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IDENTIFICATION OF DRAINAGE SYSTEMS CAPACITY USING EPA-SWMM 5.1 VERSION MODELING IN GUNUNG PANGILUN OF PADANG CITY

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ABSTRACT: Floods have often occurred in the city of Padang, PALAPA Metropolitan Urban Area in recent years, this is generally caused by high rainfall and poor drainage capabilities. NVivo software is utilized to analyze the online news which reported floods occurrence. Based on the news collected from 2009–2018, it was found that Gunung Pangilun Village, Padang Utara Subdistrict was often flooded when it rained for more than 3 hours. This area is a densely populated area (1,000 people / km^2). The cause of inundation in this area is that drainage is not able to accommodate water and high rainfall intensity with the parent river in the Batang Kuranji watershed. The flooding that occurred in this area caused several schools, offices and hospitals to be flooded, a number of houses and a number of points on the local road were flooded. Therefore, it is necessary to know the large drainage capacity that is able to accommodate the amount of runoff discharge when the rain occurs using the 5-year return EPA SWMM software modeling.

Keywords: Flood inundation, Drainage, EPA-SWMM, NVivo

1. INTRODUCTION

1.1 Background

The Metropolitan Urban Area of Padang, Lubuk Alung, Pariaman (MUA PALAPA) as a National Activity Center is oriented to encourage the development of priority production sectors such as industry, marine fisheries, tourism, trade and services. MUA PALAPA is a priority location for the national urban strategic area as the center of regional growth in the Sumatra region.

For this reason, problems need to be identified that cause damage to the urban environment, which needs alternative solutions and immediate treatment. Environmental damage problems include drainage conditions, flooding, rainwater inundation, coastal abrasion and the provision of water resources infrastructure with good maintenance and environmentally conscious communities.

One of the disasters often faced by Padang City is flooding [2]. Floods are generally caused by high rainfall [3, 4] and poor drainage capabilities [5, 6]. By using NVivo software news from online media can be evaluated. Based on the news from 2009–2018, it was found that the location of the frequent flooding in Padang City is Gunung Pangilun Subdistrict, especially when it was raining for more than 3 hours (Fig. 1). This area is a densely populated area which is 1,000 people / km^2. The cause of inundation in this area is that drainage is not able to accommodate water and high rainfall intensity with the main drainage in the Batang Kuranji watershed. The floods that occurred in this area caused inundation in several schools, offices and hospitals, houses, and local roads as well.

Therefore, this research aims to identify the ability of the Gunung Pangilun (Fig. 1) drainage network against floods using the EPA SWMM (Environmental Protection Agency Strom Water Management Model).

Location of flood in Primary School No. 17 Gunung Pangilun in 2017	Location of flood at surrounding Alfaiz Mosque in 2018

Fig. 1 Visualization of the Gunung Pangilun Area (Source: Google Earth)

1.2 Literature Review

Rossman [7] states EPA SWMM is a rainfall-runoff simulation program commonly used for quantity simulation and surface runoff quality in urban areas.

NVivo is a software commonly used for qualitative research. Usually, qualitative research aims to explore and understand the data more deeply. Qualitative data is in-depth and detailed, so it is also lengthy. As a result, the analysis of qualitative data is specific, especially to summarize data and unify it in an analytical flow that is easily understood by others.

A Digital Elevation Model (DEM) is a form of presentation of the height of the earth's surface digitally. It can be seen from the distribution of points representing the shape of the earth's surface that it can be distinguished in a regular, semi-ordered, and random form.

Hidayat [8] in his research on Understanding flood disasters in the city of Padang with the content analysis of the news article explained that articles were searched using the google.co.id search engine site with the search term 'flood field site: www.padangekspress.co.id' which produced articles about floods in the city of Padang that have been published by the Padang Ekspres website. One by one the articles were opened and explored whether each one was related to flooding in the city of Padang. Articles that met the requirements were stored in the form of Ms-word documents where one article was stored as a Ms-word file. After the articles have been collected in the form of Ms-word files, the files are processed and analyzed using NVivo software version 8.

Legowo, et al. [9] stated that the DEM appeared in soil surface morphological information was used to represent the surface runoff hydrology process. Topographic structure extraction algorithms will be sloped and current direction is an important factor in describing drainage networks.

Vinay, et al. [10] said that SWMM modeling played an important role in examining problems such as urban flash floods. SWMM has become an effective tool for flood simulation in urban areas. Frequency analysis is done using the most appropriate distribution, namely, the Gumbel distribution for different return periods and the frequency value used for the development of the IDF curve (intensity frequency duration). The intensity of rain derived from the IDF curve for different return periods is used to estimate the peak runoff of each sub-watershed used as an input parameter in a runoff simulation in SWMM. The GIS methodology is used to handle spatial data simultaneously.

Waikar, et al. [11] explained that urban floods were basically caused by damaged and inefficient urban drainage systems, and caused damage to public and private buildings and disrupted public life. In order to understand the complexity associated with urban flood management, the EPA SWMM application is used. Furthermore, daily rainfall data was obtained from Asarjan closest to the rain gauge station. Arc-GIS (10.1) is used to process DEM (Digital Elevation Model) and LULC (Land Closure of Land Use) data to obtain height and water resistance respectively. Topographic data such as area, width, length, etc. Also taken from Arc-GIS. The selected extreme daily events are separated into hourly events using the reduction formula. After that, EPA SWMM was used to simulate catch response to rainfall events where runoff, water depth profiles, and outflow hydrographs were obtained. Runoff is also obtained from rational formulas for comparison purposes.

Fairizi [12] in his research used short-term rainfall data from 2001 to 2012. Rainfall data is tested according to normal, Normal log, Pearson III log, and Gumbel distribution**.** Select one result from the distribution with the smallest standard deviation. Then, it was tested by the Smirnov-Kolmogorov test to find the rainfall intensity equation. Later, the equation will be used to find the drainage dimension. To analyze inadequate drainage, SWMM Program is utilized.

1.3 Hydrological Analysis

The hydrological analysis was used for the calculation of rainfall with a five-year return period, calculation of rainfall intensity, and hyetograph count of planned rain using the Alternating Block Method (ABM) method.

1.3.1 Rainfall Analysis

If the rain data used in the calculation is in the form of a sample (limited population), then the calculation of the rain plan based on the Gumbel Probability distribution is carried out by the following formulas [13].

$$X_T = \bar{X} + S \times K_T \quad (1)$$

where :

X: rain plan with a return period T (mm)

$\bar{X}$: the average value of X (mm)

K: Gumbel frequency factor, depends on the data Yt, Yn, S_n.

1.3.2 Rainfall Intensity

Calculation of rainfall intensity uses the Mononobe method with the following formula :

$$I = \frac{R24}{24} x \left(\frac{24}{t}\right)^{\frac{2}{3}} \quad (2)$$

where :
I: rainfall intensity (mm/hour)
R_{24} : bulk plan in a return period (mm)
t: rain duration (hour)

1.3.3 Hyetograph Rain Plan

Rain distribution models that have been developed to change daily rainfall into rainy days - the uniform rain distribution model using the Alternating Block Method (ABM) method [14].

1.4 EPA SWMM Version 5.1

EPA SWMM (Environmental Protection Agency Strom Water Management Model) is a rainfall-runoff simulation program commonly used for simulating the quantity and quality of surface runoff in urban areas. The ability of this software is to be able to calculate the hydrological process that produces runoff from urban areas such as rainfall, evaporation, infiltration and determine the flood point and calculation in runoff discharge. The objects used in this research are:

a. Rain gauge includes rainfall intensity data, observation time intervals, and rainfall data sources in the form of a time series.
b. Sub-catchment includes determining the outlet of the sub-catchment, determining land use, determining the probable and impervious sub-area, determining the slope or slope of the sub-catchment, determining the width of sub-catchment, determining the manning number for surface flow, determining the percentage of impervious sub-areas, determining the depression and impervious regions, determining the percentage of impervious area without depression.
c. Junction is the point of the drainage system where the channels join. The data needed is elevation, maximum depth, storage area when there is a flag (if any), flow from outside the drainage system (if any).
d. Channels (conduit), parameters to be used are shape (channel shape), max-depth (depth), length (channel length), roughness (channel roughness coefficient).
e. Storage unit is the point of the drainage system which is a storage volume. Safety storage units include elevation or altitude, maximum depth, initial depth, potential evaporation, seepage parameters (if any), external inflow data (if any).

2. RESEARCH METHODOLOGY

This study is carried out by:

a. Gather news about floods in the MUA PALAPA from 2009 - 2018.
b. Processing flood news using NVivo software.
c. Determine locations that often occur in MUA PALAPA based on NVivo output.
d. Determine the slope of the watershed by using DEMNAS data.
e. Check and measure drainage in the field.
f. Calculate the planned rainfall and do a match test using the Chi Kaudrat method.
g. Calculate rain intensity using the Mononobe method.
h. Calculate the hyetograph of the rain plan using the Alternating Block Method (ABM) method.
i. Simulation of the EPA SWMM 5.1 program using data that has been analyzed.
j. The program simulation results in the form of runoff discharge that is accommodated by the channel and the location of the flood points that occur along the drainage canal.

3. RESULTS AND DISCUSSION

3.1 Processing News Using Nvivo

This research uses a news article that discusses waste that occurs in the city of Pariaman, Lubuk Alung, Padang (MUA PALAPA), using news data from 2009 - 2018. As for the publication of news in 1 event a lot, the news taken has very clear information, especially the location affected by the flood. In the quotations obtained, flooding in the MUA PALAPA area was more dominated by poor drainage, and damaged river basins.

From the results of NVivo processing, the area that is very often flooded is the Gunung Pangilun sub-district, Padang City, with 8 times the number of occurrences in the period (2012-2018) from the articles obtained. The problems that occur in this region are drainage which is not functioning optimally, and so on. One example of a quote taken from the article is as follows: Sewerage in the Gunung Pangilun area [15], Jalan Gajah Mada, Padang City, spilled over to cause a number of residents' houses and several points of the road in the local area to be flooded. For this reason, the researcher conducted a study to identify the ability of Gunung Pangilun's drainage, which is more precisely in the Jalan Gajah Mada area.

3.2 Conduct Field Investigations

Field investigations aim to take secondary data such as locations affected by floods, and measurements of existing dimensions, and are used in data processing and guidelines for SWMM 5.1 modeling.

3.3 Hydrological Calculation

3.3.1 Rainfall Calculation Plan

From the rainfall station map obtained, the station closest to the study location is the Khatib Sulaiman rain station (Table 1), with a total data of 10 years. This data will be used in the calculation of planned rainfall.

Table 1. Rainfall data of the Khatib Sulaiman station

Year	Rainfall (mm/day)	Year	Rainfall (mm/day)
2009	160	2014	100
2010	220	2015	206
2011	330	2016	270
2012	143	2017	195
2013	128	2018	147

For the calculation of rainfall using the Gumbel Method, Normal, Normal Log, Persion Type III Log, and the suitability of the planned rain data. With the results of the compatibility test using the Chi-Square method with the results as shown in Table 2.

Table 2. Compatibility test results Chi Square

Distribution Probabilities	X^2	X^2cr	Information
Gumbel Method	1	5.99	Accept
Normal Method	1	5.99	Accept
Log-Normal Method	1	5.99	Accept
Log Pearson Type III Method	9	5.99	Not Accepted

The results of the calculation can be seen in Table 3.

Table 3. Recapitulation of planned rainfall with the Gumbel Method

PUH	XT (mm/day)
2	180
5	264
10	319
25	389
50	441
100	492

3.3.2 Calculation of Rainfall Intensity

After obtaining rainfall values the calculation of rainfall intensity was carried out using the Mononobe method with a 5-year return period of rain. The results of the calculation of rain intensity in the form of an IDF curve (Fig. 2) which will be used in the preparation of the Hyetograph rain plan with the Alternating Block Method (ABM). The calculation of rainfall intensity using the Mononobe formula is attached to the Table 4 below.

Table 4. Recapitulation of the intensity of the 5-year rainy season with the Mononobe method

Duration		5 Year Period
Minute	Hour	263.95
30	0.5	145.26
60	1	91.51
90	1.5	69.83
120	2	57.65
150	2.5	49.68
180	3	43.99

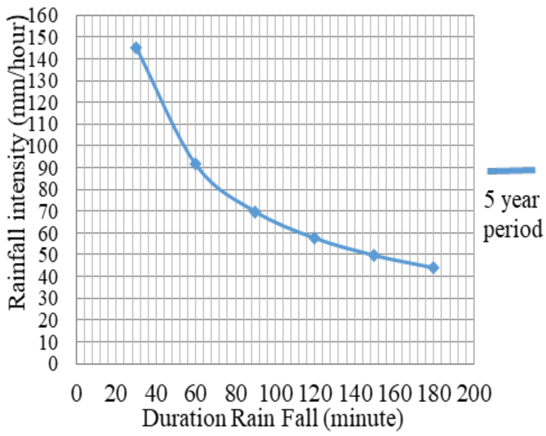

Figure 2. Curve Intensity Duration Frequency (IDF)

3.3.3 Hyetograph calculation of rain plan

The calculation of the hourly rain distribution pattern use the Alternating Block Method (ABM) with the data taken from the results of the calculation of rainfall intensity in Table 3 with the duration of the rain event taken for 3 hours (Table 5 and Fig. 3).

Table 5. Hourly rainfall distribution patterns using the ABM method

Duration (t)	Intensity (I_t)	Rainfall (I_t x t)	Cum. Rainfall	P	Hyetograph	
Hour	mm/h	mm	mm	%	%	mm
1.0	91.5	91.5	91.5	69.3	18.0	47.6
2.0	57.6	115.3	23.8	18.0	69.3	183.0
3.0	44.0	132.0	16.7	12.6	12.6	33.4
Total	193.1	338.8	132.0	100	100	264

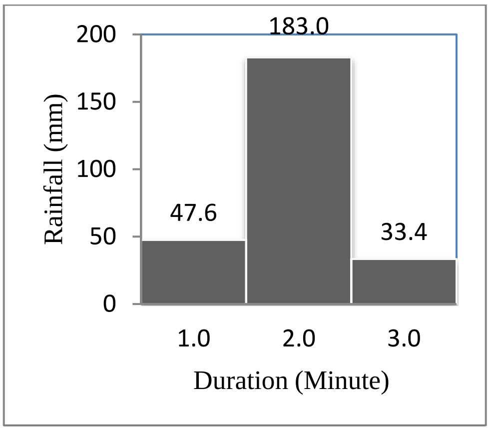

Fig. 3 Rain plan hyetograph with the ABM method

Furthermore, the results of this rain distribution will be used to calculate runoff discharge in EPA SWMM 5.1 simulations.

3.4 Simulation Results with EPA SWMM 5.1

3.4.1 Runoff discharge

From the simulation, the results are good, where the continuity error for surface runoff and flow tracing is -0.19% and -1.62% respectively. The quality of the simulation is not good if the continuity error is> 10%. From the 13 Subscathment found in this model, the highest peak runoff occurs at the subcathment6, which is 6.91M3 / second which is seen at 3:00 in Fig. 4 below. This is the peak condition of rain. While the Subcathment with the smallest flowrate is Subcathment12 with a flow of 0.62m3 / sec.

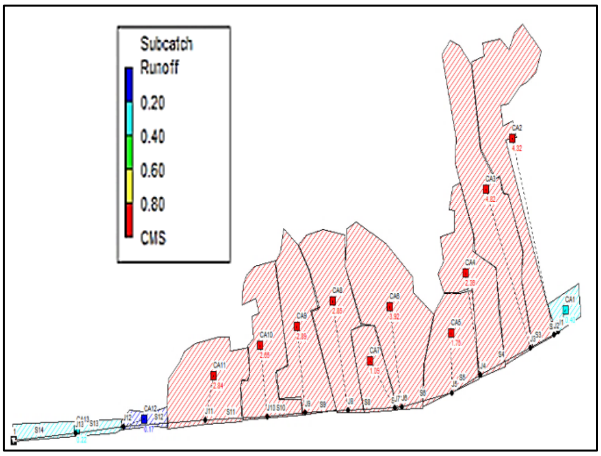

Fig. 4 Sub-catchment runoff of Gunung Pangilun area

3.4.2 Location of flood points

Table 6 below shows the location of the flooded cross-section. In addition, the duration of flooding and the volume of flooding that occurs in the affected area can also be known. Junction 6 is the longest point experiencing flooding with a duration of 4.72 hours. Junction 6 is the location of Gunung Pangilun Elementary School 17, which is almost a flood area that is in accordance with the field review. While the largest volume occurs at J3junction is a link between catchment area 3 and drainage channel Jl. Gajah Mada and is the location of the Alfa Mosque's flood permit in 2018 from news articles.

Table 6. Node flooding summary

Node	Hours Flooded	Max Rate CMS	Hour of Max Flooding	Total Flood Volume 10^6 ltr
J1	1.04	0.456	3:00	1.312
J2	3.9	6.573	3:00	31.6
J3	4.68	6.5	3:00	41.05
J4	2.48	3.095	3:00	12.14
J5	3.33	4.457	3:00	21.1
J6	4.72	5.584	3:00	21.33
J7	3.72	3.614	3:00	31.92
J8	3.49	5.211	3:00	23.74
J9	1.77	4.065	3:00	13.22
J10	3.56	5.518	3:00	30.91
J11	0.83	1.502	3:00	2.47
J12	1.13	1.765	3:00	4.17

In Fig. 5, the overflow channel is shown by a red line, the channel that is not overflowing is shown in blue, and the channel that returns to normal or recedes after overflowing is shown in green. From the simulation results it can also be seen that there is almost along the drainage channel of the Jalan Gajah Mada area, Gunung Pangilun Sub-District (Table 7) cannot accommodate runoff that occurred at the 03.30 simulations. This is caused by the dimensions of the channel that cannot accommodate runoff flow.

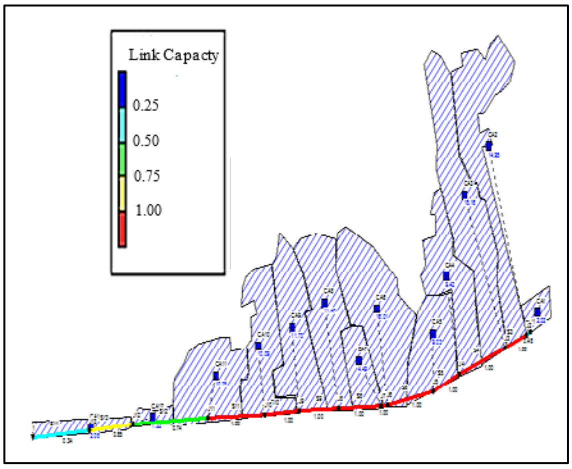

Fig. 5 The channel that overflows at the EPA SWMM 5.1 of Gunung Pangilun area

Table 7. Conduit surcharge summary

Con-duit	Hours Both Ends Full	Hours Upstream Full	Hours Down stream Full	Hours Above Normal Flow	Hours Capacity Limited
S2	1.03	1.03	1.03	0.07	1.03
S3	3.89	3.89	3.89	0.12	3.89
S4	4.68	4.68	4.68	4.58	4.68
S5	2.48	2.48	2.48	2.51	2.48
S6	3.32	3.32	3.32	3.28	3.32
S7	2.33	2.33	2.33	0.32	2.33
S8	4.72	4.72	4.72	4.66	4.72
S9	3.48	3.48	3.48	0.5	3.48
S10	1.76	1.76	1.76	1.78	1.76
S11	3.54	3.54	3.54	3.54	3.54
S12	0.82	0.82	0.82	0.82	0.82
S13	1.11	1.11	1.11	1.17	1.11

4. CONCLUSIONS

From the simulation results using the NVivo application, the location of frequent flooding was found in the MUA PALAPA area (Padang, Lubuk Alung, Pariaman), namely the Gunung Pangilun Padang area.

Furthermore, the floods were calculated in the Gunung Pangilun area where the largest peak runoff occurred at sub-catchment 6, which amounted to 6.91m3 / second, which was the location of Gunung Pangilun Primary School No. 17, which was almost flooded according to the field review, and the news obtained was carried out. Sub-catchment with the smallest runoff peak flow is sub-catchment 12 with a flow of 0.622 m^3/sec.

There are 8 channels that are the location of flood points during the simulation hours of 3:30, namely channels S3, S4, S5, S6, S7, S8, S9, S10, while the channels that do not overflow during a flood are channels S2, S11, S12 and S13. The overflow of water in the channel occurs because of the capacity of the channel that cannot accommodate runoff discharge, the waste contained in the channel, and the accumulation of sediment in the canal.

Risk flood can be minimized by: normalize the drainage, widened the dimensions of drainage, and create a retention pool in a sub-catchment area that has a large impact discharge.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Book III of National Mid-term Development Planning 2015-2019.

[2] Istijono, B., Ophiyandri, T., Aprisal and Nurhamidah. 2019. The Effect of Flood to Quality Index of Soil Physical Properties at the Downstream of Kuranji River Watershed, Padang City. International Journal of GEOMATE, Feb., 2019 Vol.16, Issue 54, pp.74 – 80.

[3] Khan, A. N. (2013). Analysis of 2010-flood causes, nature and magnitude in the Khyber Pakhtunkhwa, Pakistan. Natural hazards, 66 (2), pp. 887-904.

[4] Gale, E. L., & Saunders, M. A. (2013). The 2011 Thailand flood: climate causes and return periods. Weather, 68 (9), pp. 233-237.

[5] Adelekan, I. O. (2011). Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. Natural Hazards, 56 (1), pp. 215-231.

[6] Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., McLean, L., & Campbell, J. (2008). Unjust waters: climate change, flooding and the urban poor in Africa. Environment and urbanization, 20 (1), pp. 187-205.

[7] Rossman, Lewis A. 2015. Storm Water Management Model User's Manual Version 5.1. U.S Environmental Protection Agency, USA.

[8] Hidayat, B, 2017, Understanding Flood Disasters in Padang ity with Content Analysis of News Articles (in bahasa: Memahami Bencana Banjir di Kota Padang dengan Content Analysis Artikel Berita), Civil Engineering Journal, Andalas University.

[9] Legowo, S., Hadihardaja, I. K., Enung, T. S. H,. 2019. Application of the Digital Elevation Method for Flood Estimates on the Ciliwung River in West Java, International journal of GEOMATE, July 2019, Vol.17, Issue 59, pp.154-165.

[10] Vinay, R., Umamahesh, N., Sriramoju, P. S., Kumar, P. A. 2018. Simulation of the Urban Drainage System using the Storm Water Management Model (SWMM). National Institute of Technology, Warangal, Andhra Pradesh, India.

[11] Waikar, L, M and Namita, U. 2015. Model of Flood Transfer using EPA SWMM 5.
Department of Civil Engineering and Water Management, Technical Institute and Guru Shri Guru Gobind Singhji Teknologi Nanded, (M.S) India.

[12] Fairizi, D, 2015. Drainage Channels Analysis and Evaluation in Talang Kelapa Housing Area in Sub watershed Lambidaro, Palembang City. The University of Sriwijaya.

[13] Kamiana, I Made. 2011, Debit Calculation Techniques for Infrastructure (in bahasa: Teknik Perhitungan Debit Rencana Bangunan Air), Graha Ilmu, Yogyakarta

[14] Chow, V.T., Maidment, D.R. & Mays (1988) Applied Hydrology. New York: Mc Graw-Hill Book Company.

[15] Istijono, B., Aprisal, Ophiyandri T., and Nurhamidah. 2019. A Study of the Quality of Soil Infiltration at the Downstream of Kuranji River, Padang City. International Journal of GEOMATE, April 2019, Vol.16, Issue 56, pp. 16-20