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DRAINAGE CHANNEL CAPACITY ANALYSIS USING THE SWMM PROGRAM IN GRAHA YOUTEFA HOUSING

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Abstract

The construction of good drainage in residential areas is needed to channel runoff water to reduce the potential for puddles to arise which can lead to flooding. Graha Youtefa's housing is located in the Heram District, Yabansai, and Jayapura City. Currently, the drainage channels in the housing complex cannot accommodate runoff that occurs during high-intensity rains. One solution to help evaluate urban drainage systems is to use runoff modeling, namely the SWMM software. After analysis, due to the catchment area, there is a quite large runoff with a capacity of 0.871309824 runoff discharge in the drainage channel at Graha Youtefa while the channel capacity is only 0.002910235. After the simulation using SWMM application, the result shows that the planned rainfall of 147.10 mm and rain intensity at peak hours of 56.67 mm/hour. The simulation results show that out of 9 channels, there are 7 channels that need to be repaired. Improvement is only needed for the depth of the channel without changing the width of the channel. From each repaired channel the depth will be added as much as 10cm. The settings for re-simulation using the dimensions of the repaired channel are not found to be overflowing channels, so the dimensions of the repaired channels are considered sufficient.

Keywords: Drainage, Runoff, SWMM Application

I. INTRODUCTION

The construction of good drainage in residential area needs to channel runoff water to reduce the potential for puddles to arise which can lead to flooding. Drainage channels are water structures that have the important function of channeling excess water on the surface. By a proper drainage channel, excess water can be channeled and reduce the potential for inundation and flooding during the rainy season.

Graha Youtefa's housing is located in the Heram District, Waena, Jayapura City. Currently, the drainage channels in the complex housing cannot accommodate runoff that occurs during high-intensity rains. One solution to help evaluate urban drainage systems is to use runoff modeling, namely the SWMM software (Tamimi et all, 2016). With good drainage channels, excess water on the surface can be controlled so as to prevent stagnant water or flooding in the area. The method used in this runoff modeling is the EPA SWMM 5.1 model. SWMM can be used to estimate the ability of a channel to accommodate runoff in a drainage system.

II. LITERATURE REVIEW

A. Normal Distribution

The normal distribution or normal curve is also called the Gaussian distribution.

$X_T = X + K_T S$ .... (1)

X_T : The expected value estimate occurs with a return period T

X : Variable average value

S : The standard deviation of the variable value

K_T : The frequency factor is a function of the probability or return period and the type of probability distribution mathematical model used for opportunity analysis. The value of the frequency factor can be seen in the Gauss Reduction table.

B. Log Normal Distribution

For analysis of the frequency of rainfall using the Log Normal distribution method, with the following equation:

$\text{Log } X_T = \text{Log } X + k.\text{SxLog } X$ .... (2)

where:

$\text{Log } X_T$: The extrapolated variable is the amount of design rainfall for the return period of T years.

Log X : The average price of the data: $\dfrac{\sum_{1}^{n} \log(X_i)}{n}$

SxLog X : Standard Deviation: $\sqrt{\dfrac{\sum_{1}^{n} (LogX_i^2 - Log\sum_{1}^{n} X_i)}{n - 1}}$

K : Gaussian reduction variable

C. Gumbel Distribution

For analysis of rainfall frequency using the E.J. Gumbel, with the following equation:

$X_T = X + K.Sx$.. (3)

Where:

X_T: The extrapolated variate, namely the amount of planned rainfall for the return period of T years.

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X : The average price of the data: $\frac{\sum_{1}^{n} X_i}{n}$

Sx : Standard Deviation: $\sqrt{\frac{\sum_{1}^{n} X_i^2 - \sum_{1}^{n} X_i}{n-1}}$

K: The frequency factor is a function of the return period and the type of frequency.

D. Log Pearson Type III Method

The statistical parameters used in the Pearson type III log distribution are:

Design Rainfall:

$Log\ X_i = Log\ \overline{X} + \mathrm{G.Sd}$ .... (4)

Average value: $Log\ \overline{X} = \frac{n \sum_{i=1}^{n} \log x_i}{n}$ .... (5)

Standard Deviation: $Sd = \sqrt{\frac{n\ \sum_{i=f}^{n} (\log X_i - \overline{log}\ X)^2}{n-1}}$ .... (6)

Coefficient of Asymmetry or Disadvantage: $CS = \frac{n \sum_{i=1}^{n} (\log X_i - \overline{log}\ X)^3}{(n-1)(n-2)xSd^3}$ .... (7)

With:

$Log\ X$ = Logarithmic value of X with a return period of T years

$Log\ \overline{X}$ = Average value from Log X

Sd = Standard deviation

G = The frequency factor is a function of the return period and the coefficients kemencengan

Cs = Slope or Asymmetric Coefficient

E. Drainage Modelling with EPA Model SWMM 5.1

EPA SWMM software can simulate runoff that occurs by inputting data on objects available in the EPA SWMM application as follows (Zarkani, Sujatmoko, & Rinaldi, February 2016):

F. Rain Gauge

SWMM uses rain gauge objects to display input data to the system. Rain gage supplies precipitation data for one or more sub-catchment areas of the study area (EPA SWMM Manual).

G. Sub-Catchment

A sub-catchment is a hydrologic unit of land where the topography and drainage system elements address the runoff surface at a point of discharge (EPA SWMM Manual).

H. Junction

Junctions may feature a confluence of natural surface drains, manholes of sewage systems, or connecting pipes (EPA SWMM Manual).

I. Outfall

The outfall is the terminal point of the drainage system which is usually defined as the end of the downstream boundary (EPA SWMM Manual).

J. Flow Divider

Flow divider is a drainage system where inflow is diverted to certain conduits. A flow divider can have no more than two conduits in a single system (EPA SWMM Manual).

K. Storage Units

The storage unit is the provision of storage volume. Storage facilities can be as small as a pond or as large as a lake. The volumetric volume of the storage unit is made from a function or table of surface area and height (EPA SWMM Manual).

L. Conduit

Conduit is a channel that drains water. SWMM uses the Manning formula to express the relationship between discharge (Q), cross-sectional area (A), hydraulic radius (R), and slope (S).

M. Pumps

Pumps are used to raise the water or raise the water level. The start and stop of the pump can be adjusted dynamically as long as the control settings are defined by the user (EPA SWMM Manual).

N. Flow Regulators

Flow regulators are structures or devices used to control or divert flow (EPA SWMM Manuals).

III. METHODOLOGY

A. Data Collection

The data collection method in this study is as follows:

1. Observation, by direct observation of the research area includes roads, housing, water flow conditions, and environmental conditions.
2. Literature means taking writings on the observed activity procedures, and theories from other supporting sources.

A. Research Sites

The drainage channel evaluation that will be analyzed is the drainage channel in Graha Youtefa's Housing, Heram.

Fig 1: Research Location Map

Source: Google

Fig 2: Satellite Map of Research Locations

Source: Google

IV. RESULTS AND DISCUSSION

A. Rain Station Selection and Rainfall Data

The rainfall data used is the annual maximum rainfall data for the last 9 years from 2014-2022 obtained from the Papua River Basin Office (BWS).

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Table I: Rainfall data for IAIN station

Year	CH Maks	After Sorted	
		Year	CH. Maks
2014	79.5	2022	221.5
2015	149.0	2015	149.0
2016	99.0	2019	126.4
2017	86.4	2021	119.2
2018	91.0	2016	99.0
2019	126.4	2018	91.0
2020	75.6	2017	86.4
2021	119.2	2014	79.5
2022	221.5	2020	75.6

Source: BWS Papua

B. Rainfall Distribution

Of the four types of distribution above that have been tested with the Smirnov-Kolmogorov test and the Chi-Square test, the smallest Dmax value is taken, in this case the Log Person III distribution which has the smallest Dmax value of 0.785. So it was concluded that for further calculations using the Log Person III distribution.

Table II: Summary of design rainfall calculation results

No.	Return period. (Year)	Normal method	Log Normal method	Gumbel method	Log Pearson III method
1	2	116.40	109.83	48.27	110.11
2	5	155.30	147.00	121.47	147.10
3	10	175.63	171.18	169.93	170.91
4	20	192.43	194.13	216.42	195.12
5	50	211.33	223.66	276.59	221.91
6	100	223.93	245.80	321.68	243.11
	Smirnov Kolmogorof Test				
DP Maximum, P Max (%)		0.8885	0.825780939	0.90	0.785
Degree of significance, a (%)		5	5	5	5
D critical (%)		0.309	0.309	30	0.309
Hypotesis		hypothesis is rejected	hypothesis is rejected	hypothesis is accepted	hypothesis is rejected
	Chi Square Test				
Chi Square Count		14.11	11.89	13.00	13.00
Critical Chi Square		5.991	5.99	5.99	5.991
Free Degrees		2	2	2	2
Degrees of Significance		5.00	5.00	5.00	5.00
Hypotesis		hypothesis is rejected	hypothesis is rejected	hypothesis is rejected	hypothesis is rejected

To find runoff discharge use the following formula:

Table III: Runoff debit

Return period	Constant	C	I	A	Q
5	0.278	0.7	101.76	0.044	0.871309824

Table IV: Channel capacity

Return period	R	S	n	A	V	Q
5	0.25	0.003	0.018	0.044	0.06614171	0.002910235

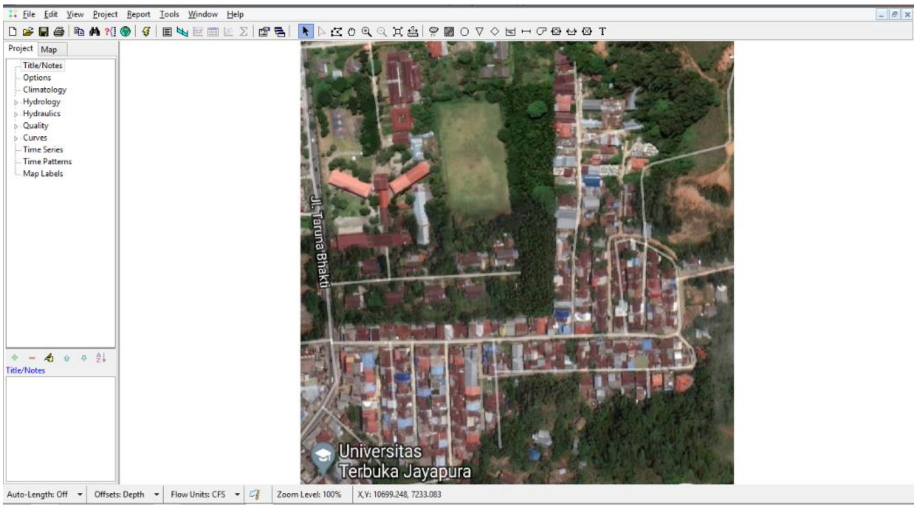
Based on the calculation, it is concluded:

Table V: Comparison of runoff discharge and channel capacity

Q Runoff	Q Channel	Conclusion
0.871309824	0.002910235	Because Q Channel < Q Runover, so the channel cannot accommodate the flow

C. Drainage Modelling with SWMM 5.1

The first step after analyzing the rainfall is to do drainage modeling using the SWMM 5.1 application by inserting a map image of the location of Graha Youtefa Housing.



Auto-Length: Off
Offsets: Depth
Flow Units: CFS
Zoom Level: 100%
X,Y: 10699.248, 7233.083

Fig 3: Study locations

Source: Personal Analysis

D. Junction

The junction is the starting point of the intersection node in the study area, which can physically represent the meeting of a natural surface drain, a culvert in a sewer system, or a pipe connection. In the study location, the junction point determination starts from junctions 1-10.

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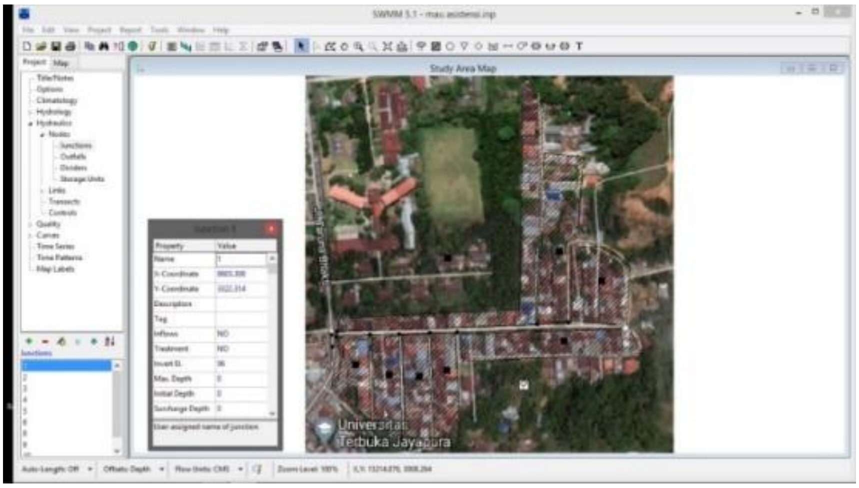


Property	Value
Name	1
X-Coordinate	[illegible]
Y-Coordinate	[illegible]
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	36
Max. Depth	0
Initial Depth	0
Surcharge Depth	0

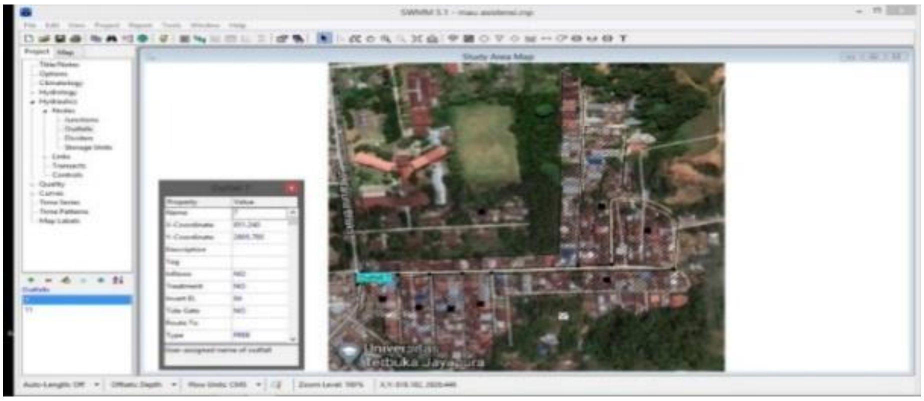
User assigned name of junction

Fig 4: Display junction

Source: Personal Analysis

E. Outfall

The outfall itself is a discharge point or a downstream point in a drainage channel flow system, in which case the outfall point itself consists of 2 discharge points in the study location. The data that needs to be included in the outfall and junction manufacturing stages is the elevation data of the study location to determine the placement of the upstream and downstream points.



Property	Value
Name	[illegible]
X-Coordinate	[illegible]
Y-Coordinate	[illegible]
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	[illegible]
Tide Gate	NO
Route To	
Type	[illegible]

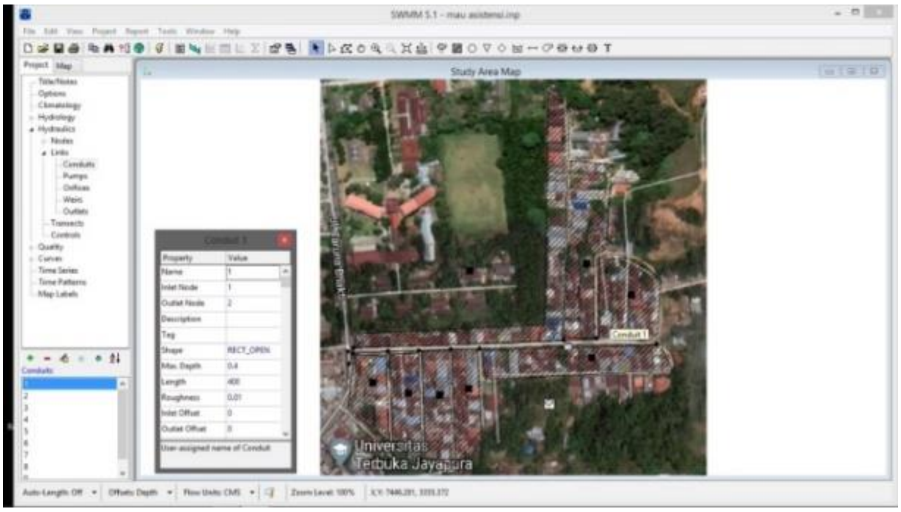
User assigned name of outfall

Fig 5: Display image outfall

Source: Personal Analysis

F. Conduit

Conduit is a channel or pipe that functions to move water from one junction to another. At the study location there are 9 conduits as a link from the junction in the previous stage. As for this stage, the selection of the shape of the channel is also carried out according to the shape of the channel in the study location, where the channel used is a rectangular channel without a lid (rectangular).

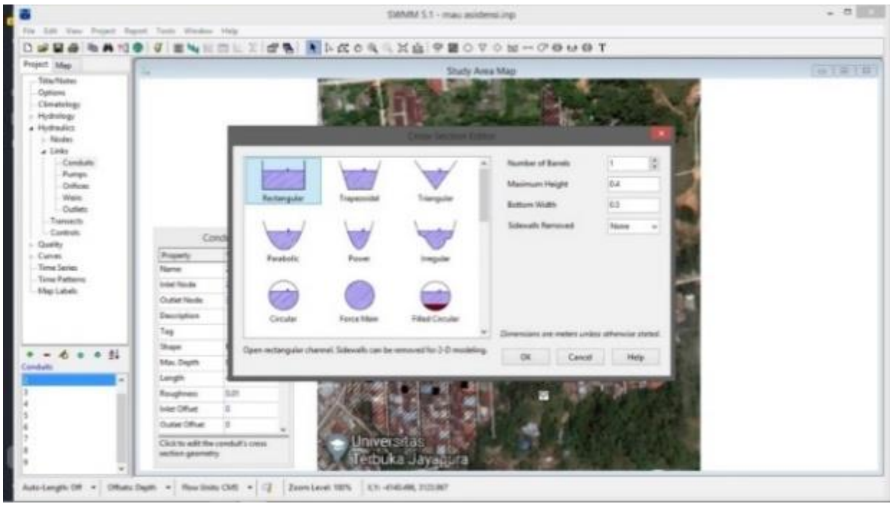


Property	Value
Name	1
Inlet Node	1
Outlet Node	2
Description	
Tag	
Shape	RECT_OPEN
Max. Depth	0.4
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0

User-assigned name of Conduit

Fig 6: Display image conduit

Source: Personal Analysis



Number of Barrels: 1
Maximum Height: 0.4
Bottom Width: 0.3
Sidewalls Removed: None

Dimensions are meters unless otherwise stated.

Open rectangular channel. Sidewalls can be removed for 2-D modeling.

Fig 7: Channel shape selection (conduit)

Source: Personal Analysis

G. Sub-Catchment

The determination of sub-catchment which is the catchment area to be analyzed. In the study area, there are 8 sub-catchment which are divided based on elevation and water flow when it rains. The data added in the sub-catchment stage is in the form of impermeable area data (imperv), which is 10% which is the statutory value for urban drainage and the slope of the channel (slope) is 0.003.

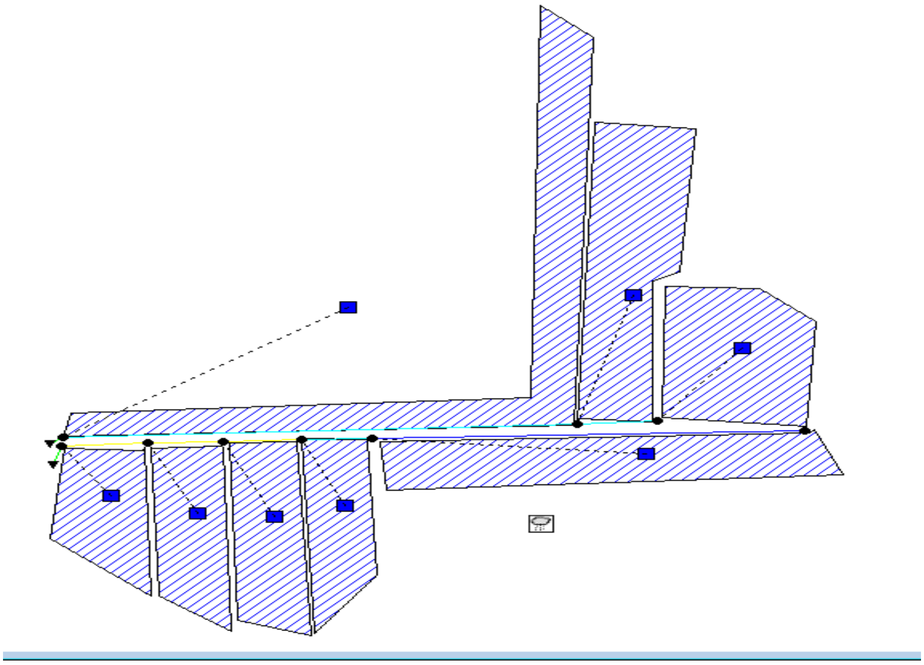


Fig 8: Display sub-catchment

Source: Personal Analysis

Table VI: Manning roughness

Channel	Information	n (Manning)
Land	Straight, new, uniform, ramps and clean	0.016 – 0.033
	Winding, sloping and grassy	0.023 – 0.040
	Not maintained and dirty	0.050 – 0.140
	The ground is rocky, rough and irregular	0.035 – 0.045
Pair stone	Empty stone	0.023 – 0.035
	Stone pair	0.017 – 0.030
concrete	Smooth, good joints and even	0.014 – 0.018
	Less smooth and uneven joints	0.018 – 0.030

Source: Google

From the table above, the channel slope value is used, which is 0.020, where the value is taken according to the condition of the channel which is less smooth, and the connection is uneven at the study location.

H. Outlet

The outlet is the gathering point for water from the sub catchment area which will go to the junction point, so that the number of outlets is determined according to the number of sub catchments at the study location, namely 8 outlets.

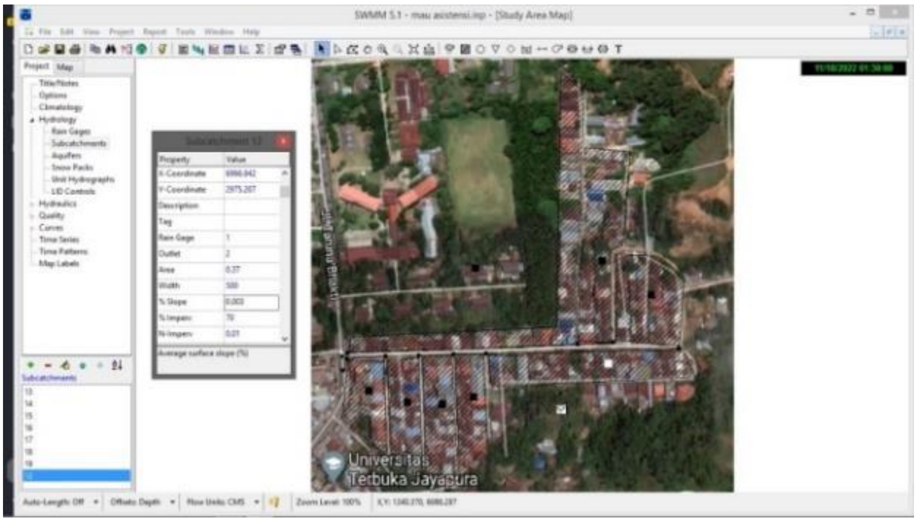
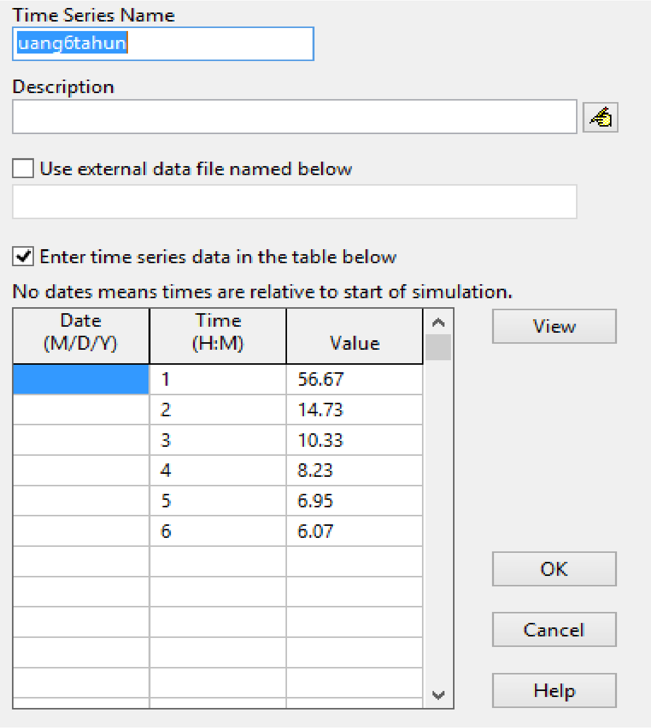


Fig 9: Display image outlet

Source: Personal Analysis

I. Time Series

In determining the time series or time series requires data results from the calculation of rainfall.



Time Series Name: uang6tahun

Description:

☐ Use external data file named below

☑ Enter time series data in the table below

No dates means times are relative to start of simulation.

Date (M/D/Y)	Time (H:M)	Value
	1	56.67
	2	14.73
	3	10.33
	4	8.23
	5	6.95
	6	6.07

Fig 10: Display image time series

Source: Personal Analysis

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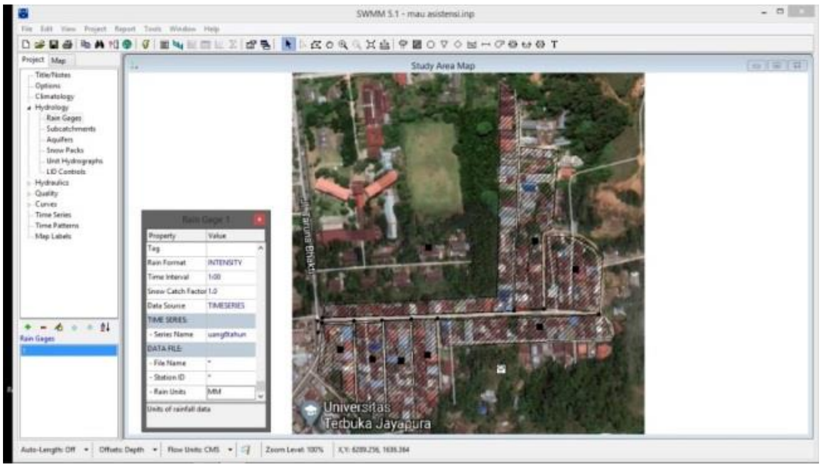
J. Rain Gauge

A complement to the time series data is the rain gauge. The rain gauge or rain station is a water catchment marker in the study area, which will then be simulated from this data to see the overflow of water in the drainage channel.



Property	Value
Tag	
Rain Format	INTENSITY
Time Interval	1:00
Snow Catch Factor	1.0
Data Source	TIMESERIES
TIME SERIES:	
- Series Name	uangftahun
DATA FILE:	
- File Name	*
- Station ID	*
- Rain Units	MM

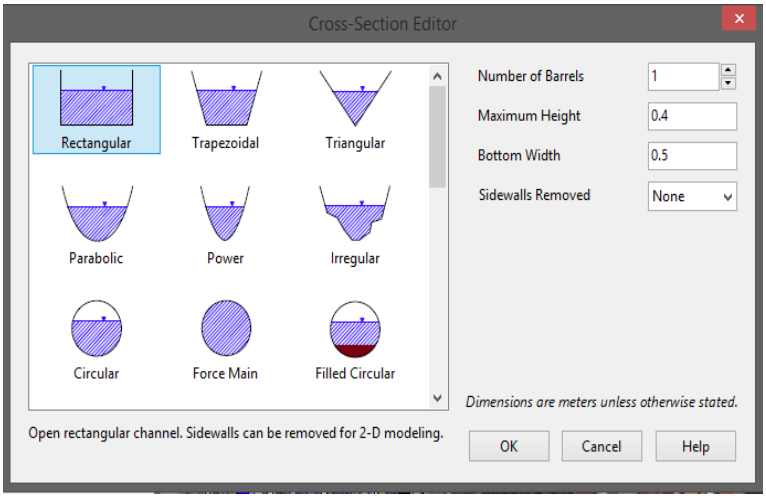
Units of rainfall data

Fig 11: Display rain gauge

Source: Personal Analysis

K. Running Process

Before the running stage, the data that has been entered will be checked to find out the value of Continuity Error, where if the Surface Runoff and Flow Routing values reach 10% then the analysis will be doubtful so it is necessary to check the data first, then it can be simulated. The following shows the flow elevation profile simulation:



Number of Barrels: 1
Maximum Height: 0.4
Bottom Width: 0.5
Sidewalls Removed: None

Dimensions are meters unless otherwise stated.

Open rectangular channel. Sidewalls can be removed for 2-D modeling.

Fig 12: Display of channel size before repair

Source: Personal Analysis

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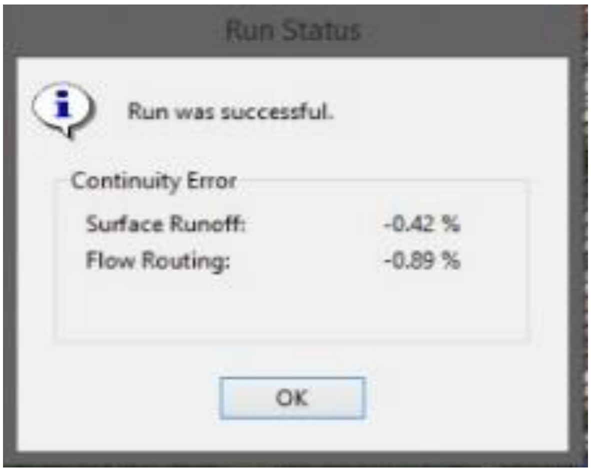


Run was successful.

Continuity Error

Surface Runoff: -0.42 %

Flow Routing: -0.89 %

Fig 13: Conduit value display

Source: Personal Analysis

The error continuity values obtained from the simulation results are 0.42% for Surface Runoff and 0.89% for Flow Routing.

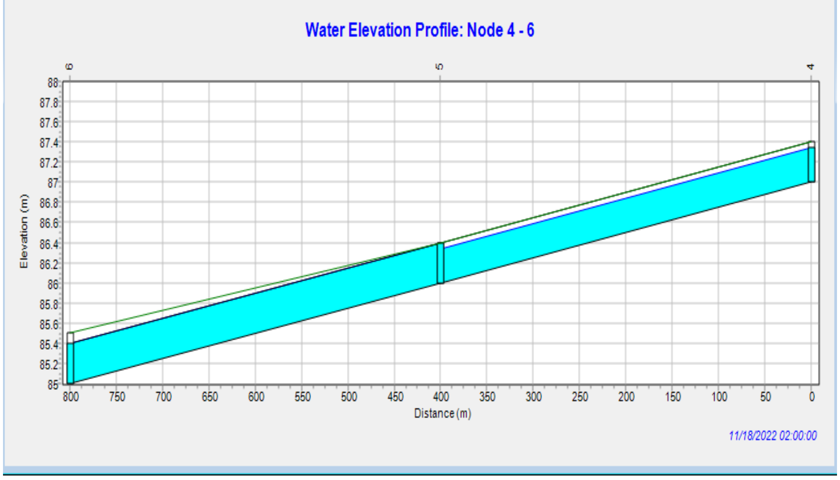
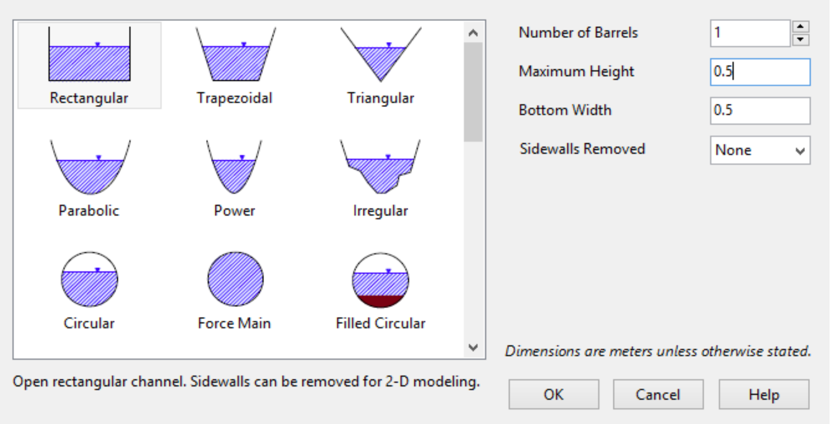


Fig 14: Display of channel 5 stream elevation profile at peak rain before repair

Source: Personal Analysis

Based on the simulation that has been done, the result shows that out of 9 channels, there are 7 channels that need to be repaired, namely channel 2,3,4,5,6,8,9. Those channels cannot accommodate high rain intensity within 6 hours (according to the simulation conducted).Channel improvement is carried out by trying to add channel dimensions, both in width and channel depth, to obtain an optimal storage capacity.



Number of Barrels: 1
Maximum Height: 0.5
Bottom Width: 0.5
Sidewalls Removed: None

Dimensions are meters unless otherwise stated.

Open rectangular channel. Sidewalls can be removed for 2-D modeling.

Fig 15: Display of channel size after repairment

Source: Personal Analysis

The redesign of the drainage channel was carried out using the trial-and-error method in the SWMM 5.1 application to obtain the dimensions of the width and height of the channel without changing the initial conditions much so that the costs incurred for channel renovation would not be large. There are things that need to be considered in changing the dimensions of the canal to be wide or deep, by increasing the depth of the canal, the water level needs to be considered so that backflow does not occur in the repaired canal, while by increasing the width of the canal, the road width will decrease so that it is avoided as best as possible.

The dimensions of channel 5 originally had a width of 0.5m and a depth of 0.4m, after evaluation the dimensions of the channel became 0.5m for width and 0.5m for depth. For all channels that experience runoff each depth is increased by 10cm. The modified channel width and depth data are then entered into SWMM 5.1 for re-simulation.

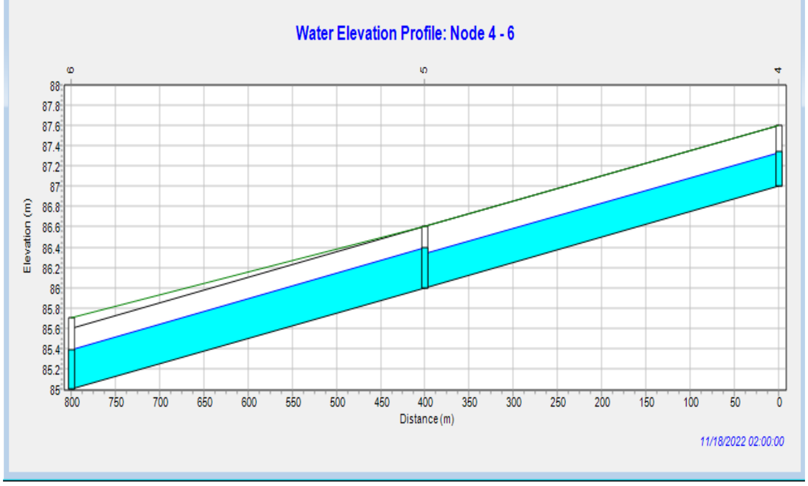


Fig 16: Channel 5 stream elevation profile display at rain peak after repair

Source: Personal Analysis

From the simulation above, no problematic channels were found after re-simulation using repair channel dimensions, so the channel dimensions were considered safe. The simulation results of the drainage network for Graha Youtefa's Housing after repairs have been carried out can be seen in Table 7. Based on the simulation results using the channel dimensions that have been corrected, there are no more channels that overflow at the peak of rainy hours. It can be seen from channel 5, which initially overflowed, now has returned to normal. The following details the dimensions of the channel before and after the repair:

Table VII: Dimensions of the channel before and after the repair

Dimensions before repair			Dimensions after repair		
Channel	**Wide (m)**	**High (m)**	**Channel**	**Wide (m)**	**High (m)**
1	0.5	0.4	1	0.5	0.4
2	0.5	0.4	2	0.5	0.5
3	0.5	0.4	3	0.5	0.5
4	0.5	0.4	4	0.5	0.5
5	0.5	0.4	5	0.5	0.5
7	0.5	0.4	7	0.5	0.4
8	0.5	0.4	8	0.5	0.5
6	0.7	0.5	6	0.7	0.6
9	0.7	0.5	9	0.7	0.6

V. CONCLUSON

1) The runoff discharge in the drainage channel at Graha Youtefa after being analyzed produces a sizable runoff of 0.871309824, due to the rain catchment area. Most of it is watertight and the channel capacity is only 0.002910235, which is the change in an urban area that was originally open land into built-up land resulting in a reduced area of infiltration and waterways can no longer hold water. Because the runoff discharge is greater than the channel discharge, the result is that most of the rain that falls to the ground surface becomes surface runoff.
2) In addition to insufficient channel capacity, water overflow also occurs due to sediment buildup from the downstream location of the Graha Youtefa housing complex.
3) After conducting a simulation using the SWMM application with a planned rainfall of 147.10 mm and rain intensity at peak hours of 56.67 mm/hour. The simulation results show that out of 9 channels there are 7 channels that need to be repaired. For channel repair, you only need to change the depth without changing the width of the channel. From each repaired channel, the depth will be added by 10cm. The settings for re-simulation using the dimensions of the repair channel are not found to have overflow channels, so the dimensions of the repair channel are considered safe.

References

1) Rangan P. R. and Tumpu M. 2021. Effect Of Calcium Hydroxide (Traditionally Called Slaked Lime) to Stabilization of Laterite Soil. IOP Conf. Series: Earth and Environmental Science 1088 (2021) 012105.

2) Rangan P. R., Tumpu M., Caroles L., Mansyur. Compressive Strength of high-strength concrete with cornice adhesive as a partial replacement for cement. IOP Conf. Series : Earth and Environmental Science 871 (2021) 012006.

3) Rangan P. R. and Tumpu M. 2021. Marshall Characteristics of AC-WC Mixture With The Addition of Anti-Flaking Additives. ARPN Journal of Engineering and Applied Sciences, 2021, 16(3), pp. 340–344.

4) Irianto and Tumpu M. 2021. Compressive Strength of Asphalt Concrete Wearing Course Mixture Containing Waste Plastic Polypropylene. ARPN Journal of Engineering and Applied Sciences, 2020, 15(17), pp. 1835–1839.

5) Tumpu M. Tjaronge M. W.. Djamaluddin A. R.. Amiruddin A. A. and La One. 2020. Effect of limestone and buton granular asphalt (BGA) on density of asphalt concrete wearing course (AC-WC) mixture. IOP Conf. Series: Earth and Environmental Science 419 (2020) 012029.

6) Tumpu M. Tjaronge M. W. and Djamaluddin A. R. 2020. Prediction of long-term volumetric parameters of asphalt concrete binder course mixture using artificial ageing test. IOP Conf. Series: Earth and Environmental Science 419 (2020) 012058.

7) Caroles L., Tumpu M., Rangan P. R., and Mansyur. 2021. Marshall properties of LASBUTAG asphalt mixes with pertalite as a modifier. IOP Conf. Series: Earth and Environmental Science 871 (2021) 012064.

8) Tumpu. M, Parung. H, Tjaronge. MW, and Amiruddin. A, A., "Failure Pattern of Prefabricated Foam Concrete as Infill Wall Under In-Plane Lateral Loading," ***Design Engineering***, issue 7 (2021), 7168-7178. ISSN: 0011-9342.

9) Anonymous. Retrieved from Wikipedia: Hydrology. Accessed 14 February 2022 8:41 p.m.

10) Anonymous (2021). Retrieved from Wikipedia: Drainage. Accessed 1 March 2022 At 18.41 p.m.

11) Anonymousi (2022). Retrieved fromi Wikipedia: Flood. Accessed March 1, 2022 At 20.42 p.m.

12) Anonymous. (2022). Retrieved from Wikipedia: Storm Water Managementi Model. Accessed March 1 2022 At 10:51 p.m.

13) C.D., I. B. (1995). Hydrology Engineering, Ke Edition 2. Jakarta: Erlangga.

14) Chrisna Justice Wicaksana, A. Y. (June 2018).

15) Hasmar, H. H. (2011). Applied Drainage, Yogyakarta.

16) Huddiankuwera A. (2018). Performance of Secondary Drainage Channels in Execution of Kelapa Dua Entrop. Scientific Journal of Engineering and Information Technology. Volume 3 issue 1. Pages 10 - 16.

17) Suripin, Dr. Ir. M.Eng (2004). Conservation of Land Resources and Ai. Yogyakarta: Andi.

18) Tamimi, R., Wahyuni, S., & Hidayah, E. (2016) 31. Evaluation Study of Drainage System in Jalan Srikoyo, District of Patrangi, Regency of Jember. Journalist of Civil and Environmental Engineering, 1: 18 - 31.

19) Yunianta A., Rochmawati R., Dwilagai D. (2022). Sustainable Drainage System in Overcoming Water Inundation Pada Hamadi Rawa Kota Jayapura. Journal of Architecture and Planning. Vol.12 No. 2 Hal. 54 - 61.

20) Zarkani, M. R., Sujatmoko, B., & Rinaldi. (February 2016). Drainage Analysis for Flood Management Using EPA SWMM (Case Study: Mutiara Witayu Housing District, Rumbai Pekanbaru). Jom FTEKNIK, Volume 3 No.1.