# Design of urban drainage system using SWMM

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**Abstract -** *Urban flooding is modern day problem faced by many towns and cities when the prevailing drainage system isn't sufficient to withstand a continuous rain. Under extreme weather conditions the current drainage isn't able to provide adequate water flow and thus leads to water logging of road pavements. A study on Kochi is done by collecting the geographical data such as road and drainage lines. Base map of the Kochi giving idea of the region under study. Existing layout of towns and drainage works are collected. Next collection of data about the weather report of Kochi is done. The rainfall data and storm hydrographs are procured from IMD (Indian Meteorological Department). A total area mapping is done by Arc GIS (Geographic Information System) software giving details of the landscape including the DEM (Digital Elevation Map) is procured. The area under study is mapped digitally giving clear details of Kochi showing the location of road, buildings, drainage works, water bodies. An urban catchment area is modeled using a hybrid modeling technique involving Arc GIS and SWMM. Using the software Storm Water Management Model (SWMM) simulations of water runoff quantity and quality in the chosen area is done. It contains a hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures. By this, design of drainage system for Kochi is done for reducing the urban flooding. Designing and sizing of new drainage system components is done for flood control. Designing control strategies combined sewer overflows.*

***Key Words*: Drainage, Design, Flood, Hydrographs, Elevation, Software**

## 1.INTRODUCTION

Kochi city has an area of 94.88 square km divided into 74 wards and is governed by Kochi corporation, which is the second largest city corporation in India. This project focuses on 3 wards. Ward No. 66: Ernakulum North (9.9920'N 76.2877 'E), Ward No. 67: Ernakulum Central (9.9807'N, 76.2777'E) and Ward No. 68: Ayyappankavu (9.9959'N, 76.2793'E).Drainage system prevailing in the study area is less organized and unscientifically planned. The drainage of storm and surface water has been a major problem in the area, especially because of narrow roads. The population density of the area is also quite high. During the rainy season the flood water enters the houses at many places and the majority of the roads are flooded with water. It takes hours and, in some occasion, days to overcome the situation.

Figure 1.1 represents the study area chosen. The three wards, Ward No 65, 66 and 67 are surrounded by lakes and other wards. Vembanad Lake is situated on the western side and all the drainage outlets are carrying the water to the lake .The drainage lies on both sides of the roads. A railway line is passing through the eastern boundary of the area. The area drains in the town act as major storm water receivers. There is no regular pattern of the area drains and it lies along roads and bye lines. The area drains are absent in many of the roads especially in the areas with urban proliferation. Most of the drains overflow during heavy rainfall. These drains need immediate attention. These are the primary cause of the water logging in the study area. The flood and water logging causes various significant social and economic issues such as health related issues, loss of labor, increased maintenance expenditure of roads, etc. Considering the importance of a proper and scientific drain system in that area, it is proposed to implement a storm water management system.

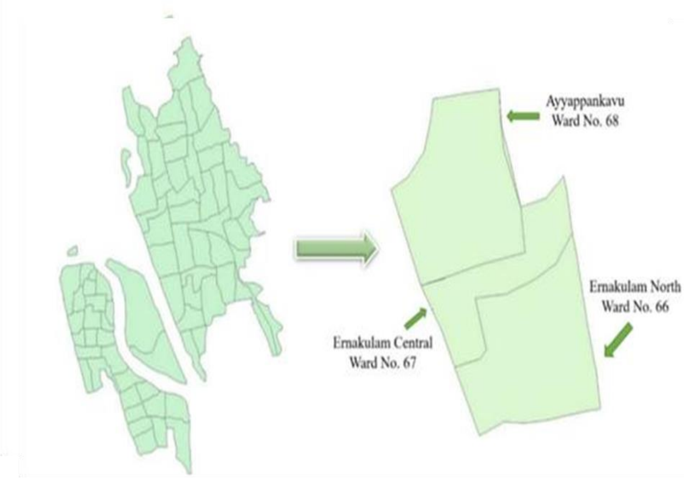



**Figure 1.1** study area

### 1.1 Objectives

The following are the main objectives of the study:

- To identity the reasons for water logging problems in the study area
- To develop intensity duration frequency curves.
- To delineate the study area into sub catchments
- To determine maximum probable runoff for the study area
- To design suitable drainage system for the study area using SWMM

## 1.2 Scope

The following are the scope of the study:
Mitigation of urban flooding
Smooth and fast economic development of city

## 1.3 Software used

**Arc - GIS 10.3**

Arc-GIS 10.3 is a geographic information system (GIS) which contains functions for creating, analyzing, editing and visualization of geographic data. It is used to summarize terrain and hydrological characteristics of the watershed for input to a model. GIS organizes the world data into layers, features and attributes. Continuously varying data over a surface can be modeled using a Raster data model, such as, elevation, temperature, rainfall and noise levels. Surfaces have numeric values, for example, temperature, slope and rainfall have measurable values for any particular location on the earth's surface.

**Storm water Management Model**

EPA's Storm water Management Model (SWMM) is used for planning, analysis, and design related to storm water runoff, combined and sanitary sewers, and other drainage systems. It can be used to evaluate gray infrastructure storm water control strategies, such as pipes and storm drains, and is a useful tool for creating cost effective green/gray hybrid storm water control solutions. SWMM was developed to help support local, state, and national storm water management objectives to reduce runoff through infiltration and retention, and help to reduce discharges that cause impairment of our water bodies. It predicts runoff quantity and quality from drainage systems. SWMM provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations which can be viewed in various formats.

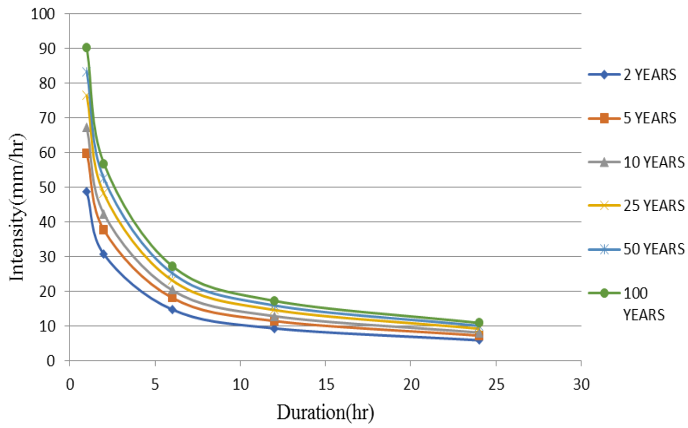
## 2. METHODOLOGY

Firstly, rainfall data from period 1/1/1980 to 31/12/2019 was received from IMD, Thiruvananthapuram. The annual maximum daily rainfall data of 40 years collected from Indian Meteorological Department (IMD) and Kochi naval base rain gauge is used for development of IDF curves which is an important input for SWMM. Using the ARC-GIS 10.3 software, the location of the study area is delineated and thus delineated map is developed. Next input was the terrain of the study area. The Digital Elevation Map (DEM) was downloaded from USGS with a pixel of 30X30 meter. From the DEM, flow of river, direction of flow and watershed in DEM could be produced. Study area is digitized and delineated in ARC-GIS. The delineated tiff file of the study area (Kochi Corporation) was converted to meta file was the reference map for SWMM.. On the satellite image from USGS 100 samples of each building, forest, open lands, vegetation, water bodies and agriculture were classified then the analysis and simulations are done in SWMM. Using the data ,the links and nodes are plotted and the parameters are defined for the simulation.

## 3. DATA ANALYSIS

**IDF Curve analysis**

The annual maximum daily rainfall data of 40 years collected from Indian Meteorological Department and Kochi naval base rain gauge is used for development of IDF curves. Frequency analysis is performed using Gumbel's distribution for different return periods 2, 5, 10, 25, and 50 years and the frequency values are used for development of IDF Curves, which is shown in graph 1.1. IDF relationship is developed for all return periods from IDF curves. Design storm intensity derived for different return periods is used to estimate peak runoff from each sub catchment and input parameter in simulation of runoff from each sub catchment in SWMM.




**Graph 1.1-** IDF curve

**Arc GIS data analysis**

Shape files of Kochi Corporation map procured was analyzed and clipped to the required study area. Watershed Analysis is done by Hydrology tool which is under the Spatial analyst tool. Toposheets were uploaded and georeferenced ,for accuracy of stream links.
Important tools which Hydrology used to delineate in Arc GIS are :
Filled DEM, Flow Direction, Flow Accumulation, Stream Network ,Stream Links, Watershed delineation of stream section
Watershed delineation is the final step to delineate the watershed for each stream section. For this , flow direction raster and the stream link raster are used as the inputs. Various defined sub basins were converted into polygons which gives details about area and perimeter of each sub catchment.
Mean percentage Slope values is one of the main input under properties of defining Sub catchments in SWMM. Slope tool under Spatial Analyst Tool in Arc Map to is used to find the slope of clipped DEM. Then using Zonal Statistics tool we can tabulate the Mean percent Slope in each Sub catchments. Stream network raster is converted into polyline and the Max Overland Flow length in each sub catchment is found by analyzing the polyline. Width of each sub catchment is given by Area of Each Sub catchment divided by the Max overland Flow length

**Storm water Management Model Analysis**

SWMM is a dynamic rainfall-runoff model used for single event or long term simulation. Runoff component of it will operates , collection of sub catchment area that receive precipitation and generate runoff . SWMM track quantity and quality of runoff generated within each sub catchment, its flow rate, flow depth and quality of water in each pipe.
First step in SWMM is to upload study area. For that, the input backdrop map for the SWMM was produced by ArcGIS

The initial road network raster and sub catchment polygon were exported into Metafiles. Next step is to divide Sub catchments. The sub catchments were drawn on the reference of imported base map showing the division of each sub catchments.

The properties of sub catchments are defined .Its Area, Outlet, percentage slope values are defined. Rest properties for pervious and impervious taken from manual of SWMM.

**Table 1.1** Properties of sub catchment (software uploaded)

| Subcatchment | Total Precip mm | Total Runon mm | Total Evap mm | Total Infil mm | Imperv Runoff mm | Perv Runoff mm | Total Runoff mm | Total Runoff 10^6 ltr | Peak Runoff CMS | Runoff Coeff |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 285.24 | 0.00 | 0.00 | 26.77 | 71.71 | 187.85 | 259.56 | 207.43 | 13.97 | 0.910 |
| S2 | 285.24 | 0.00 | 0.00 | 34.19 | 71.47 | 180.13 | 251.60 | 235.06 | 15.34 | 0.882 |
| S3 | 285.24 | 0.00 | 0.00 | 24.37 | 71.77 | 190.40 | 262.17 | 151.84 | 10.22 | 0.919 |
| S4 | 285.24 | 0.00 | 0.00 | 25.53 | 71.74 | 189.16 | 260.90 | 107.66 | 7.25 | 0.915 |
| S5 | 285.24 | 0.00 | 0.00 | 25.52 | 71.74 | 189.18 | 260.92 | 227.30 | 15.31 | 0.915 |
| S6 | 285.24 | 0.00 | 0.00 | 35.65 | 71.43 | 178.64 | 250.06 | 134.29 | 8.65 | 0.877 |

After that, Junctions were added as nodes on the specific points on the map and outfall nodes also added .Next the links were drawn between plotted nodes. Links used are Conduits.

Properties of Conduits were specified. Length of each conduit (Link) was obtained from the Google Earth Pro.
Figure 1.2 shows the Layouts of the Conduits provided, the channel section is given as open rectangular, and the maximum height of conduit provided as 1m and bottom width also 1m without side walls.

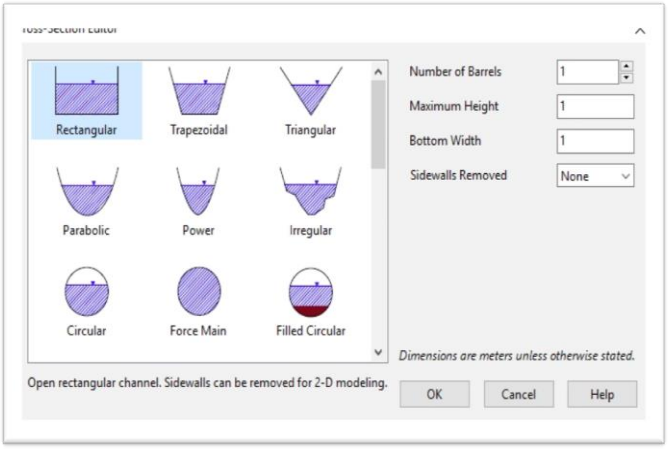



**Figure 1.2** Layouts of the Conduits(software uploaded)

Rain gauge was plotted on the outside of the map, linked to every sub catchment. The data input for rain gauge is Time Series. Various Time series can be entered .IDF curve values of 10 year Return Period was entered as Time Series.

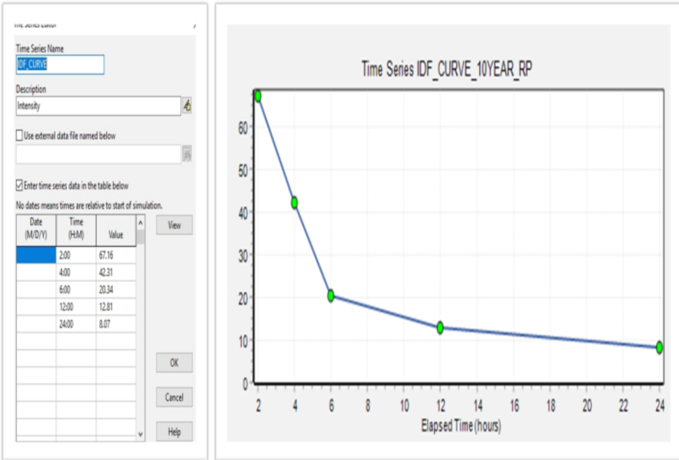



**Figure 1.3** Time series for IDF Curve of 10 year RP

Final step is to set the properties of simulation. Using dynamic wave as the routing model and using Green-Amt Infiltration model, Simulation of defined model was done. After Simulation classified results about every object is obtained .Details such as runoff and precipitation from each sub catchments, depth and velocity of water in each conduits (links) are obtained. In total the study area had 6 Sub catchments, 196 Junction Nodes, 9 Outfall Nodes, 242 Conduits Links and 1 Rain gauge.

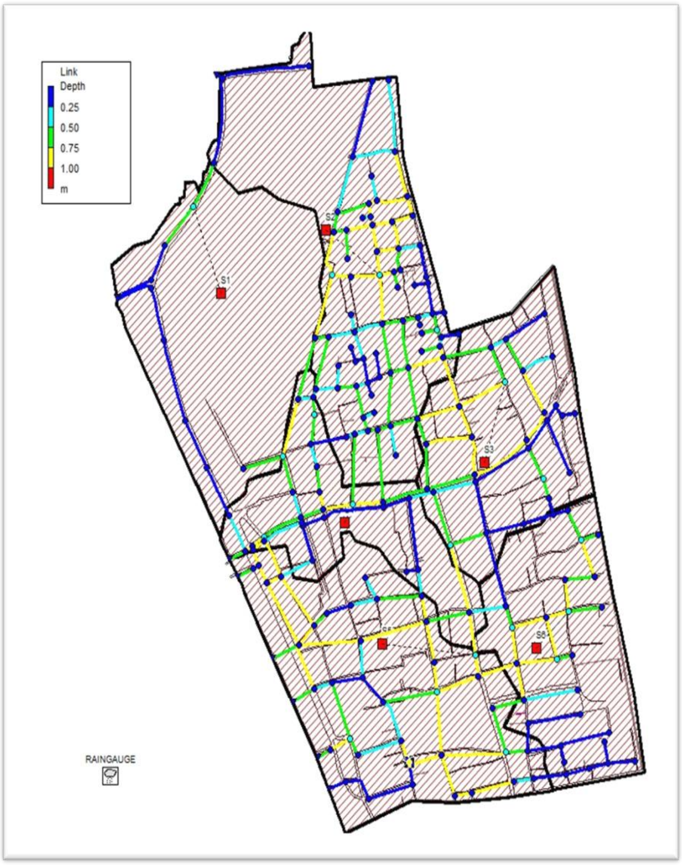



**Figure 1.4** Classification of Links according to Flow depth

Figure 1.4 illustrates the simulation image of the study area with flow depth as a parameter an it shows the color classification of links according to the depth of water flowing through it. Blue color shows the depth of water as 0.25m and green color shows depth of water as 0.5m yellow color shows a depth of 0.75 m and it can be noticed that the red color pattern is an indication for flow depth more than 1m.

1m is the maximum depth provided for the drains in the design. From the simulation image it is clear that all the conduits are having a flow depth less than 1m, which indicates none of the conduits are overflowing.

Flow depth is the primary design parameter in open channel flow. After various trial and errors, final drain depth was obtained. Another parameter was the flow velocity and it was ensured that flow velocity is also within the specific range of non-silting and non-scouring. And from this figure it is clear that there is no red color for any links which means no link is over flowing ,for all the links depth of water flowing is less than 1m.

**Table 1.2** Conduits details (software uploaded)

| Link | Type | Maximum \|Flow\| CMS | Day of Maximum Flow | Hour of Maximum Flow | **Maximum \|Velocity\| m/sec** | Max / Full Flow | Max / Full Depth |
|---|---|---|---|---|---|---|---|
| 248 | CONDUIT | 0.354 | 0 | 08:12 | 0.80 | 2.99 | 0.80 |
| 302 | CONDUIT | 0.194 | 0 | 03:03 | 0.80 | 3.55 | 0.24 |
| 245 | CONDUIT | 0.367 | 0 | 02:37 | 0.81 | 8.75 | 0.81 |
| 217 | CONDUIT | 0.267 | 0 | 02:21 | 0.83 | 3.33 | 0.61 |
| 347 | CONDUIT | 0.777 | 0 | 08:29 | 0.84 | 18.52 | 1.00 |
| 143 | CONDUIT | 0.324 | 0 | 02:33 | 0.84 | 6.11 | 1.00 |
| 273 | CONDUIT | 0.351 | 0 | 02:19 | 0.84 | 6.26 | 0.69 |
| 249 | CONDUIT | 0.612 | 0 | 07:55 | 0.85 | 12.09 | 0.75 |
| 242 | CONDUIT | 0.355 | 0 | 02:41 | 0.85 | 7.07 | 0.82 |
| 327 | CONDUIT | 0.442 | 0 | 02:41 | 0.85 | 9.12 | 0.87 |
| 229 | CONDUIT | 0.280 | 0 | 02:19 | 0.85 | 4.46 | 0.70 |
| 126 | CONDUIT | 0.194 | 0 | 03:09 | 0.87 | 2.81 | 0.22 |
| 277 | CONDUIT | 0.251 | 0 | 03:43 | 0.88 | 2.57 | 0.29 |
| 268 | CONDUIT | 0.536 | 0 | 03:22 | 0.88 | 0.13 | 0.61 |
| 247 | CONDUIT | 0.355 | 0 | 03:09 | 0.89 | 5.97 | 0.81 |
| 274 | CONDUIT | 0.433 | 0 | 03:52 | 0.90 | 7.91 | 0.71 |
| 338 | CONDUIT | 0.470 | 0 | 02:26 | 0.91 | 0.29 | 0.68 |
| 279 | CONDUIT | 0.321 | 0 | 02:31 | 0.94 | 3.52 | 0.58 |
| 257 | CONDUIT | 0.483 | 0 | 02:32 | 0.94 | 11.51 | 0.83 |
| 144 | CONDUIT | 0.577 | 0 | 02:32 | 0.94 | 8.42 | 0.99 |
| 114 | CONDUIT | 0.414 | 0 | 02:10 | 0.95 | 0.16 | 0.85 |
| 320 | CONDUIT | 0.280 | 0 | 02:26 | 0.95 | 4.98 | 0.41 |
| 254 | CONDUIT | 0.613 | 0 | 08:16 | 0.96 | 9.94 | 0.65 |
| 288 | CONDUIT | 0.289 | 0 | 02:38 | 0.97 | 3.95 | 0.57 |
| 156 | CONDUIT | 0.724 | 0 | 02:32 | 0.98 | 14.94 | 0.96 |
| 236 | CONDUIT | 0.482 | 0 | 02:22 | 0.99 | 9.61 | 0.90 |
| 264 | CONDUIT | 0.574 | 0 | 02:28 | 1.01 | 0.27 | 0.66 |
| 287 | CONDUIT | 0.589 | 0 | 03:39 | 1.02 | 12.26 | 0.58 |
| 313 | CONDUIT | 0.620 | 0 | 02:19 | 1.02 | 0.31 | 0.72 |
| 250 | CONDUIT | 0.599 | 0 | 02:40 | 1.03 | 9.44 | 0.84 |
| 226 | CONDUIT | 0.581 | 0 | 02:27 | 1.07 | 0.15 | 0.58 |
| 199 | CONDUIT | 0.345 | 0 | 02:31 | 1.07 | 4.72 | 0.50 |
| 231 | CONDUIT | 0.536 | 0 | 03:40 | 1.08 | 8.79 | 0.66 |
| 138 | CONDUIT | 0.976 | 0 | 02:31 | 1.08 | 20.99 | 0.97 |

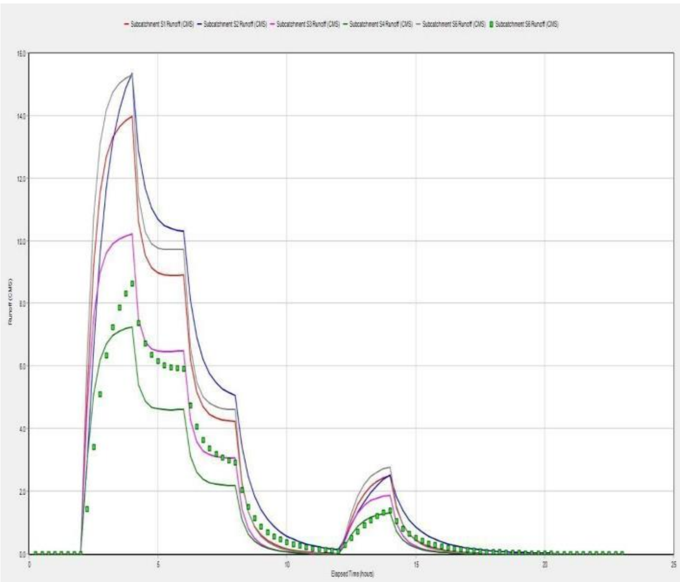
The table 1.2 represents the conduit details in SWMM showing the max flow velocity (m/s) and max flow depth (m).Table 1.3 and 1.4 provides details of outfall nodes and junctions. From the table it is clear that Max ponded depth is zero which means there will be no flooding in the junctions.

**Table 1.3** Outfall details (software uploaded)

| Outfall Node | Flow Freq. Pcnt. | Avg. Flow CMS | Max. Flow CMS | Total Volume 10^6 ltr |
|---|---|---|---|---|
| 183 | 97.66 | 0.926 | 1.337 | 49.218 |
| 27 | 98.21 | 0.386 | 0.700 | 19.380 |
| 28 | 98.05 | 0.592 | 1.019 | 30.347 |
| 31 | 0.00 | 0.000 | 0.000 | 0.000 |
| O1 | 0.00 | 0.000 | 0.000 | 0.000 |
| O2 | 0.00 | 0.000 | 0.000 | 0.000 |
| O3 | 0.00 | 0.000 | 0.000 | 0.000 |
| O4 | 97.99 | 0.659 | 0.914 | 35.622 |
| O5 | 97.46 | 0.730 | 1.262 | 37.109 |

**Table 1.4** Junction details (software uploaded)

| Node | Hours Flooded | Maximum Rate CMS | Day of Maximum Flooding | Hour of Maximum Flooding | Total Flood Volume 10^6 ltr | Maximum Ponded Depth Meters |
|---|---|---|---|---|---|---|
| 149 | 4.00 | 8.820 | 0 | 03:59 | 72.889 | 0.000 |
| 152 | 6.82 | 1.745 | 0 | 02:46 | 32.951 | 0.000 |
| 159 | 6.50 | 0.440 | 0 | 02:46 | 7.635 | 0.000 |
| 165 | 0.05 | 0.071 | 0 | 02:39 | 0.009 | 0.000 |
| 178 | 6.96 | 0.175 | 0 | 02:45 | 2.581 | 0.000 |
| 235 | 20.42 | 1.119 | 0 | 04:10 | 35.098 | 0.000 |
| 253 | 7.81 | 1.931 | 0 | 06:29 | 42.147 | 0.000 |
| 255 | 5.74 | 11.147 | 0 | 04:00 | 110.578 | 0.000 |
| 298 | 20.59 | 1.493 | 0 | 03:38 | 37.609 | 0.000 |
| 313 | 4.09 | 6.141 | 0 | 04:00 | 53.000 | 0.000 |
| 328 | 5.85 | 0.728 | 0 | 02:51 | 12.715 | 0.000 |
| 336 | 19.93 | 0.185 | 0 | 03:38 | 4.567 | 0.000 |
| 342 | 4.54 | 0.307 | 0 | 02:40 | 0.490 | 0.000 |
| 344 | 5.78 | 0.481 | 0 | 02:28 | 7.350 | 0.000 |
| 346 | 5.95 | 6.809 | 0 | 04:00 | 73.825 | 0.000 |
| 351 | 6.05 | 0.579 | 0 | 02:29 | 9.142 | 0.000 |
| J1.4 | 20.91 | 13.968 | 0 | 04:00 | 207.056 | 0.000 |
| J4.16 | 7.63 | 8.082 | 0 | 04:00 | 111.335 | 0.000 |
| J4.17 | 20.59 | 1.726 | 0 | 04:13 | 60.151 | 0.000 |
| J4.8 | 8.22 | 0.260 | 0 | 03:47 | 7.155 | 0.000 |



**Graph 1.2-** Graph showing runoff with duration

Hydrograph shown in graph 1.2 guide us in understanding the Rainfall Runoff relationship of the sub catchments with respect to rainfall events from each sub catchments. It is being observed that peak of runoff is observed for such catchments with highest catchment area and runoff coefficients. A profile plot is a graphical data analysis technique for examining the relative behavior of various parameters. Profile plots give another helpful graphical outline of the information which is one of the effective data analysis techniques. Profile plot for water elevation from node 172-183, node 360-28, node 347-27 and node 317-04 is given in Figures 1.5, 1.6, 1.7 and 1.8 respectively. From the profile plot it is observed that storm water in each conduit is not overflowing

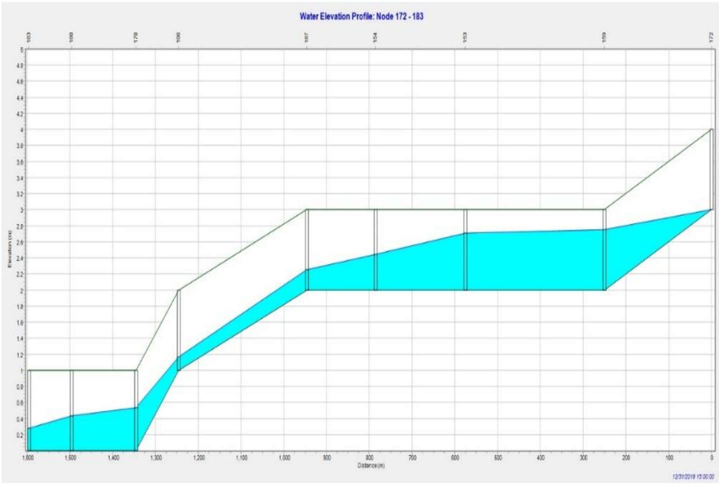



**Figure 1.5-** Water Elevation Profile Plot 1

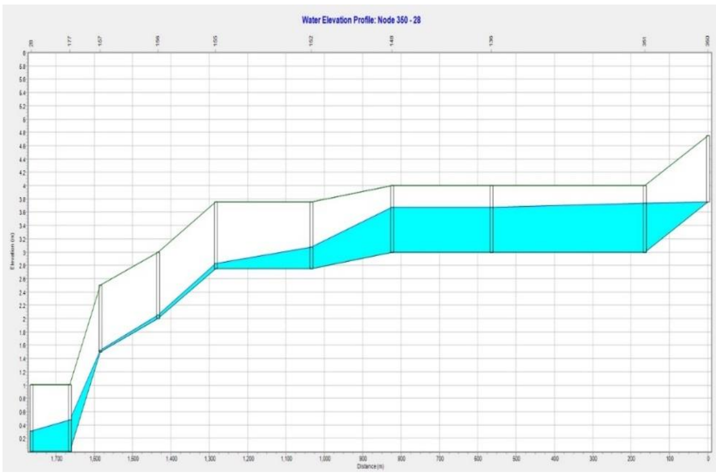



**Figure 1.6-** Water Elevation Profile Plot 2

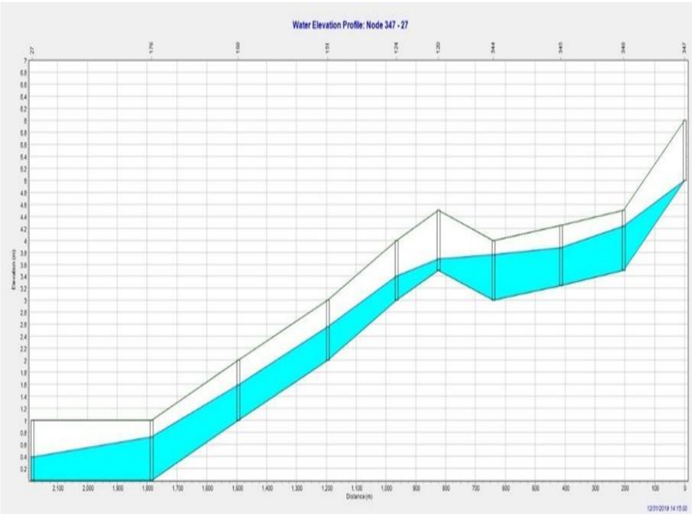


**Figure 1.7-** Water Elevation Profile Plot 3

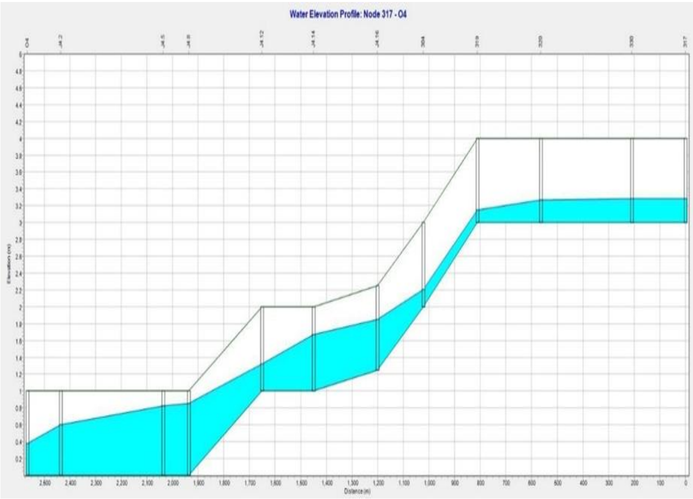


**Figure 1.8-** Water Elevation Profile Plot 4

## 3. CONCLUSIONS

After the storm water management modeling of the proposed study area it can be concluded that SWMM is best suited for the design of drainage systems for urban catchments. The SWMM achieves catchment responses to peak flow and runoff volume, which are the most essential catchment responses in urban drainage planning which state that no nodes are being flooded in the entire catchment and there are no overflow sections. Thus, the storm network system designed for the study area has been well planned and has enough carrying capacity to cater the simulated rainfall event.

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