtering toxins and impurities, and extending water availability into dry months when it is most needed.

5.11.6. PARKING POLICIES TO REDUCE NUMBER OF SPACES NEEDED

Reducing the amount of surface parking reduces the quantity, speed, and impurities of the runoff. For example, one researcher calculated that a one-inch rainstorm on a one-acre meadow would produce 218 cubic feet of runoff, while a parking lot the same size would produce 3,460 cubic feet. Among the pollutants that accumulate on parking lots are cadmium, copper, lead, zinc, nickel, cobalt, and iron, which are found in gasoline, grease and oils, antifreeze, brake linings, and rubber. Under most parking standards, the number of spaces required is often dictated by times of "peak use," such as holiday shopping, which tends to be heavier than at other times.

5.11.7. FIX IT FIRST POLICY

"Fix It First" policies have long-term effects on storm water management and can be a smart growth technique to encourage infill construction and redevelopment. In addition, "Fix It First" policies encourage replacement of older infrastructure, which can be a significant source of storm water-related problems, particularly in older urban and suburban areas. In particular, sewer overflows during wet weather events can have severe environmental impacts. Inadequate or degraded system. These programs also can include new treatment technologies to improve the performance of existing systems. Many people are unaware that most storm water runoff entering storm drains is not filtered and flows untreated into water bodies.

5.11.8. SMART GROWTH STREET DESIGNS

Because streets constitute the largest share of impervious cover in residential developments (about 40 to 50 percent), a shift to narrower streets can result in a 5- to 20-percent overall reduction in impervious area for a typical residential subdivision.[25] As nearly all the pollutants deposited on street surfaces or trapped along curbs are delivered to the storm drain system during storm events, this reduced imperviousness translates into a lower volume of storm water runoff and pollutant loadings from the development. For storm water quality factors, residential streets rank as a major source for many pollutants, including sediment, bacteria, nutrients, hydrocarbons, and metals. Within housing subdivisions, the individual, smaller streets feed into collector roads, which then lead, often through only one intersection, to arterials. The arterials (which in some cases are highways) link large, centralized trip generators, such as shopping centers, office parks, and subdivisions. Using Smart Growth Techniques as Storm water Best Management Practices . This road and intersection system features multiple turning lanes, wide intersections, and access lanes designed to minimize congestion with the collected and concentrated flow of traffic. This type of system increases the amount of land needed to handle collected traffic, concentrates traffic onto fewer roads, increases the pressure to widen the roads that handle collected traffic, and creates barriers to travel options, such as pedestrian trips.

5.11.9. STORM WATER UTILITIES

Storm water utilities have been established to provide a fair and predictable source of funding for storm water projects. As towns experience growth, they need to fund systems to handle the storm water that flows from newly developed parcels, as well as from older areas. Larger cities may need to repair and/or expand sewer and water systems to support redevelopment. Some older cities are also separating their old combined sewer pipes into two systems: one that handles storm water from the streets and a second system to deliver sanitary sewerage to a wastewater treatment plant. A storm water utility can provide stable funding to address the runoff problems associated with development and redevelopment.

5.11.10. INTEGRATED WATER MANAGEMENT

Rain water harvesting, water reuse/ recycling; design of green drainage system, The term **"smart water"** incorporates water and wastewater infrastructure that ensures optimization of water consumption and the energy used to transport it - is managed effectively. A smart water system gathers meaningful and actionable data about the flow, pressure and distribution of a city's water. Further, it is critical that that the consumption and forecasting of water use is accurate. Water loss management is becoming increasingly important as supplies are stressed by population growth or water scarcity. Smart water system implies transforming wastewater treatment plants into resource recovery facilities, which includes generation of energy. Smart Water systems also imply engineering alternatives to design of the drainage network. Drains which receive filtered surface run off are designed with permeable edges that in-turn help grow riparian vegetation that supports aqua flora and fauna.

5.11.11. SUSTAINABLE STORM WATER

The Sustainable Storm water Coordinator *(SSC)* position designates a SEFS research aide appointment to spread awareness about and physically improve storm water treatment on campus. This is accomplished by investigating the current quantity and quality of campus storm water, analyzing a suite of suitable water management tools, and building a collaborative student-faculty-administration approach to this pressing issue. In sum, continuation of this project seeks concrete and actionable runoff strategies, informed by water quality testing of discharges from parking lots, rooftops and sports fields.

5.11.12. SUSTAINABLE DRAINAGE SYSTEMS (SUDS)

Sustainable drainage systems: a sequence of management practices and control measures designed to mimic natural drainage processes by allowing rainfall to infiltrate and by attenuating and conveying surface water runoff slowly compared to conventional drainage. SUDS can operate at different levels; ideally in a hierarchy of source control, local control and regional control, and can be used in both rural and urban areas. Sustainable drainage systems – at a glance SUDS are used as an alternative to conventional ways of managing surface water. In built environments they aim to mimic the way rainfall drains in natural systems, avoiding many of the problems typically caused by surface water runoff from developments. As we all work to find sustainable solutions to the challenges of growth and climate change, SUDS play a critical role in flood and pollution prevention by freeing up capacity in our sewers. Importantly too, SUDS add considerable aesthetic and environmental value, offering attractive natural amenities for the local community and protecting and enhancing biodiversity. SUDS techniques SUDS use a number of techniques generally based on natural drainage features to collect, treat, store and then release storm water slowly to the environment: Filter strips and swales use vegetation to filter and control flows. Filter drains, permeable surfaces, green roofs, bioretention areas and other permeable structures allow water to percolate through a pervious surface into voided construction below to allow cleaning, storage and controlled release. Infiltration devices are specific design features that allow soakage into the ground and include soakaways and infiltration basins, although most SUDS features can also provide infiltration depending on design and ground conditions. Quantity Quality Amenity and Biodiversity 1.2 The SUDS drainage philosophy SUDS manage the flooding and pollution aspects of drainage and ensure that the community and wildlife are considered in SUDS design. SUDS deliver efficiently and effectively across four key criteria: Quantity -SUDS reduce the risk of flooding and erosion by controlling flow volumes and the frequency of surface water runoff. Quality – SUDS prevent and treat pollution in surface water runoff to protect the environment. Amenity – SUDS provide visual and community benefits for people. Biodiversity – SUDS enhance and create habitats for wildlife. Basins, ponds and wetlands are open depressions in the landscape that collect, clean and store water in a natural way and can provide amenity and wildlife benefits for the community. Engineered below-ground storage structures, including geocellular boxes, tanks and oversized pipes can augment the attenuation capacity of a SUDS design but do not clean surface water runoff. — Inlets, outlets and control structures manage the flow of water through the SUDS.

5.11.12. STORMWATER HARVESTING

Rain smart Solutions integrated approach to storm water management is the key. This integrated approach regards storm water as a resource rather than a burden and considers all aspects of run-off within a development, including environmental social and cultural issues. Rain smart Solutions water sensitive urban design offers a point source solution, an alternative to the traditional conveyance approach to storm water management. It seeks to minimise the extent of impervious surfaces and mitigate changes to the natural water balance, through the approach of principles of “Zero Contamination & Zero Discharge, by creating permeable surfaces, on-site reuse of the water and ground water recharge systems. By integrating major and minor land flow paths in the landscape and adopting a range of water sensitive design techniques, the size of the structural storm water system required can be reduced. These techniques include detention and retention basins to lower peak flows, and grassed swales and vegetation to facilitate water infiltration and pollutant filtration. Managing urban run-off in a water sensitive manner not only resolves problems associated with storm water, but it enhances the social and environmental amenity of the urban landscape. Reducing peak flows and maintaining a more natural storm water system can also potentially reduce capital and maintenance costs of drainage infrastructure costs

5.11.13. STORM DRAIN MODEL SOFTWARE CONTROLS (OPTIONAL)

- The FLO-2D Model has been integrated with the EPA Storm Water Management Model Version 5.022 (SWMM) to simulate the exchange of surface water flow with a storm drain system.
- The two models run simultaneously and FLO-2D will calculate all hydrologic and hydraulic surface water routing (channel, street and unconfined overland flow) while SWMM will only solve the conduit hydraulics and flow routing in a given storm drain network.
- Data is shared on a time step basis controlled by the FLO-2D model.

The basic steps for developing a storm drain model once the FLO-2D model is functional are:

1. Open the GDS and locate the Storm Drain folder.
2. Important aerial images from the folder to help visualize the location of the storm drain system.
3. From the GDS initiate the SWMM GUI interface.
4. Create the SWMM storm drain system SWMM GUI.

Figure 5.4. SWMM Model for the Project

The remaining steps for finalizing the storm drain input data are:

1. Assign the remaining SWMM controls including starting time, ending time, report time and routing time steps and routing equation of motion.
2. Save the project.

3. Input the storm drain inlet geometry .
4. View the SWMM storm drain system in the GDS .
5. Run the project from GDS.
6. Review SWMM results are reported in the SWMM.rpt file.

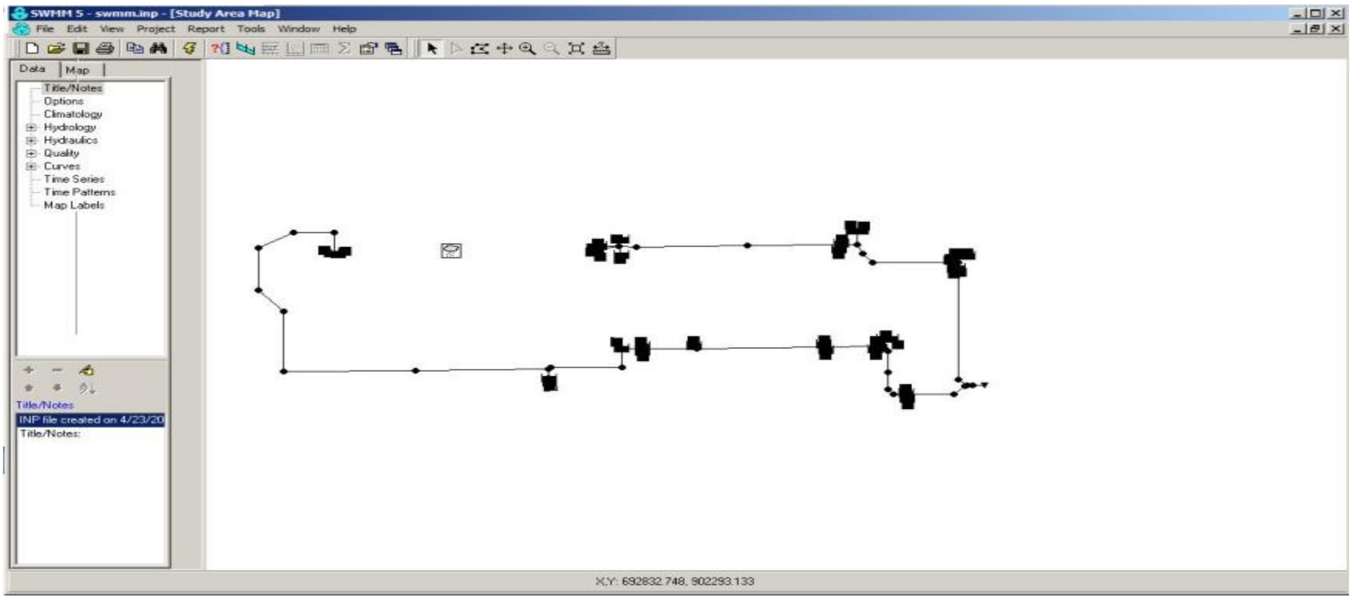

Figure 5.5 : Storm Drain System Displayed showing inlets, outlets and conduits

- The storm drain results can be reviewed in the GDS following the successful completion of the flood simulation can display the storm drain inlet hydrographs (inflow and return flow), the water surface head on the storm drain inlet and outlet and the pipe hydraulic and energy grade lines.
- The SWMM GUI also has many display options for viewing the results of each node of the storm drain network.

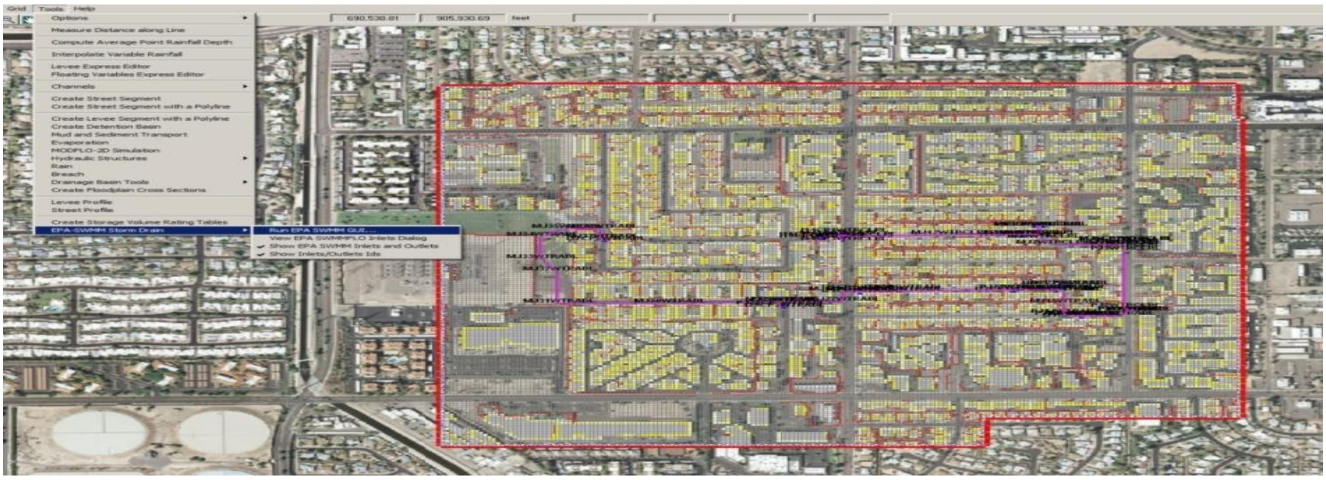

Figure 5.6: The Storm Drain System in a FLO-2D Project with 20 ft Grid

6. CONCLUSION

6.1 GENERAL

Attempts have been made to simulate the rainfall – runoff process in an urban catchment to check the adequacy of the existing drainage system. SWMM model were adopted to simulate the rainfall runoff process in the adopted sub catchments and manning roughness coefficient to derive the design capacity of existing channels. For SWMM input parameters, field survey has been conducted to collect the basic parameters like, slope, elevation, soil type, infiltration rate. From the results it is clear that SWMM model predict the reasonably accurate results for the adopted sub catchments, and since the peak discharge value from SWMM model is less than design capacity of existing drainage system. So it can be said that existing drainage system is adequate for existing conditions but if in future the impervious cover increases or rainfall intensity increases, the peak discharge may exceed the design capacity of existing channel.

6.2 OVERALL CONCLUSIONS

From the study of rainfall characteristics, highest annual maximum 1 day rainfall occurred in 2015, where in all the remaining period, it showed no significant change with respect to time.

- From the SWMM, high runoff occurred in sub-catchment 3 in the range of 0.41 -0.63 m3/s where, low runoff occurred in sub –catchment 1 in the range of 0.41 -0.55 m3/s.
- From the manning's equation, high runoff occurred in sub-catchments1 to 3 is0.71 m3/s.
- The result of three sub-catchments, it can be said that existing drainage system is adequate for existing conditions but as the impervious cover increases above 60% or rainfall intensity increases in future, the peak discharge may exceed the design capacity of existing channel in sub catchment 3. To control the runoff on the sub catchment 3 we can change the drainage dimension to 0.6m × 0.63 m Refer figure 4.5 for the proposed drains for NMIT CAMPUS.

So that in future we can reduce the runoff or we can provide

- Green roofs
- Continuous permeable pavement
- Infiltration trenches
- Smart techniques for smart drainage
- Sustainable drainage

6.3 LIMITATIONS

- Not directly applicable to large-scale, non-urban watersheds.
- To simulate the SWMM model 1 hr rainfall intensity is used. If 15 min rainfall is used for simulate the SWMM model, result of 15 min is virtuous compare to 1 hr rainfall.
- The land–use land–cover map derived from AUTOCAD MAP, obtained from Project department Office of NMIT , it is not up to the scale, if present land-use land-cover of NMIT map is used for simulation than the result virtuous to the present result.

6.4 SCOPE FOR FUTURE STUDY

- This model can be applied to study area of low humid region also.
- This model can be applied to large-scale area.
- This model can be applied can be applied to 15 min and 1 min rainfall data.
- Smart drainage system implementation is for better future as per smart city projects.

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