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Lid Analysis using EPA SWMM 5.2 Application (Case Study: DPR Road Section, Padang City)

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ABSTRACT

Padang City has experienced rapid development in infrastructure, but the limited green open space presents a significant challenge to the city's drainage system, resulting in frequent flooding during the rainy season which has a negative impact on the economy, health, and safety of the community. This study aims to identify the intensity of rainfall, analyze the implementation of Low-Impact Development (LID) technology and without LID implementation using EPA SWMM 5.2 software in the DPR Street area, Dadok Tunggul Hitam Village, Padang City. The practical implications of the implementation of Low Impact Development (LID) for general city management are to reduce drainage loads by managing rainfall locally, improve water quality by reducing rainfall pollution, reduce flood risks by managing rainfall effectively, improve city aesthetics by creating green and beautiful open spaces, and reduce infrastructure costs by managing rainfall locally and reducing the need for large drainage systems. The main benefits of the research results for flood management policies in Padang City are to improve the quality of life of city residents by creating a healthier and more comfortable environment, increase city resilience to climate change and natural disasters, and improve resource management efficiency by managing rainfall locally. Using 10 years of rainfall data from BMKG and primary data related to drainage channel dimensions, hydrological and hydraulic analyses and drainage system simulations were carried out. The results of the study showed that the application of LID, such as Rainfall Garden, Rainfall Barrel, Bioretention Cell, Infiltration Trench, and Permeable Pavement, application of LID an area can reduce the depth of inundation by 57,717%, the volume of runoff by 74.247%, and the peak runoff by 68,069%. The implementation of LID in an area of 73.54 Ha has proven effective in reducing the risk of flooding, strengthening drainage infrastructure, and providing sustainable solutions in dealing with urbanization in Padang City.

Keywords: *Drainage System; Rainfall; SWMM; LID; Tunggul Hitam*

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INTRODUCTION

The city of Padang is experiencing rapid development in terms of facilities and infrastructure, with an increasing number of housing development projects, city facilities and industry from year to year. This change in spatial planning has an impact on reducing green open land, which in 2023 will only be recorded at around 8.77% of the total area of Padang City (Annisa, 2023). As development continues, the city faces challenges in providing an effective urban drainage system. Adequate drainage is needed to support community comfort and mitigate the impact of reduced land for absorbing rainfall In the rainy season, flooding is one of the main problems that often occurs. Data from the Central Statistics Agency (BPS) in 2021 noted that 8 out of 11 sub-districts in Padang City experienced flooding, with Koto Tangah being the most affected sub-district, experiencing flooding 15 times (Sastra, 2023). Flooding is caused by high rainfall intensity, as well as people's behavior of littering and piling up materials that clog drainage channels. Jalan DPR in Dadok Tunggul Hitam is located in Padang City, West Sumatra, which has geographical conditions and high rainfall that results in waterlogging in the Jalan DPR area, with a depth of ±40 cm (Maarifatullah, 2022), causing material losses and threats to public health and safety. To overcome the problem of flooding, the Low-Impact Development (LID) approach can be applied as a solution. Some specific urgencies of using LID compared to conventional approaches in Padang City are that it is more environmentally friendly compared to conventional approaches that often use heavy chemicals and technology, more sustainable compared to conventional approaches that often only focus on short-term solutions, more flexible compared to conventional approaches that often require large investments and complex planning. Thus, LID can be an effective solution to overcome environmental problems and improve the quality of life of the people in Padang City.

METHODS

Research location

Research location in the Dadok nggul Hitam sub-district area, Koto Tangah District, Padang City. especially the Jalan DPR area is located with an area of 73.54 Ha. Boundaries of the DPR road drainage evaluation observation area, Ex. Dadok stump Hitam, subdistrict. Koto Tangah, Padang City only includes:

a. North Side: Drainage channels and housing (Jalan Anyelir)
b. South side: Empty land drainage channel (Jalan Heler)
c. West Side: Drainage channels and housing (Jalan DPR V and Jalan DPRD V)
d. East Side: Drainage channels and housing (Bypass Road)

Figure 1. Research Location

Research Equipment

The equipment needed for this research is

a. Meter
b. Laptops
c. Microsoft Excel Software

d. EPA SWMM 5.2 software

Data collection

The data obtained from this research are primary and secondary data. Primary data obtained by direct research in the field such as taking documentation, measuring drainage size. Secondary data is data obtained from related investigations. Then data processing uses the EPA Swmm 5.2 application. Field data validation method against model simulation used in EPA SWMM 5.2.

1. Comparison of Field Data with Simulation Results: Comparing field data with EPA SWMM 5.2 model simulation results to determine the suitability between the two.
2. Statistical Analysis: Using statistical analysis to compare field data with EPA SWMM 5.2 model simulation results.
3. Data Visualization: Using data visualization to compare field data with EPA SWMM 5.2 model simulation results.

Data Processing Procedures

The data processing steps include:

1. Processing rainfall data with a data length of 10 years, namely from 2014 – 2023 Bendung Koto Tuo Station.
2. Calculation of probability distribution rainfall data and testing using the Smirnov-kolmogorof method to obtain the design rainfall intensity duration and rainfall curve graph.
3. Look for the intensity of rainfall with return periods of 2, 5 and 10 years. Rainfall intensity is found using the mononobe formula.
4. Data on segment area/subcatchman width, %slope, %imprevious, outlet, infiltration, LID control, and others.
5. Data on channel dimensions, channel length, channel elevation, and Manning roughness coefficient to obtain junctions and conduits.
6. Run the drainage program, after all the data has been entered, select run simulation and the program will run a simulation of the data that we have entered. The resulting output is a simulation of the data that we have entered and a report on the results of the running program (status report), infiltration values, run off, discharge Q values and flow velocity. The simulation of this model can be considered successful assuming that there are no errors during the machining process and the demonstration properties should be good if the conformance error is <10%. Men (2022)
7. Simulation results without applying LID and using LID, the results show a comparison between the inundation height without LID and the inundation height with LID. Analysis of the simulation results to determine the effectiveness of LID practices in reducing runoff and increasing infiltration. Compare before and after LID implementation scenarios to assess the positive impact.

Application of LID

The application of Low Impact Development (LID) is highly dependent on site characteristics such as topography, soil type, land use, and rainfall patterns. Here are some applications of LID in subcatchments. Rossman (2022):

1. Bio-retention Cell

   A bio-retention cell is a depression containing vegetation growing in an engineered soil mixture placed on a gravel drainage base to provide storage, infiltration, and evaporation of both direct rainfall and runoff captured from the surrounding area. The reason for choosing a bio-retention cell is because it can be effective in reducing surface runoff, improving water quality, and providing habitat for plants and animals.

2. Rain Garden

   A rain garden is a type of bio-retention cell that consists only of an engineered soil layer without a gravel layer underneath, has a vegetated area designed to capture and absorb rainwater from roofs, roads, and sidewalks. Important parameters include garden size, plant type, soil depth, and infiltration capacity. Reason for selection: Rain gardens are chosen because they can be effective in reducing surface runoff, improving water quality, and providing habitat for plants and animals.

3. Permeable Pavement

   Permeable Pavement is an excavated area filled with gravel and paved with porous concrete or asphalt mixture. The Block Paver system consists of impermeable paver blocks placed on a layer of sand or gravel with a gravel storage layer underneath. Reason for selection Permeable pavement is chosen because it can be effective in reducing surface runoff, improving water quality, and reducing drainage loads.

4. Infiltration trench
5. Infiltration trench is a trench filled with permeable material such as gravel to facilitate rainwater infiltration into the soil. Parameters that must be considered include trench dimensions, type of filling material, and infiltration capacity. Reason for selection: Infiltration trench is chosen because it can be effective in reducing surface runoff, improving water quality, and providing habitat for plants and animals
6. Rain Barrels

   Rain barrels are containers used to capture and store rainwater that flows from the roof of a building. Parameters to consider include storage capacity, container material, and water discharge system can release or reuse rainwater during the dry season. Reason for selection: Rain barrels are chosen because they can be effective in reducing surface runoff, saving water, and reducing maintenance costs.

RESULT AND DISCUSSION

Hydrological Analysis

Hydrological analysis uses 10-year BMKG rainfall data, from the West Sumatra Province Water Resources and Construction Service at Bendung Koto Tuo Station, Koto Tangah District.

Table 1. Maximum Annual Rainfall Data

No	Year	Average Rainfall
1	2014	153
2	2015	145
3	2016	218
4	2017	140
5	2018	151
6	2019	111

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7	2020	143
8	2021	174
9	2022	162
10	2023	137

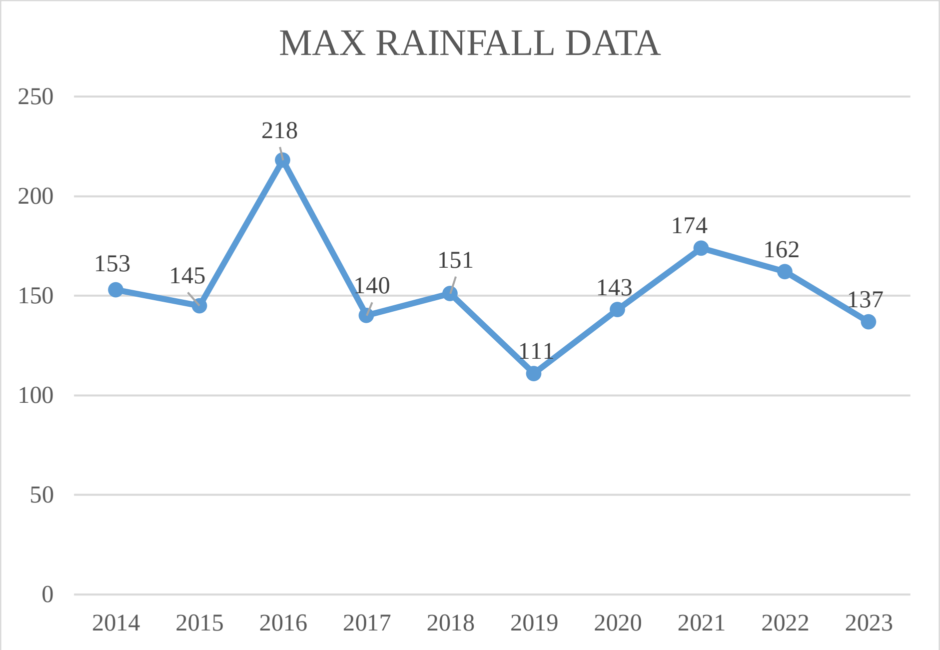

Figure 2. Maximum Annual Rainfall Graph

Rainfall Data Processing
To determine the frequency distribution that will be used in analyzing data using the Cumbel, Normal, Log Normal, and Log Pearson Type II methods with predetermined statistical parameters. Kamiana (2011).

Table 2. Rainfall Analysis Using 4 Methods

Distribution Type	Condition	Calculation		Conclusion
Normal	Cs ≈ 0	Cs =	1,217	Not Eligible
	Ck ≈ 3	Ck =	3,004	
Gumbel	Cs = 1.1396	Cs =	1,217	Not Eligible
	Ck = 5.4002	Ck =	3,004	
Log Normal	Cs = 0,104	Cs =	0,537	Not Eligible
	Ck = 3,194	Ck =	2,128	
Log-Pearson III	Apart From The Above Values	Cs =	0,537	Eligible
		Ck =	2,128	

From the calculation of statistical parameters, the four methods that meet the requirements are the Log Pearson III method.

Conformity Test Processing
This conformity test examination is intended to determine the truth of the frequency distribution hypothesis. The results of the Smirnov-Kolmogorov test analysis can be seen in the image below:

Table 3. Smirnov-Kolmogorof test

Year	X	Log X	Largest Sequence	f(t)	i	P(Xi)	P'(Xi)	D = ΔPi
						i/(n+1)		|P'(Xi) - P(Xi)|
2014	153,00	2,185	2,338	2,093	**1**	0,091	0,032	0,0593
2015	145,00	2,161	2,241	0,802	**2**	0,182	0,201	0,0192
2016	218,00	2,338	2,210	0,393	**3**	0,273	0,338	0,0656
2017	140,00	2,146	2,185	0,066	**4**	0,364	0,448	0,0845
2018	151,00	2,179	2,179	-0,010	**5**	0,455	0,473	0,0188
2019	111,00	2,045	2,161	-0,242	**6**	0,545	0,560	0,0143
2020	143,00	2,155	2,155	-0,321	**7**	0,636	0,591	0,0455
2021	174,00	2,241	2,146	-0,443	**8**	0,727	0,638	0,0890
2022	162,00	2,210	2,137	-0,567	**9**	0,818	0,687	0,1314
2023	137,00	2,137	2,045	-1,772	**10**	0,909	0,976	0,0670
Total		**21,80**				**D Maks.**		**0,131**

From the calculations in the image above, it shows that the value of ΔPi max = 0.131. Critical ΔP data at rank n = 10 (number of data) and for 5% degrees of freedom, we obtain Critical ΔP = 0.41 from the data in Table 2.8. Because the ΔPi max value is smaller than the Critical ΔP value (0.131 < 0.41), the distribution equation obtained is acceptable.

Analysis of Rainfall Planning for Return

Calculating the design rainfall with the K_T value based on the T value and Cs or G value, planned rainfall with a return period (T) = 5 years and Cs value (Log Pearson III method). Kamiana (2011).

Log X_5 = (LogX)̅+K_T×S Log
X_5 = 10^2.0185 = 173.935 mm

The recapitulation of design rainfall using the Log Pearson Type III method can be seen from the table below:

Table 4. Rainfall Table Designed by the Pearson Log Method III

T	P(%)	Cs	K_T	Log X_T	X_T (mm)
2	50	0,5372	-0,0889	2,1730	148,922
5	20	0,5372	0,8000	2,2404	173,935
10	10	0,5372	1,3249	2,2802	190,634
25	4	0,5372	1,9208	2,3254	211,544
50	2	0,5372	2,3288	2,3564	227,171

Rainfall Intensity

Based on the research location, the DPR road area has an area of more than 10 Ha and less than 100 Ha, so a return period of 2-5 years is used. Rainfall intensity using the mononobe formula for a 5 year return period is as follows. Kamiana (2011)

Rainfall Intensity Hujan (I) = $\frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{2/3}$

$t_c = t_o + t_d$

$t_o = \frac{2}{3} \times 3{,}28 \times L \times \frac{n}{\sqrt{S}}$

$t_o = \frac{2}{3} \times 3{,}28 \times 676 \times \frac{0{,}011}{\sqrt{0{,}355}} = 27{,}29\ menit$

$t_d = \frac{ls}{60 \times V} = \frac{400}{60 \times 3} = 2{,}2\ menit$

t_c= 27,29 menit $+ 2{,}2\ menit$ = 29,49 menit = 0,4915 jam

Intensitas Hujan (I) = $\frac{173{,}935}{24} \times \left(\frac{24}{0{,}4915}\right)^{2/3}$ = 96,82 mm/jam

Table 5. Calculation of Rainfall Intensity

Return period		**2th**	**5th**	**10th**	**25th**
R24 (mm)		**Rainfall Intensity(mm/hour)**			
t (minute)	t (Hour)	148,9	173,9	190,6	211,5
10	0,2	170,5	199,1	218,2	242,2
30	0,5	82,0	95,7	104,9	116,4
60	1,0	51,6	60,3	66,1	73,3
90	1,5	39,4	46,0	50,4	56,0
120	2,0	32,5	38,0	41,6	46,2
150	2,5	28,0	32,7	35,9	39,8
180	3,0	24,5	28,6	31,3	34,8

The results of the calculation of rainfall intensity can be seen that the shorter the rainfall, the higher the intensity and the longer the birthday, the higher the rainfall intensity.

DPR Road Area Subcatchment

DPR road area, Kel. Dadok stump Hitam, subdistrict. Koto Tangah, Padang City, the case study area is divided into 6 subcatchments or rainfall catchment area segments which can be seen in the image below:

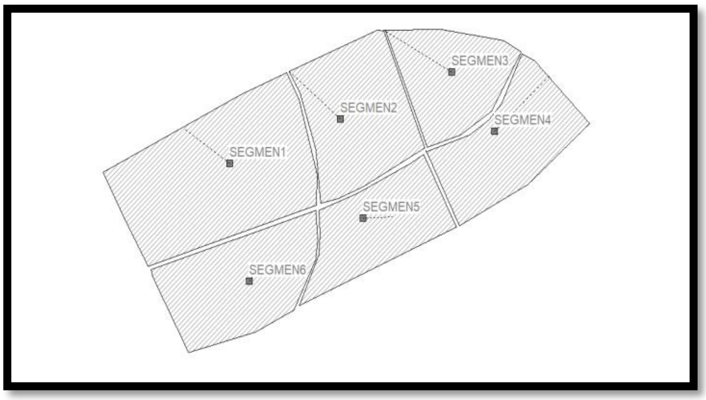

Figure 3. Research Area Subcatchment

Drainage Channel Data
From the results of a survey at the research location which was carried out over 4 days, namely on 15 August 2024, 20 August 2024, 29 August 2024, and finally on 15 September 2024. A total of one hundred and sixty six drainage channels were found, each of which had different dimensions. -different and also different types of drainage.

Hydraulic Analysis
QMax = At ×V
P06 (At) = H ×b
At = 1,1 × 3,2 = 3,52 m^2
V = 2 m/s (Permen PUPR no.12/PRT/M 2014)
QMax P06 = 3,52 m^2× 2 m/s = 7,04 m^3/s
Tinggi jagaan P06 (f) = 0,3 (Sumber: Kementerian Pekerjaan Umum Direktorat Jeneral Cipta Karya, 2012, Kustyaningrum, 2020)
P06 (h) = H-f
h = 1,1 - 0,3 = 0,8 m
P06 (A)= b × h
A = 3,2 × 0,8 = 2,56 m^2
P06 (P) = b + (2 ×h)
P = 3,2 + (2×0,8) = 4,8 m
P06 (R) = A/P
R = 2,56/4,8 = 0,533 m
P06 (S) = Δt/l
S = (5,770-5,620)/101,67 = 0,001
P06 (V) = 1/n×R^(2/3)×S^(1/2)
V = 1/0,012× 〖0,693〗^(2/3)× 〖0,001〗^(1/2) = 0,842 m/s
Channel Discharge
P06 (Q) = A× V
Q = 2,56 × 0,842 = 2,156 m^3/s
Peak Discharge of Surface Runoff . Kamiana (2011).
Segment 1
= 0.278 × C × I × A
= 0.278 × 0.6 × 96.82 × 0.2
= 3.2 m^3/s

Implementation of LID
Technical constraints that may arise during the implementation of Low Impact Development (LID) at the research location of Jalan DPR in Dadok Tunggul Hitam may include:
1. Land Limitations: Limited land available for LID implementation can be a technical constraint.
2. Non-ideal Topography: Non-ideal topography can affect the effectiveness of LID in reducing surface runoff.
3. Poor Soil Quality: Poor soil quality can affect the ability of the soil to absorb rainwater.
4. Resource Limitations: Limited resources, such as costs and labor, can be technical constraints.
5. Dependence on Technology: Dependence on technology can be a technical constraint if the technology used is ineffective or unreliable.

6. Infrastructure Expansion: Expansion of infrastructure required for LID implementation can be a technical constraint.
7. Coordination with Other Parties: Coordination with other parties, such as the government and the community, can be a technical constraint.

Factors Affecting the Effectiveness of LID in Reducing Runoff Volume and Inundation Depth

1. Runoff Coefficient: The runoff coefficient can affect the effectiveness of LID in reducing runoff volume.
2. Area: The area can affect the effectiveness of LID in reducing runoff volume.
3. Inundation Depth: Inundation depth can affect the effectiveness of LID in reducing runoff volume.
4. Infiltration Capacity: Infiltration capacity can affect the effectiveness of LID in reducing inundation depth.
5. Storage Capacity: Storage capacity can affect the effectiveness of LID in reducing inundation depth.
6. Flow Capacity: Flow capacity can affect the effectiveness of LID in reducing inundation depth.

Long-Term Environmental Benefits in the Study Area

1. Flood Risk Reduction in the Study Area by managing surface runoff effectively.
2. Improving Water Quality in the Study Area by reducing pollution and increasing soil infiltration capacity.
3. Reducing Infrastructure Needs by managing surface runoff effectively.

Analysis Results Using the EPA SWMM 5.2 Application

After running it using existing data without applying LID (Low Impact Development), it turned out that there was flooding in the Jalan DPR area with a depth of 91,909 mm and a volume of 41,491 x 10^6 liters which can be seen in the status report.

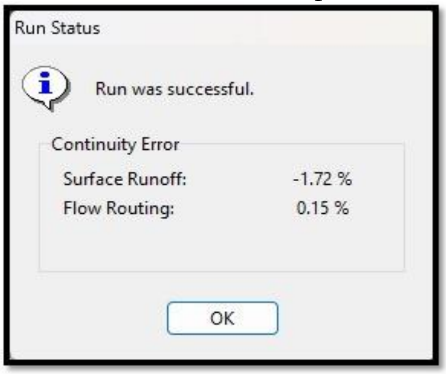

Figure 4. Results of Running Without LID

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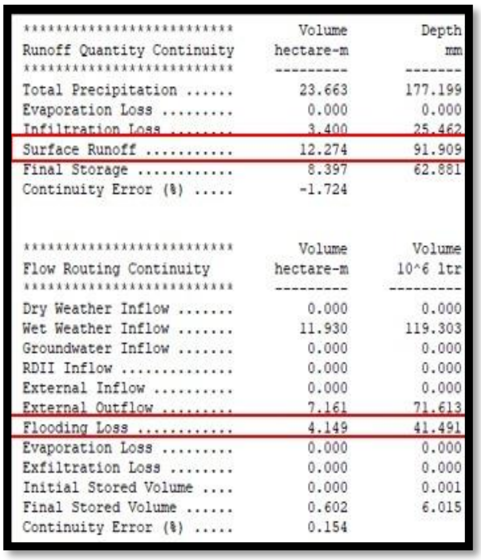

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	23.663	177.199
Evaporation Loss	0.000	0.000
Infiltration Loss	3.400	25.462
Surface Runoff	12.274	91.909
Final Storage	8.397	62.881
Continuity Error (%)	-1.724	

Flow Routing Continuity	Volume hectare-m	Volume 10^6 ltr
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	11.930	119.303
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	7.161	71.613
Flooding Loss	4.149	41.491
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.001
Final Stored Volume	0.602	6.015
Continuity Error (%)	0.154	

Figure **5.** Report Results Without LID

There are nodes where the water level reaches a maintenance level or excess pressure surcharge nodes due to air flow that is greater than the capacity of the connected pipe or channel. This results in the flow of water being pushed back or blocked, causing the potential for local flooding around the node

After running it using existing data and applying additional 5 LID (Low Impact Development) concepts, namely: bio-retention cell, permeable pavement, infiltration trench, rainfall garden and rainfall barrel, it turns out that the inundation in the Jalan DPR area is reduced from before to a depth of 53.048 mm and the volume of 10,685 x 10^6 ltr can be seen in the status report.

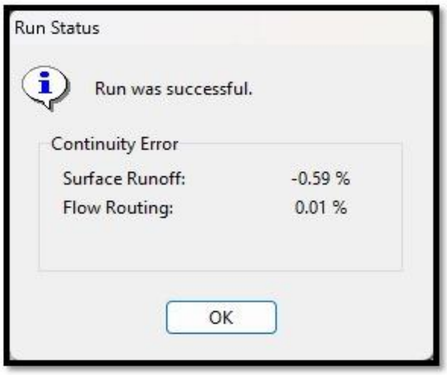

Figure **6.** Results of Running With LID

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Runoff Quantity Continuity	Volume hectare-m	Depth mm
Initial LID Storage	0.432	5.880
Total Precipitation	13.031	177.200
Evaporation Loss	0.000	0.000
Infiltration Loss	1.639	22.289
Surface Runoff	3.901	53.048
LID Drainage	0.009	0.124
Final Storage	7.994	108.702
Continuity Error (%)	-0.592	

Flow Routing Continuity	Volume hectare-m	Volume 10^6 ltr
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	3.787	37.870
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	2.419	24.195
Flooding Loss	1.068	10.685
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.001
Final Stored Volume	0.299	2.985
Continuity Error (%)	0.014	

Figure **7.** Report Results With LID

CONCLUSIONS

Application of LID in the DPR Road area Kel. Dadok Tunggul Hitam, Koto Tangah District, Padang City with an area of 73.54 Ha can reduce the depth of inundation by 57.717%, the volume of runoff by 74.247%, and the peak discharge of runoff (peak flood discharge) by 68.069%. From the percentage results obtained, the application of LID has a large impact on reducing flooding, but there is still flooding. To overcome the flooding, the author suggests changing the size of the channel dimensions where the flooding occurs. More specific recommendations on the most effective and feasible types of Low Impact Development (LID) to be widely implemented in Padang City:

1. Bio-retention Cell can be an effective option to reduce surface runoff and improve water quality in Padang City.
2. Rain GardenThis technique involves creating a catchment area with vegetation designed to capture and filter rainwater, allowing infiltration into the soil and reducing surface runoff. Bioretention is effective in improving water quality and reducing flood risk.
3. Permeable Pavement: Replacing pavement with porous material allows rainwater to seep directly into the ground, reducing runoff and helping to recharge groundwater. This technique is suitable for parking areas, sidewalks, and roads with low to moderate traffic.
4. Rain Barrels: Collecting rainwater from building roofs for reuse, for example for irrigation or other non-potable purposes, helps reduce runoff volume and utilize water resources efficiently.
5. infiltration trench The advantages of infiltration trench include relatively low implementation costs, ease of maintenance with regular cleaning, and the ability to be combined with other LID techniques such as bioretention or rain gardens to increase the effectiveness of sustainable rainwater management.

Research Implications

1. This study emphasizes the importance of sustainable and environmentally friendly drainage planning in reducing flood risks and improving water quality.
2. This study shows that Low Impact Development (LID) technology can be an effective solution in reducing surface runoff and improving water quality.
3. Integration with City Planning: This study emphasizes the importance of integrating drainage planning with overall city planning.

Thus, this study can provide significant implications for local government policies in Padang City drainage planning.

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