# Mitigating Urban Drainage Problems and Improving Drainage Systems of Some Selected Areas in Yangon

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***Abstract:*** *In this paper, Modified Rational Method is used to check whether the existing drainage capacity and drainage system are sufficient to carry and withstand the annual mean rainfall intensity or not. According to the current flooding problems occuring frequently in the study area, it is found that the existing drainage systems cannot carry the rainfall intensity properly because of inadequate drain sizes, lack of proper maintenance and the tidal effect at the outfalls. As an effective solution by applying the Manning's equation, new detailed dimension of drain sections were proposed to mitigate the current flooding problems. According to the topography, there is an external inflow to the study area and its peak discharge is evaluated by using Hydrological Modeling, HEC-HMS. In order to stimulate the rainfall-runoff process, Stormwater Management Model, SWMM is used to check whether the proposed drain sizes are sufficient or not. According to the simulation result by SWMM, it can be seen that the capacities of the proposed major and minor drains are sufficient enough to carry the peak discharge of 10 Year Return Period.*

***Key Words:*** *Drainage capacity, peak discharge, Modified Rational Method, Stormwater Management Model .*

## 1. INTRODUCTION:

Urban flooding problems causing in Yangon City Area become a major potential disaster due to the some causes and vulnerabilities such as rapid urbanization, land cover changes and increased impervious paved surface, uncoordinated infrastructure, climates changes and increased rainfall intensity. Urban flooding is a serious and growing challenge which causes widespread devastation, economic damages and transportation problems. The occurrence of floods in the area is the most frequent among all natural disasters. Many urban areas in the world also have such problem because urban growth in developing countries has taken place in an unsustainable way. Urban areas, on average, yield 90% of the storm rainfall to runoff, whereas the non-urban forested watersheds generally give way as runoff not more than 40% of the rainfall [1].

There are two types of urban flooding such as according to duration: slow-onset flooding, rapid-onset flooding, and flash flooding and according to location: coastal flooding, arroyos flooding, river flooding and urban flooding [2]. When the piped system is overwhelmed or cannot drain effectively into an outfall because of downstream boundary river level raises, the excess flows down roads and other paths of least resistance and floods low lying areas. These can contain property and infrastructure. Moreover, flooding can cause costly damage, distress and sometimes even loss of life [3].

Yangon is the Secondary City of Myanmar and it has total area of 795 sq.km with own population of 5.2 million (2015) and its infrastructure is looked after by the Yangon City Development Committee (YCDC). Urban storm drainage system in Yangon city consists of about 50 open channels flowing out into 6 major rivers and canals and 14 drainage pipe networks were constructed in Central Business Downtown area. The drainage seems designed with inadequate rainfall intensity was designed for only 25mm of hourly precipitation, so inundations are happened in downtown area frequently. Yangon has average annual rainfall of 2749 mm. Maximum annual rainfall was recorded as 3592 mm in 2007. Maximum 24 hour rainfall observed during the last 35 years was 343 mm in Year 2007 [4].

The storm water of the drainage basin in Yangon City is drained out by natural gravity flow through. Most of the outlets are un-gated and affected by tidal water. The current drainage system has been built since the time when Myanmar was under British rule. The main existing storm water drainage facilities in Yangon City Area in current situation are underground conduits, box culverts, open channels and detention ponds [5]. Yangon is situated in a region that is influenced directly by the southwest monsoon. The increased urbanization and the global climate change impacts on stormwater runoff in Yangon city are assumed to become severe in near future.

## 2. GENERAL BACKGROUNG OF STUDY AREAS:

Yangon, the main commercial city of Myanmar is situated in the delta area of Ayeyarwaddy River and comprises with 33 Townships. In this study, Latha and Lanmataw Townships are selected to mitigate the existing drainage problems and to improve the existing drainage system. The highest area of Latha Township is located 6.1 m above sea level and it has total area of 0.77sq.km and its total population is 27744 by the year, 2015. The highest area of Lanmataw Township is located 9.1 m above sea level and its total area is 1.41 sq.km and total population is 37,390 by the year, 2015. Since Lanmataw Township is adjacent to Dagon Township and according to the topography, Lanmataw Township receives external inflow from the external catchment, Dagon Township at Lanmataw Street. The total area of Dagon Township is about 1.2 $km^2$ and it has total 6 sub-catchments. The runoff combines near the railroad flowing across Lanmataw Road and it drains through the major drainage channel along Lanmataw Road and Kyone Gyi Drain of the study area and finally, these runoff drains toward Yangon River.

Both study areas are located at the bank of Yangon River with total nine outfalls in both Townships which drain into Yangon River. Tidal hydrograph of Yangon River is used for the consideration of tidal effect. Figure 1 shows the study area map and Figure 2 shows external catchment, Dagon Township.

## 3. METHODOLOGY:

In this study, Modified Rational Method is used initially and based on Rainfall Intensity-Duration-Frequency curve for Yangon to estimate the design flood from all catchment areas of both Townships. Both existing and proposed drain capacities are checked by Manning's equation. In order to check whether the existing drainage capacity and network system are sufficient to carry and withstand the current and future rainfall intensity or not, Manning's equation is used. To revise the inadequate existing drainage structures, Manning's formula are applied with their adopted parameters.

Since the study areas are located at the bank of Yangon River, the tidal hydrograph of Yangon River is used in this study. Among two Townships, Lanmataw Township has external inflow from Dagon Township and HEC-HMS Hydrological Model is used to estimate the peak discharge of Dagon Township. After estimating the proposed drains and culverts parameters, Storm Water Management Model (SWMM) is applied to obtain more accurate drains and culverts capacity and network system.

### *Modified Rational Method:*

The Modified Rational Method is a method to estimate simple runoff discharges which take into account storage coefficient of storage within the flowing channels. This method is based largely on the same assumptions used in the conventional Rational Method and is a conceptual extension of the rational method for development of runoff hydrographs and it is accurate for catchment sizes up to 150 ha. Design flood of each catchment area is estimated by using the following Modified Rational formula:

$$\mathbf{Q = 0.00278\ Cs\ C\ I\ A} \qquad (1)$$

Where, Q = Design Flood (cubic meters per second)
Cs= Drain Channel Storage Coefficient
C = Runoff Coefficient (80 for residential areas)
I = Rainfall Intensity (millimeter per hour)
A = Sub-catchment Area (square meter)

### *Time of concentration (tc):*

The time of concentration, tc is defined as the time required for the surface runoff from the most distant part of the catchment to reach the outlet. In this study, tc for each waterway is estimated with the following equation with the following equation:

$$\mathbf{tc} = \frac{\textbf{total drain length}}{\mathbf{V \times 60}} + \mathbf{t_0} \qquad (2)$$

Where, tc = time of concentration (minute)
v = velocity = 1.5 to 2.5 ( meter per second)
$t_0$ = overland flow = 3 (catchment width within 100m)

### *Rainfall intensity-duration-frequency relationship:*

The total storm rainfall depth at a point, for a given rainfall duration and Average Recurrence Interval, ARI, is a function of local climate. Rainfall depths can be further processed and converted into rainfall intensities (intensity =depth/duration), which are then presented in IDF curves. Such curves are particularly useful in storm water drainage design because many computation procedures require rainfall input in the form of average rainfall intensity. The three variables, frequency, intensity and duration are all related to each other. The data are normally presented as curves displaying two of variable, such as intensity and duration, for a range of frequencies. These data are then using as the input in most storm water design processes [6]. Rainfall intensities of different return periods (ARI) for various durations at Yangon City were developed by joint effort of Myanmar Meteorology & Hydrology Department and Irrigation Department. The Intensity-Duration-Frequency curve for Yangon Project Area is shown in Figure 3. In this regard, the maximum daily rainfall of Kabar-Aye station from 1962 to 2016 was used in conjunction with the research paper of 1986 [7].

The temporal distribution of rainfall within the design storm is an important factor that affects the runoff volume, and the magnitude and timing of peak discharge. Design rainfall temporal patterns are used to represent the typical variation of rainfall intensities during a typical storm burst. The standard durations recommended for urban storm water studies are listed in Table 1 [6].

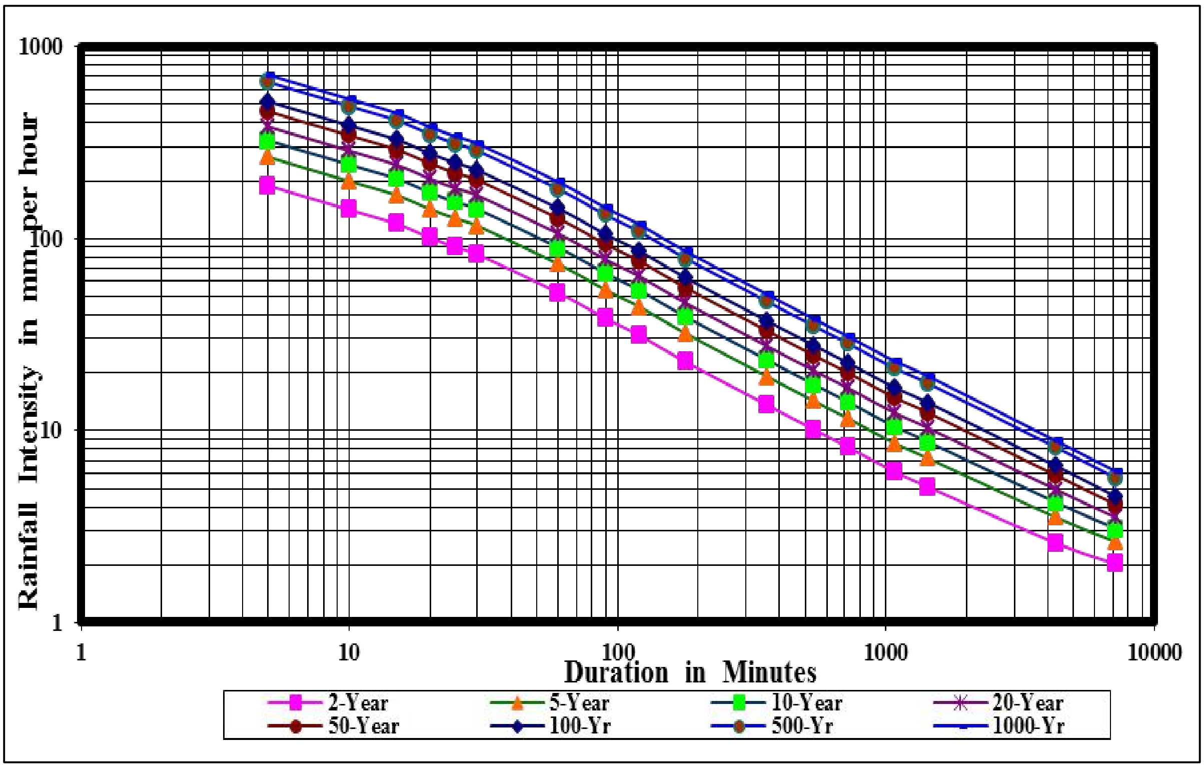


Figure 3. Rainfall Intensity-Duration-Frequency Curve for Yangon (1980-2016) [7]

Table 1.Standard Time Interval for Temporal Distribution

| Standard Duration | Number of Time Intervals | Time Interval (minutes) |
|---|---|---|
| 10 | 2 | 5 |
| 15 | 3 | 5 |
| 30 | 6 | 5 |
| 60 | 12 | 5 |
| 120 | 8 | 15 |
| 180 | 6 | 30 |
| 360 | 6 | 60 |

[8]

***Modification of drain capacity:***

Sizing of culverts and drains are carried out using the well-known hydraulic formula of Manning's equation:

Design discharge, $\mathbf{Q} = \frac{1}{n} \mathbf{A} \mathbf{R}^{\frac{2}{3}} \mathbf{S}^{\frac{1}{2}}$ (3)

Where, n = Manning's roughness

A = Area of proposed drain or culvert

R = Hydraulic radius of drain or culvert

S = Hydraulic gradient

By applying Manning's formula, the channel carrying capacity was calculated by using the existing dimensions of the drains which were obtained from Yangon City Development Committee. The roughness coefficient "n" was taken as 0.014 for the normal concrete lining value [9].

***Tidal Analysis:***

When the piped system is overwhelmed or cannot drain effectively into an outfall because of river level raises, the excess water travels down roads and other paths of floods towards low lying areas. In this study, all of the storm water from both Townships disposes into the Yangon River and so, it is needed to consider about the tidal effect at each of the drainage outfalls. According to the topography, the downstream boundary of Latha Township is only 0.9m above Mean Sea Level (MSL) and it is the township which downstream boundary is the lowest one among all of the CBD areas. Another study area, Lanmataw Township, is situated only 1m to 1.5m above MSL. Since, the downstream levels of both study areas are very low, the high tide of Yangon River effects at each nine outfalls.

The Yangon River tidal data are supported by Myanmar Port Authority and they are recorded in Chart Datum (CD) which is 3.6m above MSL. These data are available only in maximum and minimum water levels varying with time but not in hourly and not available for continuous water levels. Since those data were recorded in Chart Datum and not in hourly, they were constituted into hourly tidal hydrograph based on MSL with the reference of Malaysia Port Klang tidal records. The constituted tidal hydrograph of Yangon River is shown in Figure 4.

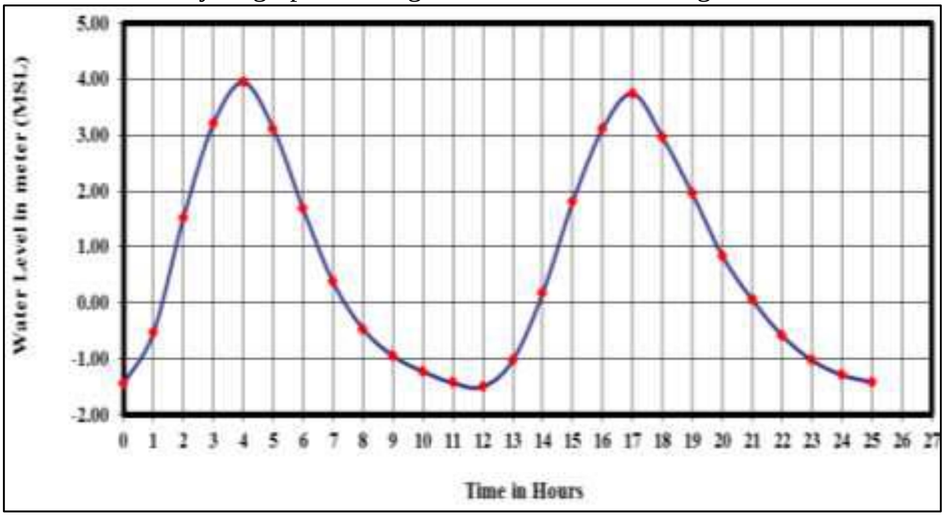


Figure 4. One complete Spring Tide Cycle
[Source: Development By U Tin Mg (Visiting Professor)]

***Estimation of Peak Discharge from external catchment:***

Hydrologic Modeling System (HEC-HMS) was developed by Hydrologic Engineering Centre of the U.S Army Corps of Engineers and it was designed to simulate the precipitation-runoff processes of dendritic watershed systems. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, flood plain regulation, and system operation. In HEC-HMS model, there are four main components for hydrological modeling; loss method, transform method, base -flow method and routing method [10].

In this study, HEC-HMS is used to evaluate design discharge from external catchments. The simulated design discharge is used also in evaluation of existing drainage capacity of Ywa Thit Chaung outfall in Lanmataw Township. For each of these components, a suitable method is chosen. Initial and Constant loss and SCS unit hydrograph are selected for loss and transform method respectively. Recession and lag methods are assigned for base-flow and routing method respectively and applied for rainfall-runoff simulation in the study area. Before processing HEC-HMS model, the external catchment characteristics are prepared for each sub-basin as shown in Table 2 and Table 3.

Table 2. Summary of Input Parameters for HES-HMS

| | Catchment Area (km²) | Stream Length (m) | Stream Drop (m) | Stream Slope (m/km) | tc (min) | Impervious (%) |
|---|---|---|---|---|---|---|
| Subbasin-1 | 0.26 | 342 | 5.00 | 14.62 | 13 | 50 |
| Subbasin-2 | 0.49 | 555 | 3.90 | 7.03 | 24 | 60 |
| Subbasin-3 | 0.17 | 324 | 3.20 | 9.88 | 14 | 60 |
| Subbasin-4 | 0.15 | 524 | 6.10 | 11.64 | 23 | 50 |
| Subbasin-5 | 0.03 | 325 | 2.60 | 8 | 18 | 50 |
| Subbasin-6 | 0.10 | 546 | 28.00 | 51.28 | 18 | 50 |
| Kandawmin Basin | 0.02 | 294 | 1.00 | 3.4 | 20 | 50 |

Table 3. Summary of Input Parameters for HES-HMS

| | |
|---|---|
| Initial Loss | 30 mm |
| Constant Rate | 4 mm/hr |
| Recession Constant | 0.7 |
| Initial Discharge | 0.0547 m³/s/km² |
| Ratio to Peak | 0.02 |

Maximum duration of travel time from Dagon Township Lanmataw Township is 84 mins and 90 mins standard duration design rainfall for 10 Year ARI is applied in HEC-HMS. By using the above data, the model gives simulated peak discharge of external catchments for 10 Year ARI which is 18.7 cumecs and it is shown in Figure 5.

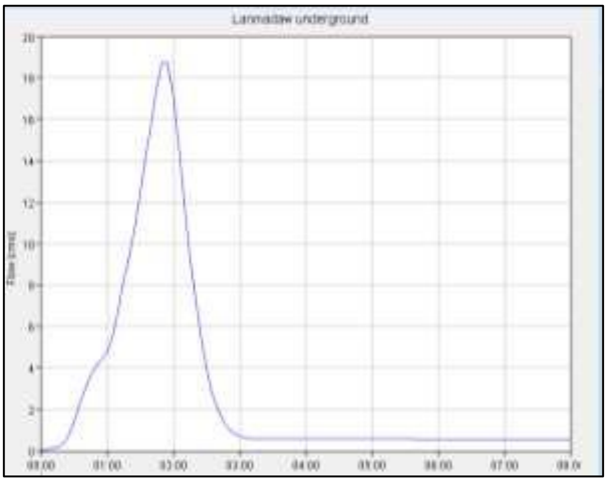


Figure 5. Simulation Runoff Hydrograph for 10-year ARI

***Storm Water Management Model (SWMM):***

In this study, US EPA Storm Water Management Model (SWMM) is used to check whether the proposed drain capacities and network system are enough to withstand and carry the current and future rainfall intensities or not. SWMM is a dynamic rainfall-runoff simulation model, developed by the United States Environmental Protection Agency. It is public domain software and it can be used for either single events or long-term simulation of runoff quantity and quality from primarily urban areas. The model is widely used for planning, analysis and design related to drainage systems in urban areas [11].

First of all, delineate the catchment boundary and determine its area on study area map. Then, define the flow path from the upper-most portion of the catchment to the design point. The study area map is divided into 420 numbers of sub-catchments, 579 numbers of junctions, 581 numbers of conduit links (including culverts) and 9 outfall nodes as seen in Figure 6.

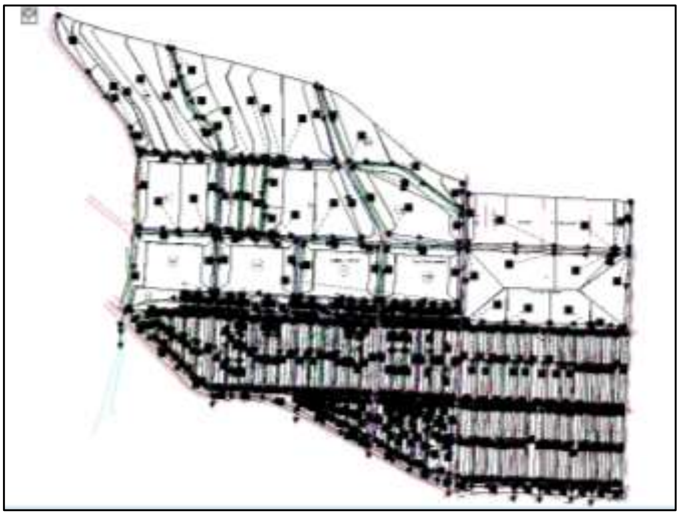

Figure 6. Drainage Network of Study Area Setup in SWMM

Time of concentration, tc for each selected waterway is estimated with Equation (2) mentioned above and the maximum value of tc among total 9 outfalls is 22 minutes and 30 minutes rainfall duration is used and divided into five minutes interval according to the temporal rainfall distribution pattern as shown above in Table 1.

For sub-catchment properties, areas are collected from Auto-CAD software file which is supported by the Exp. Venture Consultants and sub-catchment width is obtained by dividing the sub-catchment's area with the length of longest overland flow path of it. Slope of each sub-catchment is calculated by dividing the difference in existing ground level by runoff length. The value of Percent Impervious is taken as 80 according to the current land cover and N-Impervious and N-Pervious (Manning's n for overland flow over the impervious portion/pervious portion of the sub-catchment) is taken as 0.012 (for smooth concrete) and 0.025. For all of the conduits, open rectangular shape with roughness value 0.014 and for culverts, closed rectangular shape with roughness value 0.012 is selected and the value of slope for culverts is taken as 0.05%. In this research, the general options used in SWMM are rainfall-runoff process model, dynamic wave routing model and Green-Ampt infiltration model.

The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub-catchment, and the flow rate, flow depth and quality of water in each pipe and channel during a simulation period comprised of multiple time steps [12]. SWMM uses a nonlinear reservoir model to estimate surface runoff produced by rainfall over a sub catchment. Assuming that flow across the sub catchment's surface behaves as if it were uniform flow within a rectangular channel of width W(m), height (d-ds), and slope (S), the Manning's equation can be used to express the runoff's volumetric flow rate Q (m3/sec) as:

$$\mathbf{Q} = \frac{W}{n}(d - ds)^{\frac{5}{3}} S^{\frac{1}{2}} \qquad (4)$$

SWMM accounts for the spatial variability of rainfall by allowing the user define any number of Rain Gauge objects along with their individual data sources, and assign any rain gauge to a particular SWMM sub-catchment object from which runoff is computed [13]. The following Figure 7 shows the modeling process of SWMM.

***External Inflow features used in SWMM:***

In this study, external inflow is added in SWMM as direct inflow method. It is based on the time-varying inflow and it is added as time series pattern simulated by HEC-HMS that is added directly to the node where the external inflows drain into Lanmataw Township.

## 4. RESULTS:

After running a simulation, the model gives output results as shown in Figure 8 and 9. According to the results from the storm water management model (SWMM), it was founded that all proposed drain sections are sufficient enough to carry design flood for 10yrs ARI. Although there are some pressured pipe flows at some nodes as shown in Figure 8, the flooded hours at those nodes are insignificant and maximum flooded duration is 4.8 minutes and they are negligible. To overcome tidal effect condition, sluice gate should be installed at the outlet where the associated road levels are lower than the spring tide levels. Table 4 shows the comparison of design flood between simulated result by SWMM and Modified Rational Method. It shows that the value of design flood simulated by SWMM is not very different when compared with design flood calculated by Modified Rational Method and it can be concluded that these results are reliable to some extent. Therefore, the existing drain sections should be replaced with proposed drain sections to mitigate the urban flooding in the study areas.

Table 4. Comparison of Design Flood between Modified rational Method and SWMM

| Outfall | | Modified Rational Method (cumecs) | SWMM (cumecs) |
|---|---|---|---|
| O 1 | YTCO | 42.445 | 39.453 |
| O 2 | WDSO | 5.515 | 4.95 |
| O 3 | LTSO | 8.112 | 6.85 |
| O 4 | PGSO | 9.219 | 8.78 |
| O 5 | LMDRO | 10.664 | 10.568 |
| O 6 | 19thSO | 1.571 | 1.298 |
| O 7 | LTRO | 11.163 | 10.028 |
| O 8 | 22ndSO | 1.305 | 1.224 |
| O 9 | 23rdSO | 1.83 | 1.668 |

## 5. DISCUSSION AND CONCLUSION:

In this study, the capacity of existing drainage were checked by using Manning's formula and the runoff from sub-catchment areas were calculated by applying Modified Rational Method. The design average recurrence interval (ARI) is taken as 10-year for drains and 50-year for culverts. Time of concentration was estimated as 30 minutes and runoff coefficient C is taken as 0.8 for downtown area. The runoff from external catchment was estimated by applying HEC-HMS. The simulated outflow discharges from external catchments is applied as inflow time-series value for certain nodes in simulation of SWMM.

It is concluded that the existing drain capacities of the study areas are not sufficient enough to carry the current storm water and the drainage capacities should be improved such as lining and modification of drain sizes enough to carry future storm water to cope with urbanization of the study area. SWMM used in this study was developed especially for urban areas and it is reliable enough to verify the proposed drain capacities. The storm water in the study area is being discharged by gravity flow without any flap gate at the outlet to Yangon River. The lack of tidal gate is the major cause of flooding in outfall area. So, the construction of a tidal control gate at the outlets should be considered because the incoming tidal water is blocking the flow of the main drainage channel especially when heavy rain occurs during high tide. During high tides, pump operation is necessary to drain out this runoff in order to avoid flooding in the study area.

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