Study of Adequacy of Drainage in Urban Areas

A Report of CVD 411-Project Part 1 submitted in partial fulfilment of the requirements for the degree of Bachelor of Technology

Submitted by

Mukul Anand

2016CE10271

Department of civil Engineering

Indian Institute of Technology Delhi

November 2019

CERTIFICATE

"I do certify that this report explains the work carried out by me in the Course CVD 411 - Project Part 1 under the overall supervision of **Dr. A.K. Keshari**. The contents of the report including text, figures, tables, computer programs, etc. have not been reproduced from other sources such as books, journals, reports, manuals, websites, etc. Wherever limited reproduction from another source had been made, the source had been duly acknowledged at that point and also listed in the References."

Signature of Student

(Mukul Anand)

Name of Student

"This is to certify that the report submitted by **Mukul Anand** describes the work carried out by him in the Course CVD 411 - Project Part 1 under my overall supervision."

(Signature of Supervisor)

Dr. A.K. Keshari

(Name of Supervisor)

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my supervisor, Dr. A.K. Keshari, for the continuous support, expert guidance, understanding and encouragement in my B-Tech Project and also for his immense patience, motivation, enthusiasm, and knowledge. His guidance helped me throughout the research and writing of this report. I could not have imagined having a better advisor and mentor for my project.

I am obliged to everyone who helped me directly or indirectly during the project.

Mukul Anand

2016CE10271

ABSTRACT

India has witnessed rapid economic growth and urbanisation over the past two decades. The economic activities and a boom in high technology and services sector has led to a demand for work, leisure, and living spaces fuelling a construction boom in cities like New Delhi, Mumbai and Bangalore etc. The construction of large office complexes, shopping malls, roads, pavements, parking lots and high-rise apartment buildings have led to an increase in paved surfaces. Increase in paved surfaces in a city leads to instances of urban flash floods and decreases the percolation of rainwater into the water table. Because the drainage in urban areas has not been renovated as per requirement due to which we often encounter the situation of urban flooding. The increased instances of urban flash floods causes water logging in the slums which are usually located in low-lying areas - leading to a potential health and safety hazard. New Delhi and adjoining areas of Noida, Ghaziabad, Gurgaon and Faridabad have witnessed severe flash floods during the annual monsoon rains over the last few years. Flooded streets, overflowing drains and waterlogged slums have become increasingly common. All of this is causing a major harm to the society living in these areas. The aim of this study is to find out how an efficient drainage could be designed if having some of the crucial data required for the study. Also how could we mitigate the problems existing in the current drains of the urban areas. The study has been carried out with a couple of design storm on an urban area whose hydrological properties has been approximated. All the simulation for the study has been carried out on a publicly available software which is EPA-SWMM.

Key words: Urban flooding, Drainage, SWMM

CONTENTS

Topic Page No.

List of Tables: Page No.

List of Figures Page No.

List of Figures Page No.

Chapter 1

INTRODUCTION

1.1 General Introduction:

The majority of the world's population lives in the so-called "developing" countries – many of them living in dire conditions in the slums to be found in most towns and cities. A particular problem associated with these slums is poor drainage. Many slums are informal settlements that have come about through land invasion and lack proper planning. Slums arise through a combination of: rapid population growth (both through high birth rates as well as large inmigration), weak local government (resulting in inadequate planning and management), insufficient investment (perhaps a consequence of a small tax base or/or high levels of corruption) and a lack of skilled personnel (both professional as well as maintenance).

By definition, all informal settlements are illegal when they are formed and therefore not officially part of the city and are excluded from urban services. However, many subsequently gain recognition from the local authorities, often as a result of political patronage. As a result, they become legitimised and are subsequently entitled to receive the same urban services as the rest of the city. However, many remain marginalised and are poorly served by municipal services. The provision of drainage infrastructure is invariably inadequate and a wide range of problems prevail related to flooding and environmental health issues caused by poor drainage.

In hilly cities, the location of informal settlements is often predictable as they will invariably be found alongside existing drainage paths and on steep hillsides. It is, however, less obvious where the topography of the city is flat. The majority of the informal settlements are located on erstwhile agricultural land and their layout is therefore heavily influenced by the path of irrigation canals and drains, which often later become part of the urban drainage system. These drains frequently become fetid, slow flowing open sewers but the local farming community continue to abstract water from the drains for irrigation even though this presents significant health hazards.

In other cases, notably where water resources are scarce, it is not uncommon for farmers to deliberately block sewerage systems to divert wastewater onto adjacent fields. As well as abstraction of wastewater from the drainage system for irrigation, water in the drains is often used for various domestic purposes and commercial activities. These activities are likely to result in transmission of a range of water-related diseases.

All these problems come from a situation which we call Urban flooding. Urban flooding not only causes major property damage, it is also responsible for fatalities and injuries. Each year, people die while trying to move cars through deep or fast-moving water in streets. Individuals and communities are getting affected, "such as loss of hourly wages for those unable to reach their workplaces; hours lost in traffic rerouting and traffic challenges; disruptions in local, regional, and national supply chains; or school closings with resultant impact on parents." These effects are especially disruptive to lower-income and minority residents, who are more likely to live in flood-prone areas and less likely to be covered by flood insurance. "For those lacking critical resources (savings, insurance, etc.)," they write, "the flood losses gnaw away at their well-being." And that doesn't even include the physical and mental health effects linked to chronic flooding, such as asthma resulting from mold exposure. It's clear that urban flooding poses a threat to people who are already socially and economically vulnerable. In addition, urban flooding is often too localized to trigger a federal disaster declaration, even when it causes relatively large amounts of damage and disruption. This limits the public assistance available to victims, who are then left on their own to deal with the aftermath, over and over again.

The problem is persisting because there is no clear responsibility or jurisdiction for urban flooding at the federal level. This complicates data collection, funding availability, and priority setting. Even at state and local levels, flood management and stormwater management are often overseen by different programs, whose responsibilities may not be clearly defined.

It is of concern that whilst the world is on track to meet the Millennium Development Goal (MDG) target on drinking water, it does not look set to meet the target on sanitation (to halve the number of people without access). Based on current trends, the total world population without improved sanitation in 2015 will still be a massive 2.4 billion (WHO, 2008). Whilst not all sanitation need be water-borne, the need to cater for greywater (domestic wastewater) in addition to stormwater in high density urban areas makes it important that more serious consideration be given to providing adequate drainage. No MDG target has yet been set for drainage; it is apparently not acknowledged to be a problem.

1.2 What is urban drainage?

Urban drainage includes the removal of all unwanted water from urban areas. It includes wastewater – including sewerage and greywater - and stormwater. Greywater, sometimes called sullage, is domestic wastewater predominately from baths, basins and washing machines. The unwanted water may, or may not, be used for other purposes with, or without treatment.

1.3 What Is Urban Flooding?

When many of us think about flooding, we think about events like these: major disasters that upend entire communities and trigger a large response from state and federal agencies. However these days the attention is on the widespread and costly destruction caused by a lesser-recognized threat: chronic urban flooding due to city landscapes that cannot absorb or otherwise manage rainfall. Based on the results of a nationwide survey of stormwater and floodplain management professionals, the report (by researchers from the University of Maryland and Texas A&M University) demonstrates how urban flooding is a separate phenomenon from coastal and riverine flooding. It is more frequent, more localized, and not as well understood; in addition (as with other aspects of climate change), it is most likely to affect those who can least afford to deal with it.

FEMA defines urban flooding as “the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. It excludes flooding in undeveloped or agricultural areas. It includes situations in which stormwater enters buildings through a) windows, doors, or the openings; b) water backup through pipes and drains; c) seepage through walls and floors.” The definition has been expanded to include specific issues, such as sewer water backing up into homes, water seeping through foundation walls, clogged street drains, and overflow from sound walls, roads, or other barriers that restrict stormwater runoff.

Urban flooding is not just “flooding that happens in an urban area.” This isn’t what happens when a river overflows its banks or when a hurricane drives a storm surge across a coastal neighbourhood. Instead, it’s caused by excessive runoff in developed areas where the water doesn’t have anywhere to go.

1.4 Why urban flooding is happening:

(a)Large increase in concrete an impervious surface.

(b)Unplanned uses of urban land.

(c)Lack of proper drainage/ insufficient or outdated stormwater infrastructure

(d)Loss of wetlands

(e)Less ground water usage/recharge.

(f)heavy precipitation (which is expected to become more frequent due to climate change).

(g)increased amount of storm runoff to already stressed drainage systems.

1.5 Objective of this study:

- To estimate the design of drainage requirement in the urban areas using SWMM.
- To find out the probable ways in which we can mitigate or reduce the problem of urban flooding.
- To develop a sustainable drainage system in the urban areas.

1.6 Scope of the study:

The study will help in understanding the causes of urbanisation boom and its effects. The impact of climate change in rainfall intensity. It also discuss how the old infrastructure of drainage would not be able to withstand the high runoff generated by paved surfaces and high rainfall intensity. The result of which would be a localized urban flooding. Since old drainage are little bit difficult to renovate in the environment of India we can design the current drainage with better efficiency. we need a broad set of the data to do a through analysis of the drains and its efficiency which is also discussed in methodology section.

This study has been done on a some of example storm and a model catchment area. The trend of flooding occurred in the drainage has been observed with the varying period of rainfall duration. This study also suggest the ways in which the problem of inefficient drainage could be mitigated to some extent.

Chapter 2

LITERATURE REVIEW

Armitage et al.() It is not about the sewer! The main challenges to sustainable urban drainage in developing countries has to do with the inability of local government to provide appropriately serviced sites for the multitudes steaming into the towns and cities. Subsequent "crisis management" fails to address the needs of the new residents who are then all too often forced through circumstances to fend for themselves. Whilst technical solutions are available, in the absence of adequate social and institutional planning and support, success is rare. Services are often implemented without due regard to consequences. Ultimately, the real obstacles to sustainability are the lack of adequate numbers of skilled personnel who are able to plan and implement urban drainage in a timeous and holistic manner – coupled with the lack of funding needed to pay for the work. Given historical problems with aid to developing countries, probably the best way developed countries can help with achieving sustainable urban drainage is by providing professional support to local authorities. NGOs have also shown themselves to be a considerable asset in mediating drainage solutions.

Davis and Naumann et al.(2017) European cities continue to experience a steady increase in the intensity and frequency of floods, largely due to high urban densities and resultant soil sealing. In the last decade, flooding as a natural hazard has produced the highest economic losses in Europe and storm water management has become a serious urban challenge.

(Gupta, 2007) Over 60% of Mumbai was inundated to various degrees on 26 July 2005 as shown in Figure 4-2. The IMD was unable to issue advance warnings of this event. Even when there was heavy rainfall in the northern suburbs, the IMD was unable to monitor the rainfall and issue warnings in real time. This has been attributed to the lack of state-of -the-art equipment like tipping bucket rain gauges with the IMD. IMD has only two rain gauges in Mumbai and both are of the symphonic type which record data on graph paper attached to clockwork driven drums. These are read only at 08:30 daily. The main causes of flooding in Mumbai were .low ground levels Low ground levels, low Level of outfalls, silt of drains/nallas, dilapidated drains, obstructions of utilities, encroachment along nallas, slums along outfalls, urbanization, loss of holding ponds, garbage dumping in SWDs/nallas mainly in slums and increase in runoff coefficient.

(Ahmad 2016) One of the most populous area of Delhi is to the eastern side of Delhi ridge. It includes Connaught Place, the hub of commercial activity. Unfortunately, during storm showers, it is the site for heavy water impounding. This may be attributed to providing concrete surface over the entire available surface on the pretext of beautifying the area. The non-availability of sufficient recharge surface has compounded the problem of water impounding. The drains in the Delhi were initially designed to transport excess storm water and sewerage flow. However, due to improper layout and improper maintenance and unsuitable geomorphological conditions, these now form pool of stagnant water in north-west and northern parts of Delhi. As a part of solution, check dams and small lakes or ponds may be designed for increasing ground water table and as storm water holding points. The design shall preserve the natural.

Chapter 3

METHODOLOGY

3.1 Urban drainage design- Requirements:

Rainfall data: for design of drainage system, the conventional practice is to choose an appropriate, statistically relevant design storm to establish the stormwater flows to be conveyed, based on existing national & international practices.

Design storms: can be estimated from rainfall data records where available.

IDF(Intensity Duration Frequency): updated IDF relationships need to be used to maintain design standards for new systems & retrofitting/replacement of old urban drainage systems.

IDF curves should be developed for each city, based on extraction of data from the raw data charts at min. 15- minutes resolution.

Frequency of thunderstorms: additional consideration for planning future urban drainage systems.

Design flow: To protect urban areas, safe management & passage of water, resulting from frequent storm events (hydrologic design aspects) & adequate capacity (hydraulic design aspects) must be considered.

Urban Drainage Design: main objectives of hydrologic analysis & design are to estimate peak flow rates &/or flow hydrographs for the adequate sizing & design of conveyance & quantity control facilities. To estimate **peak flow rates**, knowledge of the rainfall intensity its duration & frequency is required

3.2 Urban Drainage Design- Problems:

Increasing rainfall intensities: induced by climate change, urban heat islands and other factors, will possibly result in varying return periods for a givenintensity of rainfall.

Rainfall intensity to be used for design will also depend on the **time of concentration.**

Higher the **catchment area**, higher will be the time of concentration & lower will be the design rainfall intensity, other factors remaining the same. Peak flow rates can be estimated using Rational Method **Q = C I A.**

3.3 Some of the public domain software used for flood routing:

3.3.1 HEC-HMS(for hydrologic modelling of watershed)**:** The Hydrologic Modelling System (HEC-HMS) is designed to simulate the complete hydrologic processes of dendritic watershed systems. This software includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing. HEC-HMS also includes procedures necessary for continuous simulation including evapo-transpiration, snowmelt, and soil moisture accounting. Advanced capabilities are also provided for gridded runoff simulation using the linear quasi-distributed runoff transform (ModClark). Supplemental analysis tools are provided for model optimization, forecasting streamflow, depth-area reduction, assessing model uncertainty, erosion and sediment transport, and water quality.

This software features a completely integrated work environment including a database, data entry utilities, computation engine, and results reporting tools. A graphical user interface allows the user seamless movement between the different parts of the software. Simulation results are stored in HEC-DSS (Data Storage System) and can be used in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

3.3.2 HEC-RAS(for river modelling)**:** HEC-RAS is a computer program for modeling water flowing through systems of open channels and computing water surface profiles. HEC-RAS finds particular commercial application in floodplain management and [flood insurance] studies to evaluate floodway encroachments. Some of the additional uses are: bridge and culvert design and analysis, levee studies, and channel modification studies. It can be used for dam breach analysis, though other modeling methods are presently more widely accepted for this purpose.

3.3.3 SWMM(stormwater management model): EPA's Stormwater Management Model (SWMM) is used throughout the world for planning, analysis, and design related to stormwater runoff, combined and sanitary sewers, and other drainage systems. It can be used to evaluate gray infrastructure stormwater control strategies, such as pipes and storm drains, and is a useful tool for creating cost-effective green/gray hybrid stormwater control solutions. SWMM was developed to help support local, state, and national stormwater management objectives to reduce runoff through infiltration and retention, and help to reduce discharges that cause impairment of our Nation’s waterbodies.

SWMM is used for single event or long-term simulations of water runoff quantity and quality in primarily urban areas—although there are also many applications that can be used for drainage systems in non-urban areas. SWMM provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses. *I have used SWMM for my objective.*

3.4 Creating a model on SWMM:

3.4.1 About model:

We have build a model which is serving a 12 acre residential area. The system layout is shown below and consists of subcatchment(a subcatchment is a land containing a mix of pervious and impervious whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment .) areas S1 through S3, storm sewer conduits C1 through C4, and conduit junctions J1 through J4. The system discharges to a creek at the point labeled Out1. We will first go through the steps of creating the objects shown in this diagram on SWMM's Study Area Map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year record.

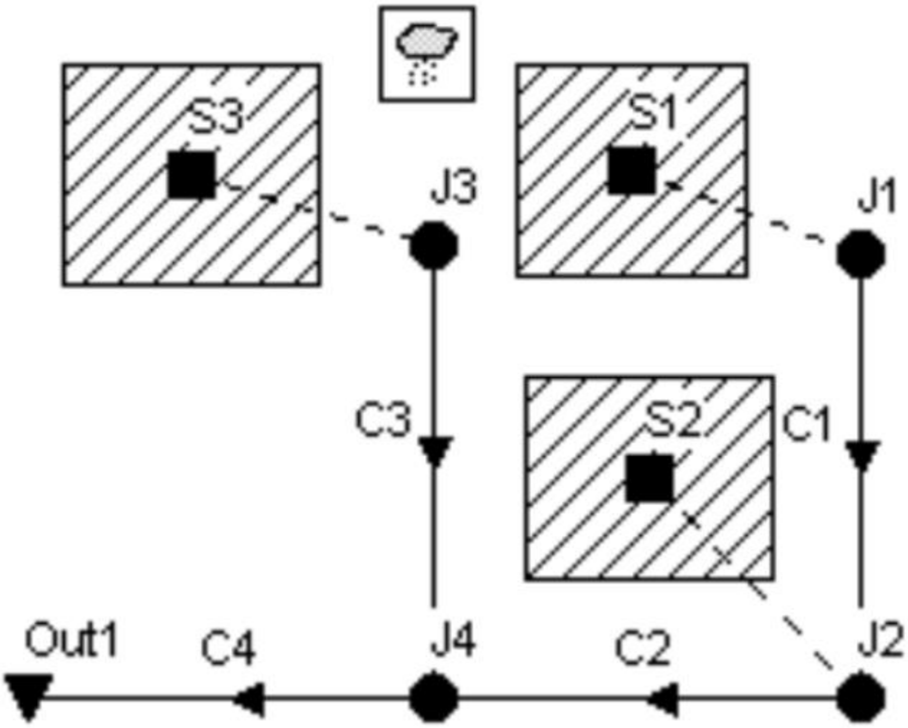

Fig 3.1: System layout showing all the elements of the model.

3.4.2 Setting up project defaults:

After creating a new project file we need to setup all the project defaults.

Table 3.1: Default ID labels

Object	ID Prefix
Rain Gages	gage
Subcatchments	S
Junctions	J
Outfalls	OUT
Dividers	
Storage Units	
Conduits	C
Pumps	
Regulators	
ID Increment	1

Table 3.2: Subcatchments

Property	Default Value
Area	4
Width	400
% Slope	0.5
% Imperv	50
N-Imperv	0.01
N-Perv	0.1
Dstore-Imperv	0.05
Dstore-Perv	0.05
%Zero-Imperv	25
Infiltration Model	GREEN_AMPT

Table 3.3: Nodes/links

Option	Default Value
Node Invert	0
Node Max. Depth	4
Node Ponded Area	0
Conduit Length	400
Conduit Geometry	CIRCULAR
Conduit Roughness	0.01
Flow Units	CFS
Link Offsets	DEPTH
Routing Method	Kinematic Wave
Force Main Equation	Hazen-Williams

Standard circular pipe for this model has been used however this can be changed from cross-section editor.

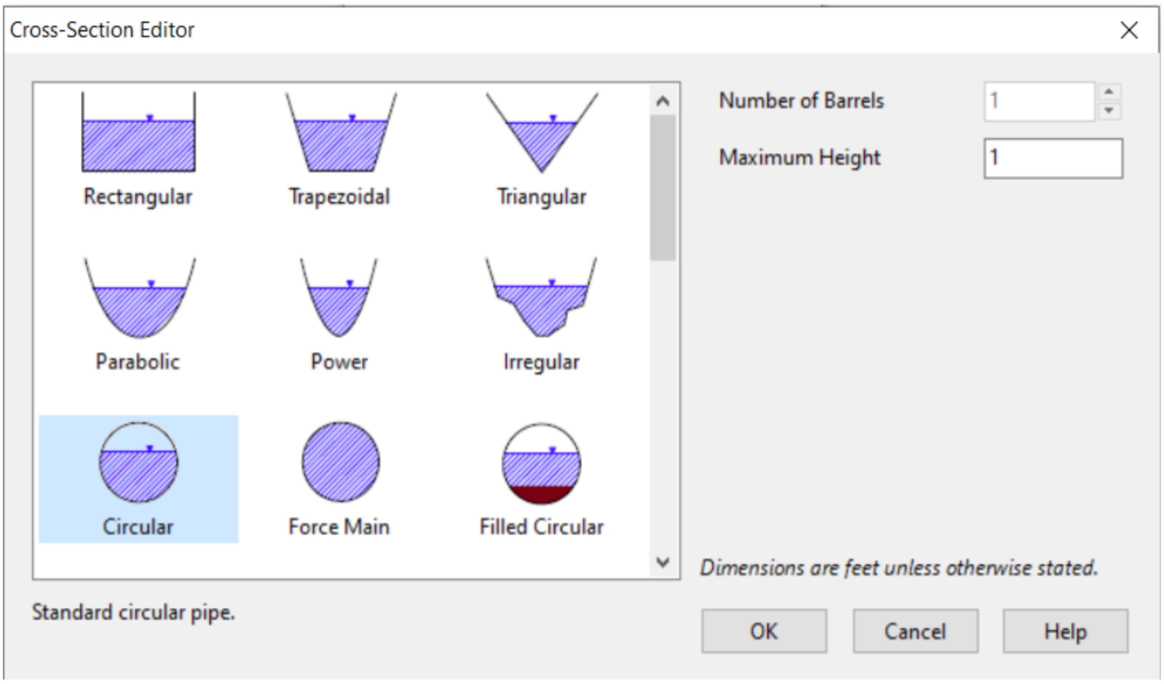

Fig 3.2: Selection of Conduit Geometry

Project defaults being done we can now add all the components of study area map. When all the components like subcatchments, joints, conduits and outlets are drawn. We finally get a figure which is shown in fig 3.1.

3.4.3 Setting up Sub-catchment Properties:

As visual objects are added to our project, SWMM assigns them a default set of properties. We need to change this according to the requirement of our model.

Table 3.4: Properties of subcatchment 1

Property	Value
Name	S1
X-Coordinate	4976.959
Y-Coordinate	7553.764
Description	
Tag	
Rain Gage	gage1
Outlet	J1
Area	4
Width	400
% Slope	0.5
% Imperv	50

Table 3.5: Properties of subcatchment 2

Property	Value
Name	S2
X-Coordinate	5211.214
Y-Coordinate	4224.270
Description	
Tag	
Rain Gage	gage1
Outlet	J2
Area	4
Width	400
% Slope	0.5
% Imperv	50

Table 3.6: Properties of subcatchment 3

Property	Value
Name	S3
X-Coordinate	-3.840
Y-Coordinate	7649.770
Description	
Tag	
Rain Gage	gage1
Outlet	J3
Area	4
Width	400
% Slope	0.5
% Imperv	25

Two key properties of our subcatchments that need to be set are the rain gage that supplies rainfall data to the subcatchment and the node of the drainage system that receives runoff from the subcatchment. We have assumed that all the all of our subcatchments utilize the same raingage i.e Gage 1. Also the outlets for all the subcatchments can be modified.

We are taking area S3(i.e subcatchment 3) as less developed than others for that we have assigned a % imperviousness of 25% to the subcatchment 3. Subcatchment width is the width of the area where overland flow occurs.

3.4.4 Node/link Properties:

The junctions and outfall of our drainage system need to have invert elevations.

Table 3.8: Nodes and their corresponding invert level

Node	**Invert**
J1	96
J2	90
J3	93
J4	88
Out1	85

Table 3.9: Properties of Junction 1

Property	Value
Name	J1
X-Coordinate	7012.289
Y-Coordinate	6159.754
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	96
Max. Depth	4
Initial Depth	0
Surcharge Depth	0

Table 3.10: Properties of Junction 2

Property	Value
Name	J2
X-Coordinate	7258.065
Y-Coordinate	2288.786
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	90
Max. Depth	4
Initial Depth	0
Surcharge Depth	0

Table 3.11: Properties of junction 3

Property	Value
Name	J3
X-Coordinate	2465.438
Y-Coordinate	6282.642
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	93
Max. Depth	4
Initial Depth	0
Surcharge Depth	0

Table 3.12: Properties of junction 4

Property	Value
Name	J4
X-Coordinate	2772.657
Y-Coordinate	2135.177
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	88
Max. Depth	4
Initial Depth	0
Surcharge Depth	0

Table 3.13: Properties of Outlet

Property	Value
Name	OUT1
X-Coordinate	-1835.637
Y-Coordinate	2227.343
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	85
Tide Gate	NO
Route To	
Type	FREE

3.4.5 Properties of conduits:

Table 3.14: Properties of Conduit 1

Property	Value
Name	C1
Inlet Node	J1
Outlet Node	J2
Description	
Tag	
Shape	CIRCULAR
Max. Depth	1
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0

Table 3.15: Properties of Conduit 2

Property	Value
Name	C2
Inlet Node	J2
Outlet Node	J4
Description	
Tag	
Shape	CIRCULAR
Max. Depth	1
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0

Table 3.16: Properties of Conduit 3

Property	Value
Name	C3
Inlet Node	J3
Outlet Node	J4
Description	
Tag	
Shape	CIRCULAR
Max. Depth	1
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0

Table 3.17: Properties of Conduit 4

Property	Value
Name	C4
Inlet Node	J4
Outlet Node	OUT1
Description	
Tag	
Shape	CIRCULAR
Max. Depth	1.5
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0

3.4.6 Rain Gage Properties:

In order to provide a source of rainfall input to our project we need to set the rain gage properties. And we need to simulate the response of our study area for different storms.

For simulation of our study area we have chosen 3 design storms whose timeseries are names as TS1, TS2 and T3 which are 3 inch-6 hour, 3 inch-4 hour and 3 inch-8 hour storms respectively. Also we have assumed that the rainfall hydrograph of the timeseries as triangular in nature. Before running the simulation we will have to choose the time series of design storm for which we would want run the simulation. The table 3.18(which is shown in the left side) shows the table in which we will have to fill in the properties of rain gage. In the given table the data source is given a value of TIMESERIES, which means that we will be providing a time series for simulation. And in the given table the timeseries is selected as TS1 which can be changed if we would want to use a different time series.

Table 3.18: Properties of the rain gage which is used for all subcatchments.

Property	Value
Name	gage1
X-Coordinate	2557.604
Y-Coordinate	8986.175
Description	
Tag	
Rain Format	INTENSITY
Time Interval	1:00
Snow Catch Factor	1.0
Data Source	TIMESERIES
TIME SERIES:	
- Series Name	TS1

Table 3.19: Timeseries of TS1 for a storm of 3 inch-6 hour storm.

Time (H:M)	Value
0	0
1	.5
2	1
3	.75
4	.5
5	.25
6	0

Table 3.20: Timeseries of TS2 for a storm of 3 inch-4 hour storm.

Time (H:M)	Value
0	0
1	1.5
2	1
3	.5
4	0

Table 3.21: Timeseries of TS1 for a storm of 3 inch-8 hour storm.

Time (H:M)	Value
0	0
1	.25
2	.5
3	.75
4	.6
5	.45
6	.3
7	.15
8	0

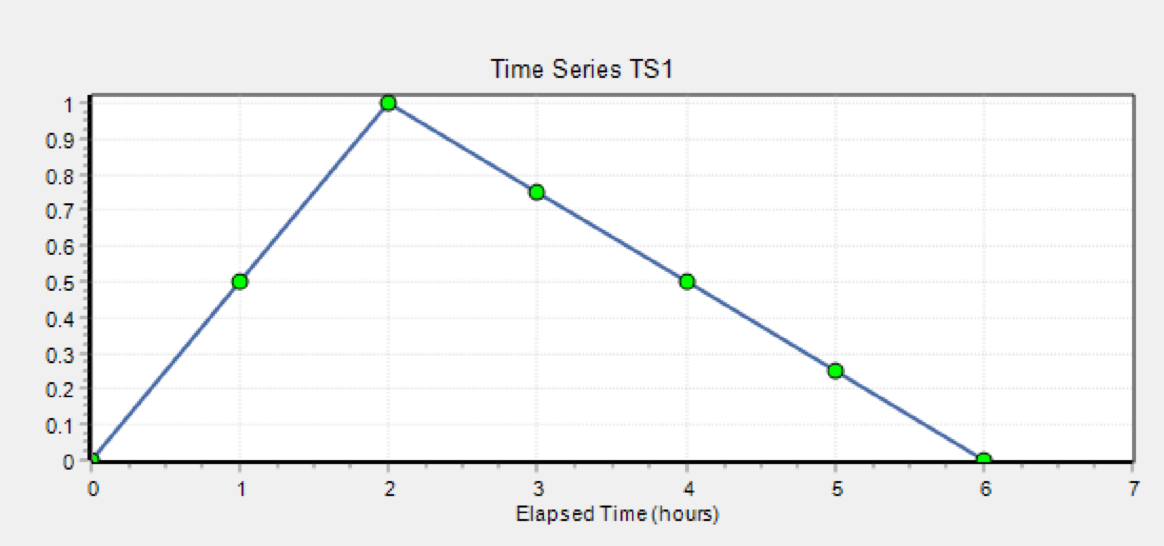

Fig 3.3: Hyetograph of storm of 3 inch-6 hour storm.

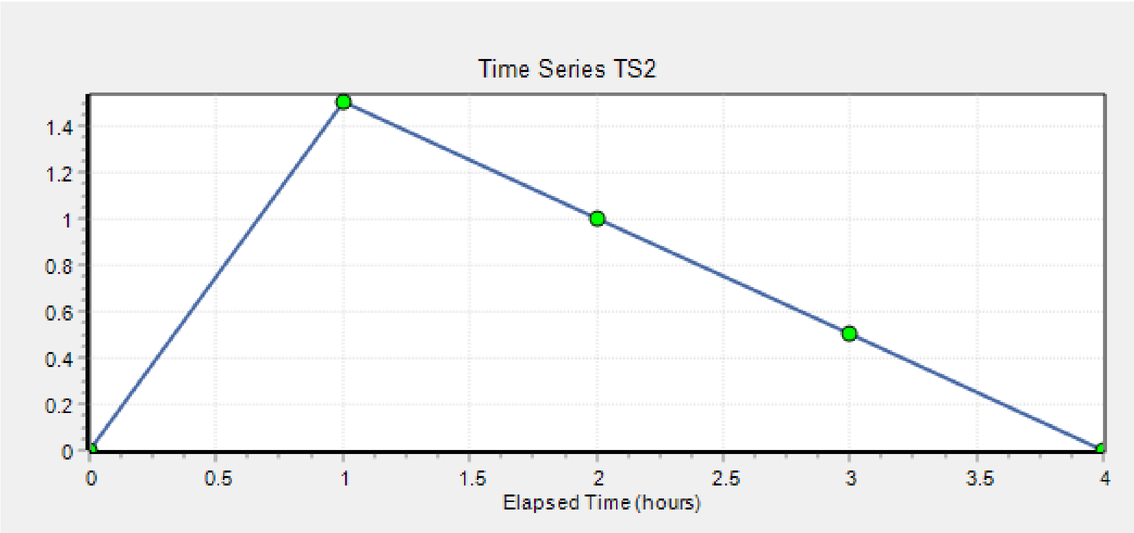

Fig 3.4: Hyetograph of storm of 3 inch-4 hour storm.

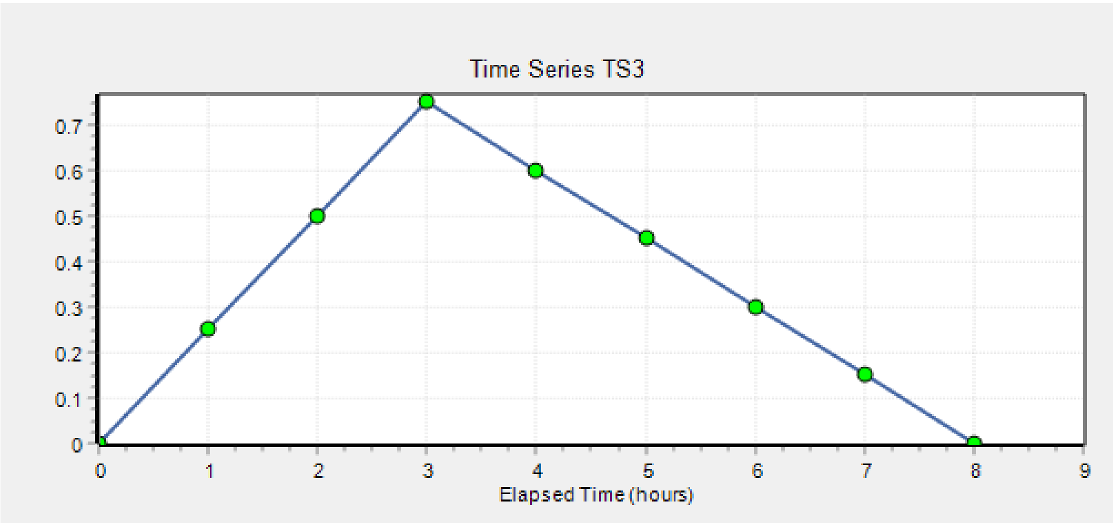

Fig 3.5: Hyetograph of storm of 3 inch-8 hour storm.

Chapter 4

Running the analysis

For the performance of our example drainage system we need to choose some simulation options. For the flow routing method we have selected kinematic wave model. The flow units are already set to CFS. We will see the results for different infiltration model for example Green-Ampt, Modified Green-Ampt, Horton etc, that can be chosen with the simulation options. And we will simulate the model with all 3 times series. We will also have to starting and ending time of the simulataion i.e for what duration we would like the simulation to run. As we know that the runoff does not stop instantly with rain. So we keep the duration of simulation longer than the duration of rainfall. In this model for the storm of 3 inch-6 hour and 3 inch-4 hour we will keep the duration of simulation of 12 hours i.e we Start the analysis at 00:00 and End the analysis at 12:00 of the same day. But for the storm of 3 inch-8 hours we will set the duration of simulation to . 15 hours because the runoff may extend little longer due to longer period of the rainfall.

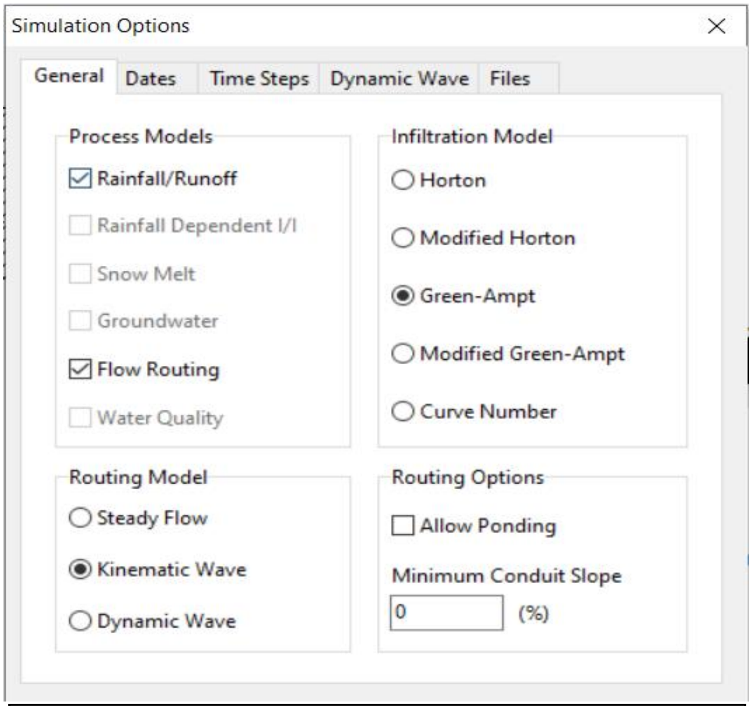

Fig 4.1: Setting up simulation options for the analysis.

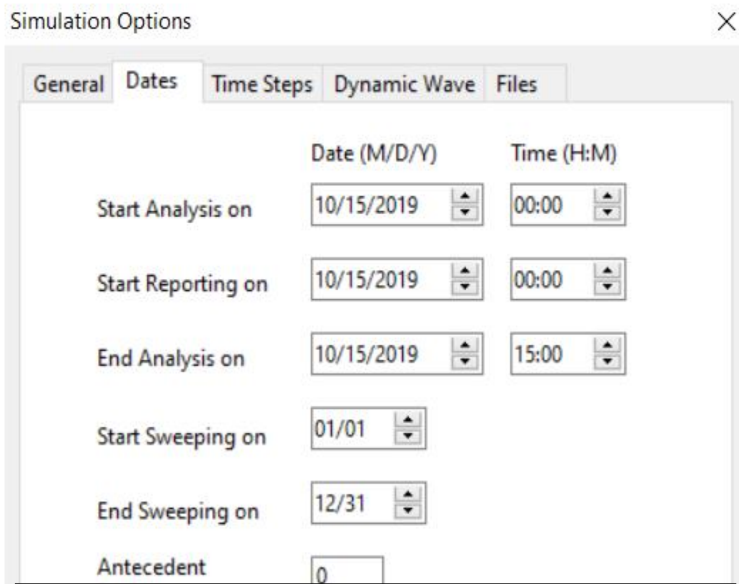

Fig 4.2: Setting up duration of simulation.

Chapter 5

Results of Simulation

5.1 Using Green-Ampt infiltration model:

In the simulation options we will selection infiltration model to Green-Ampt

5.1.1 Result of analysis with timeseries1(TS1):

After simulation we can check the profile at different elapsed time and different profiles.

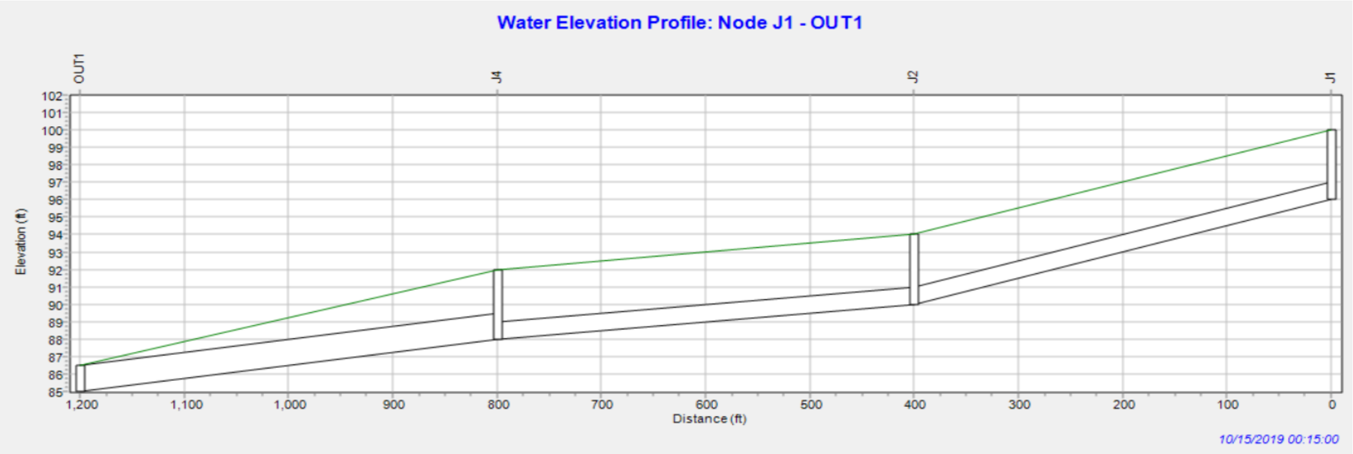

Fig 5.1: Water elevation profile of profile J1 to OUT1 at the elapsed time of 00:15:00

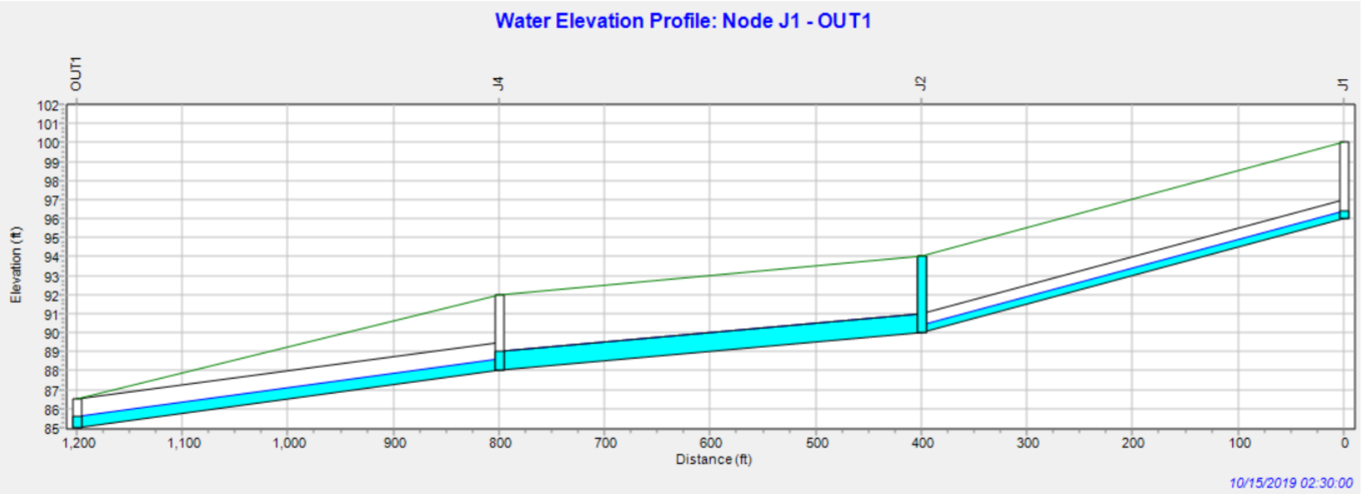

Fig 5.2: Water elevation profile of profile J1 to OUT1 at the elapsed time of 02:30:00

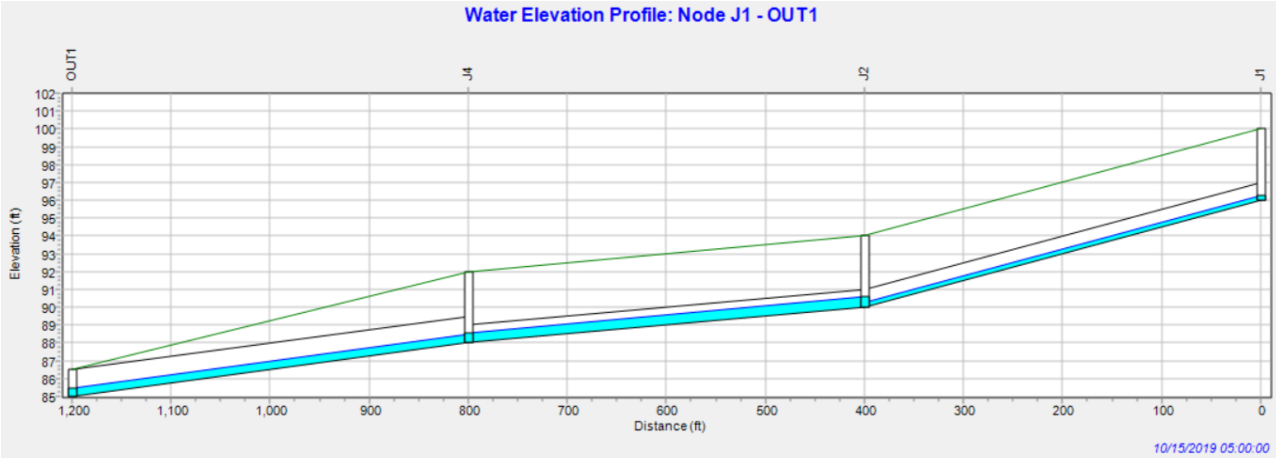

Fig 5.3: Water elevation profile of profile J1 to OUT1 at the elapsed time of 05:00:00

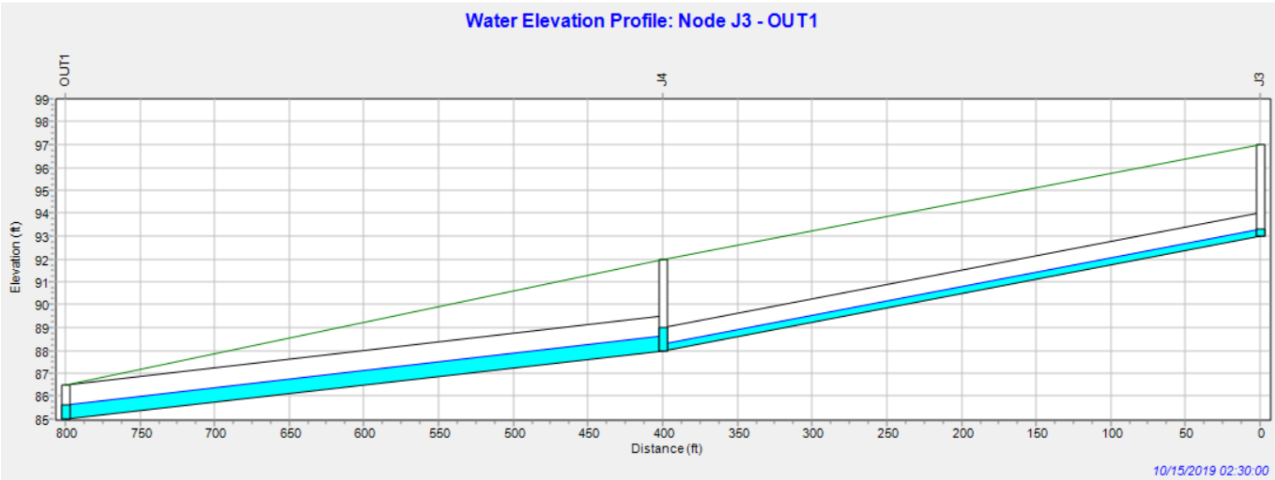

Fig 5.4: Water elevation profile of profile J3 to OUT1 at the elapsed time of 02:30:00

For the design storm of 3 inch-6 hour our drainage is getting flooded at the elapsed time of 02:30:00 (which is shown in Fig 11) and the runoff is almost over at an elapsed time of 07:15:00. However the profile J3 to OUT1 doesn't get flooded at any time.

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.43	1.48	0.07	1.55	0.17	2.16	0.516
S2	3.00	0.00	0.00	1.43	1.48	0.07	1.55	0.17	2.16	0.516
S3	3.00	0.00	0.00	2.17	0.74	0.08	0.83	0.09	1.16	0.275

Table 5.1: Summary result of subcatchment Runoff

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
J2	1.95	1.02	0	03:01	0.023	0.000

Table 5.2: Summary result of node flooding

5.1.2 Result of analysis with timeseries2(TS2):

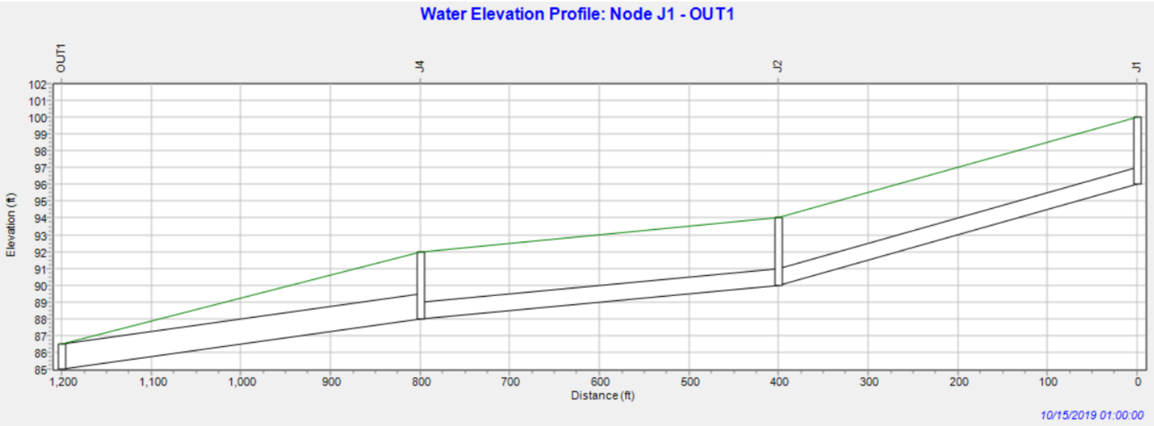

Fig 5.5: Water elevation profile of profile J1 to OUT1 at the elapsed time of 01:00:00

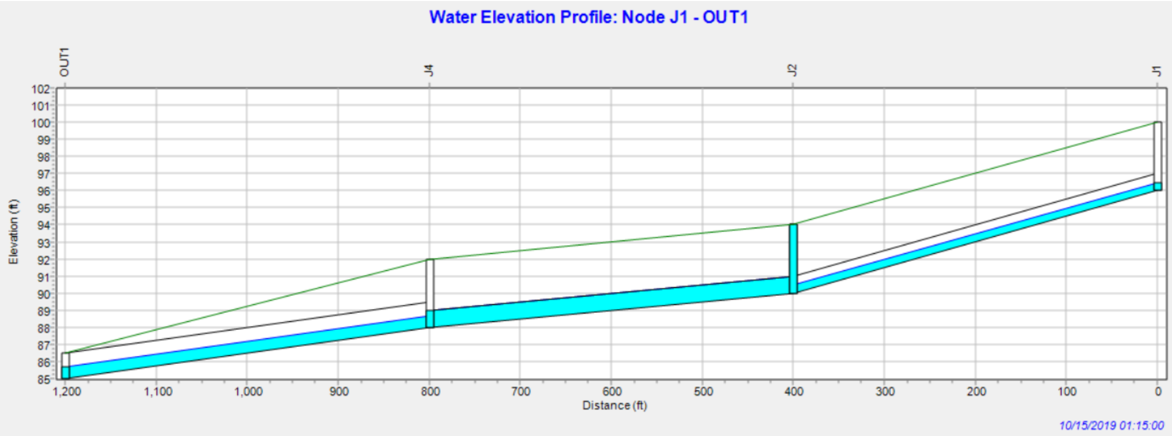

Fig 5.6: Water elevation profile of profile J1 to OUT1 at the elapsed time of 01:15:00

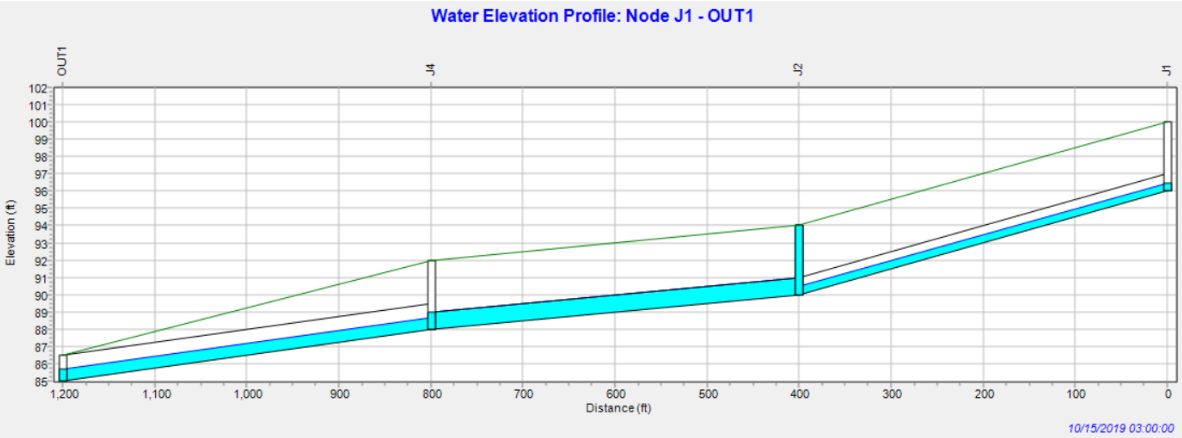

Fig 5.7: Water elevation profile of profile J1 to OUT1 at the elapsed time of 01:15:00

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.36	1.49	0.14	1.63	0.18	3.49	0.544
S2	3.00	0.00	0.00	1.36	1.49	0.14	1.63	0.18	3.49	0.544
S3	3.00	0.00	0.00	2.06	0.75	0.19	0.93	0.10	2.02	0.312

Table 5.3: Summary result of subcatchment runoff

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
J2	1.98	3.66	0	02:01	0.113	0.000

Table 5.4: summary result of node flooding

For the design storm of 3 inch-4 hour the junction 2 has been flooded for a long duration due to high inflow of water into the drains which is over the capacity of drains. In this case also the profile J3 to OUT1 doesn't get flooded at any time.

5.1.3 Result of analysis with timeseries3(TS3):

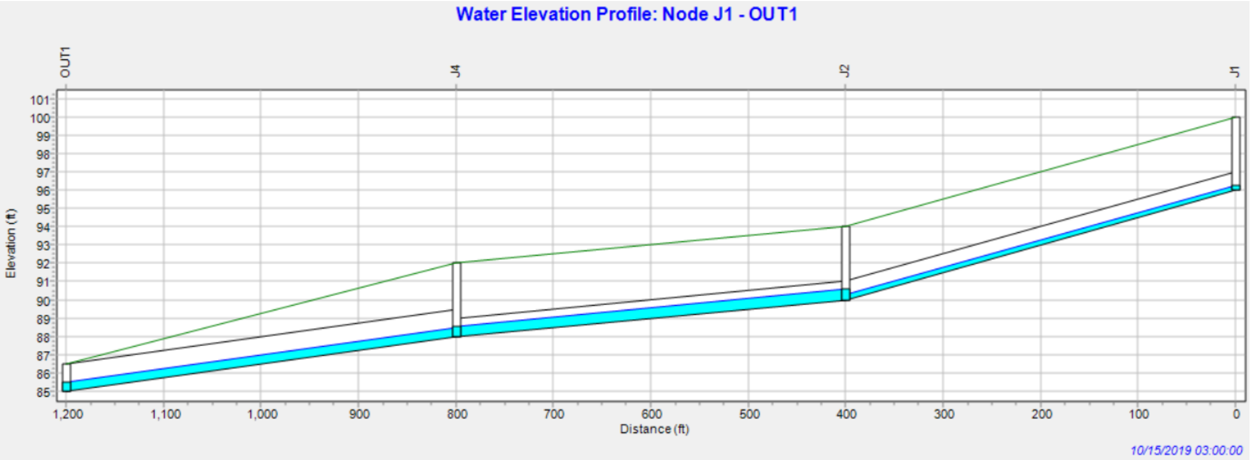

Fig 5.8: Water elevation profile of profile J1 to OUT1 at the elapsed time of 03:00:00

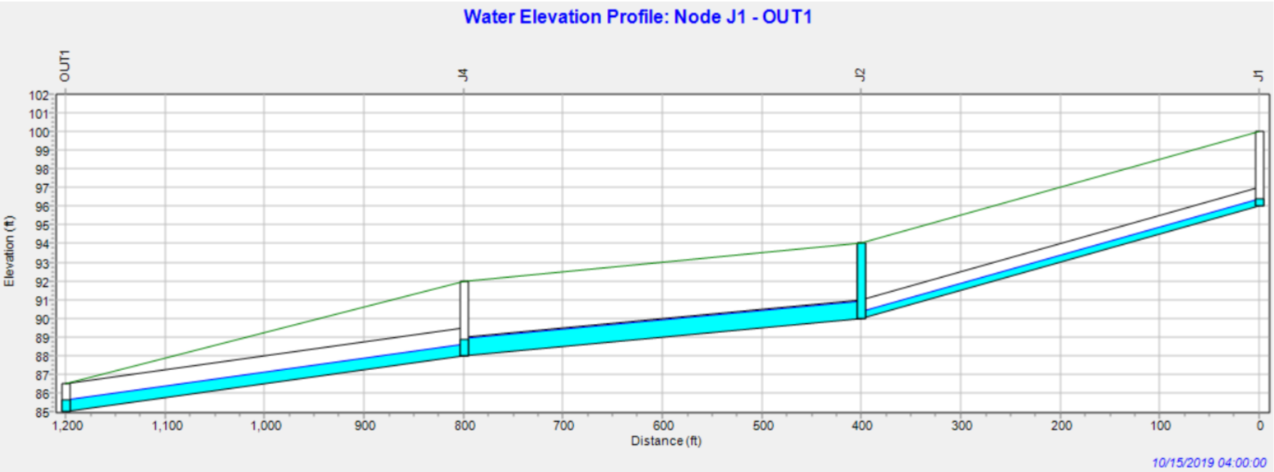

Fig 5.9: Water elevation profile of profile J1 to OUT1 at the elapsed time of 04:00:00

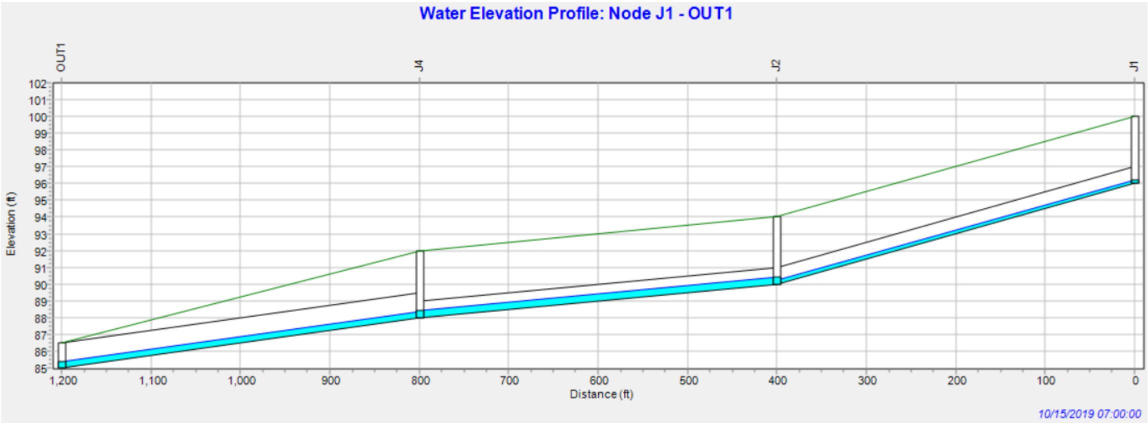

Fig 5.10: Water elevation profile of profile J1 to OUT1 at the elapsed time of 07:00:00

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.39	1.48	0.11	1.59	0.17	1.80	0.530
S2	3.00	0.00	0.00	1.39	1.48	0.11	1.59	0.17	1.80	0.530
S3	3.00	0.00	0.00	2.10	0.74	0.15	0.89	0.10	1.08	0.296

Table 5.5: Summary result of subcatchment runoff

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
J2	0.48	0.30	0	04:01	0.002	0.000

Table 5.6: summary result of node flooding

For the design storm of 3 inch-8 hour the junction 2 gets flooded at an elapsed time of 04:00:00 because the duration of rainfall is longer and peak precipitation is low. In this case also the profile J3 to OUT1 doesn't get flooded at any time. The reason for all this is that we have provided a conduit C4 of higher diameter.

5.2 Using modified Green-ampt infiltration model:

5.2.1 Result of analysis with timeseries1(TS1):

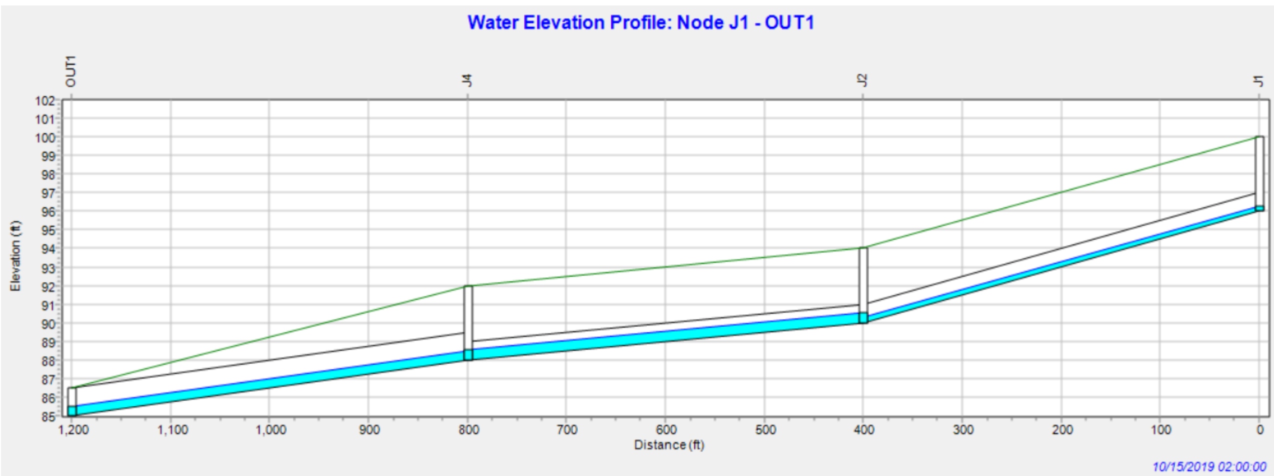

Fig 5.11: Water elevation profile of profile J1 to OUT1 at the elapsed time of 02:00:00

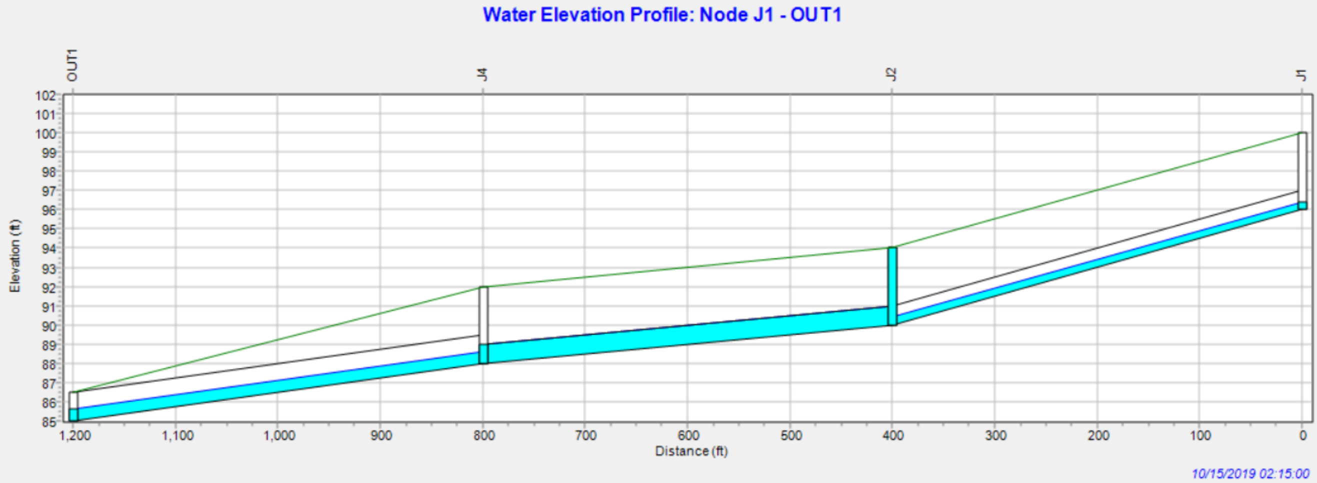

Fig 5.12: Water elevation profile of profile J1 to OUT1 at the elapsed time of 02:15:00

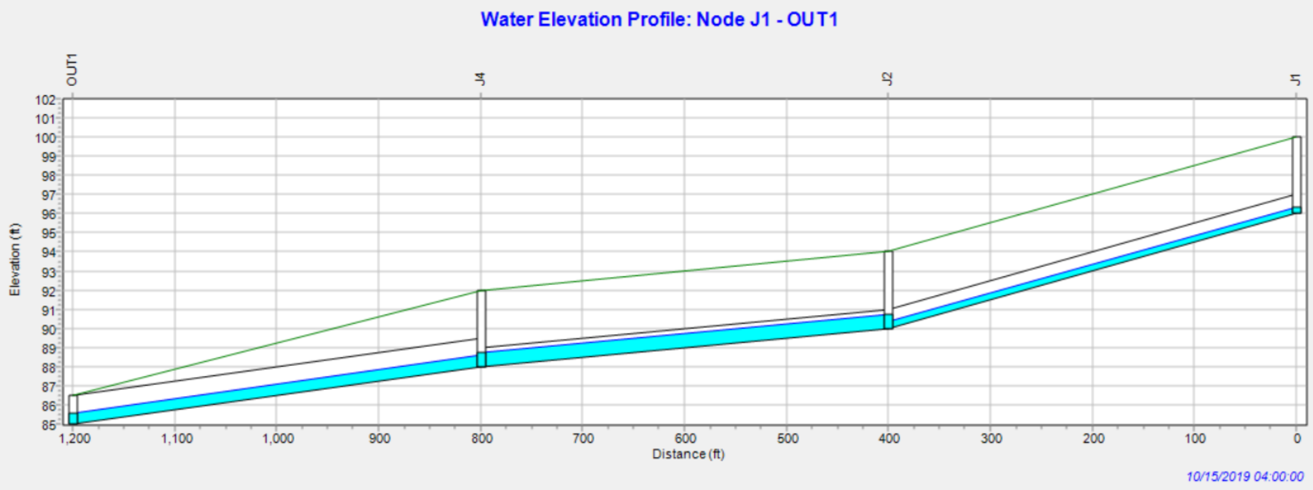

Fig 5.13: Water elevation profile of profile J1 to OUT1 at the elapsed time of 04:00:00

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.02	0.494
S2	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	2.02	0.494
S3	3.00	0.00	0.00	2.25	0.74	0.00	0.74	0.08	1.01	0.247

Table 5.7: Summary result of subcatchment runoff

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
J2	1.05	0.77	0	03:01	0.018	0.000

Table 5.8: summary result of node flooding

5.2.2 Result of analysis with timeseries2(TS2):

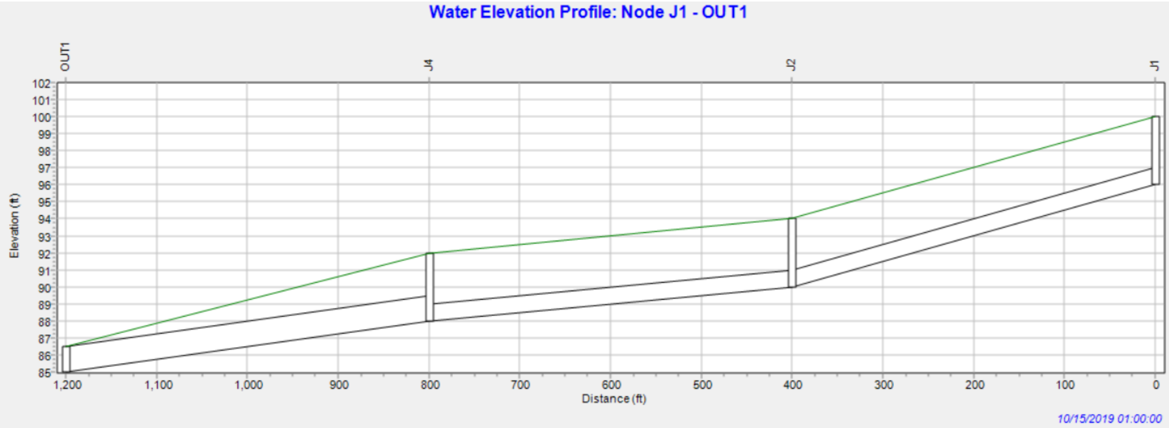

Fig 5.14: Water elevation profile of profile J1 to OUT1 at the elapsed time of 01:00:00

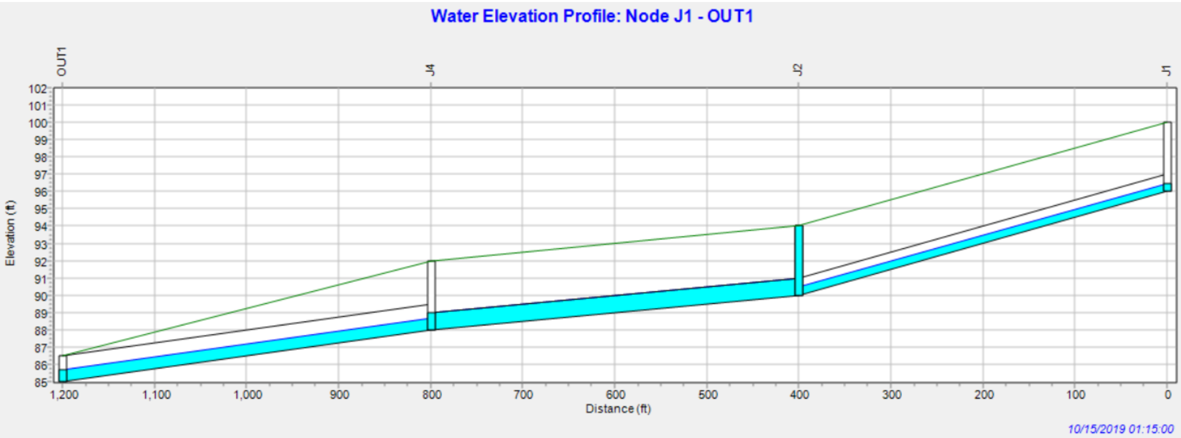

Fig 5.15: Water elevation profile of profile J1 to OUT1 at the elapsed time of 01:15:00

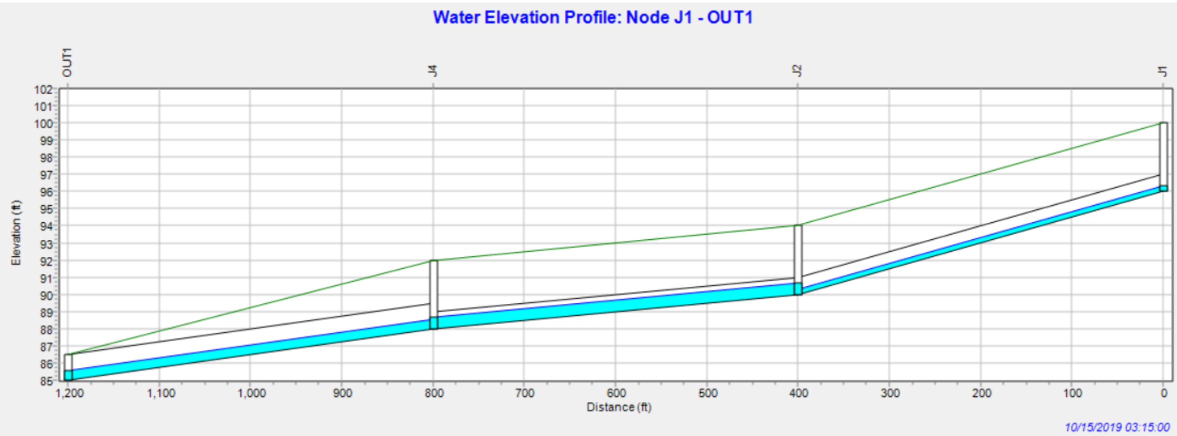

Fig 5.16: Water elevation profile of profile J1 to OUT1 at the elapsed time of 03:15:00

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.36	1.49	0.14	1.63	0.18	3.49	0.544
S2	3.00	0.00	0.00	1.36	1.49	0.14	1.63	0.18	3.49	0.544
S3	3.00	0.00	0.00	2.06	0.75	0.19	0.93	0.10	2.02	0.312

Table 5.9: Summary result of subcatchment runoff

Node	Hours Flooded	Maximum Rate CFS	Day of Maximum Flooding	Hour of Maximum Flooding	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
J2	1.98	3.66	0	02:01	0.113	0.000

Table 5.10: summary result of node flooding

5.2.3 Result of analysis with timeseries3(TS3):

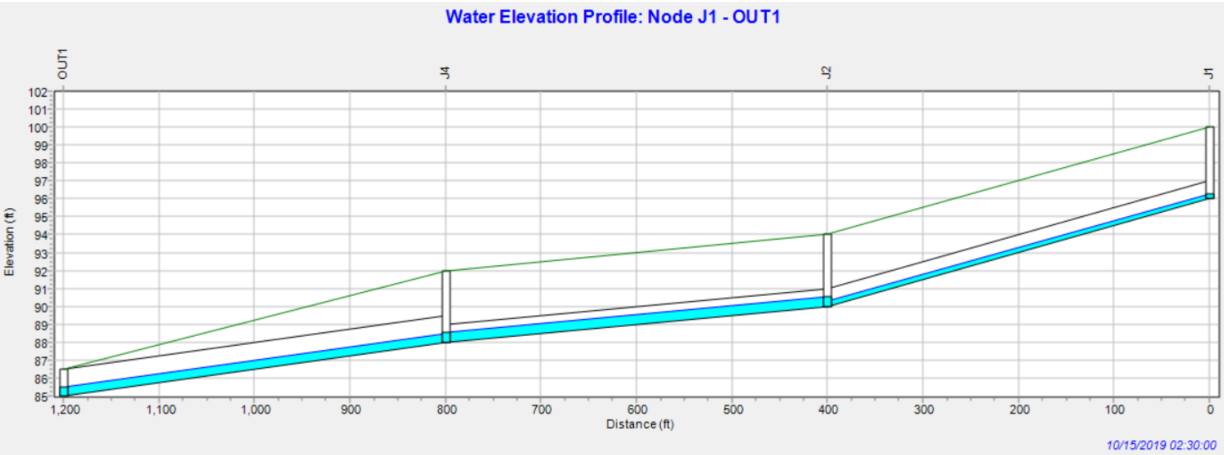

Fig 5.17: Water elevation profile of profile J1 to OUT1 at the elapsed time of 02:30:00

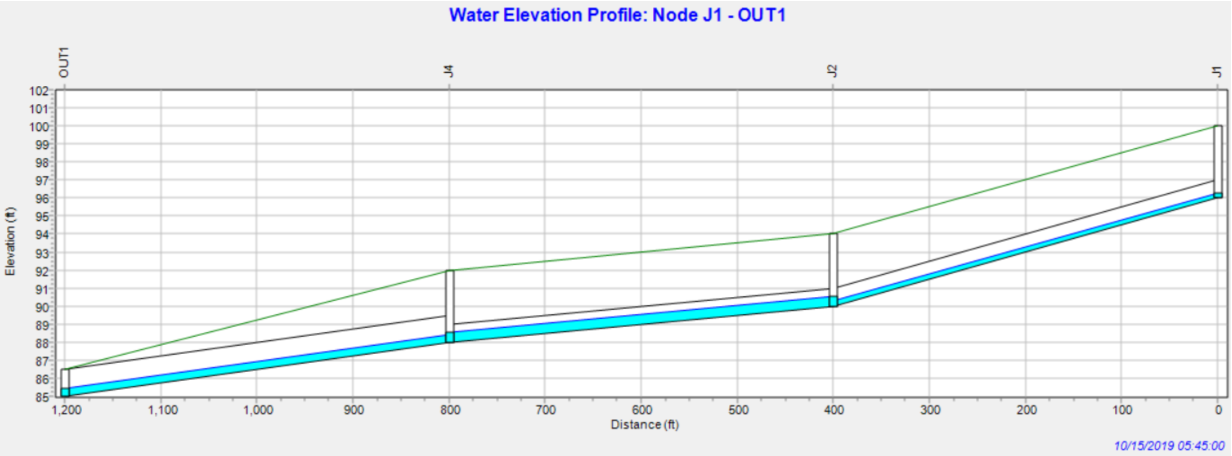

Fig 5.18: Water elevation profile of profile J1 to OUT1 at the elapsed time of 05:45:00

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
S1	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	1.51	0.494
S2	3.00	0.00	0.00	1.50	1.48	0.00	1.48	0.16	1.51	0.494
S3	3.00	0.00	0.00	2.25	0.74	0.00	0.74	0.08	0.76	0.247

Table 5.11: Summary result of subcatchment runoff

Chapter 6

Discussion

A broad literature review has been performed to identify urban drainage system's challenges due to rapid urbanization and climate change. Urbanization and climate change are the two major issues impacting the performance of conventional drainage systems. Climate change would impact the availability of reliable hydrological data, and associated extreme events would result in urban flooding. Due to the low availability of the relevant data and to avoid the extensive process of official paper work for collecting the data a sample study has been done on the approximated values of storm and hydrological properties of subcatchments. The problem of node flooding has been observed in various scenario. Conditions like very high intensity, small conduit diameter low difference in the invert level of nodes etc. There are some ways in which the problem of node flooding could be mitigated. According to my observation we can move with following strategies:

(a) We can increase the diameter of conduits. However replacing the conduits of current drainage could cost a lot of money but that could encounter the losses occurring due to flooding due to inefficient drains. In our study also we have observed no cases of flooding on the path of J3 to OUT1. The reason for this is higher diameter of conduit 4.

(b) We can keep a higher difference of invert levels so that the flow could be easier.

(c) Keeping in mind the climatic changes the catchment treatment could be really better way to solve this. We need to promote afforestation which will be helpful in increasing the perviousness of the land resulting in low runoff and higher infiltration to the ground water. In this it would also be helpful for the ground water recharges. Also these days we are noticing a storms of higher intensity and lower duration which is the result of climatic changes. In the infiltration model of Modified Green-Ampt we observed that there is no flooding in case of 3 inch- 8 hour rainfall. Because the duration of rainfall is higher in this case and water is getting more time to infiltrate and drains are getting more time to drain out the water and also less inflow. Afforestation could be help with all these matter.

REFERENCES

1. http://www.switchurbanwater.eu/outputs/pdfs/W2-2_GEN_PAP_Challenges_of_sustainable_urban_drainage_in_developing_countries.pdf
2. https://www.nrdc.org/experts/anna-weber/what-urban-flooding
3. https://www.tandfonline.com/doi/full/10.1080/15730620701464224
4. https://cdr.umd.edu/sites/cdr.umd.edu/files/resource_documents/COMPRESSEDurban-flooding-report-online-compressed-0319.pdf
5. https://link.springer.com/chapter/10.1007/978-3-319-56091-5_8
6. https://www.hec.usace.army.mil/software/hec-hms/
7. https://www.researchgate.net/publication/228327252_Sustainable_Urban_Drainage_Systems_-_A_possible_solution_to_the_problems_of_Flash_Floods_in_New_Delhi_India
8. https://iwaponline.com/wst/article/72/2/165/14899/Urban-drainage-system-planning-and-design
9. https://www.researchgate.net/publication/326441140_Urban_Floods_in_India