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IMPLEMENTATION OF POROUS-WALLED INFILTRATION WELL DESIGN TO REDUCE SURFACE RUNOFF AT CAMPUS I STATE UNIVERSITY OF MALANG USING EPA SWMM 5.2 SOFTWARE

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ABSTRACT

The rapid expansion of urban activities at Universitas Negeri Malang has reduced rainwater infiltration and increased surface runoff, raising flood risks. At Campus I, the limited drainage capacity necessitates a green infrastructure-based solution. This study designs an optimal porous-walled infiltration well system and determines its quantity and distribution using EPA SWMM 5.2. Unlike previous studies, this research integrates site-specific permeability data from laboratory testing into the modeling process for greater accuracy. A descriptive quantitative approach was applied, with runoff discharge estimated using the Rational Method and permeability tested via the Falling Head Permeability Test. EPA SWMM 5.2 modeling, incorporating the Low Impact Development (LID) feature, was used to analyze flooding and assess system effectiveness. The findings provide recommendations for an optimized infiltration well design, offering a precise and adaptable rainwater management solution.

Keywords: *Infiltration Well; Porous Wall; Surface Runoff; EPA SWMM.*

1. Introduction

Population growth and urban development in Southeast Asia have led to a significant increase in groundwater extraction, with a decline reaching 113–510 million cubic meters per year. As urbanization and industrialization continue to expand, land conversion for infrastructure development has intensified, reducing the capacity of natural infiltration areas for rainwater [1]. Consequently, surface runoff has increased, heightening the risk of flooding, particularly in densely populated areas and regions experiencing rapid infrastructure expansion [2]. Educational institutions, including university campuses, also face similar challenges due to land constraints and the continuous need for development to support academic activities.

Universitas Negeri Malang, as one of the leading educational institutions in Malang City, encounters similar drainage system issues. A hydrological study by Rahman et al. [3] found that Campus I of Universitas Negeri Malang, with an area of 463,992 m², requires a drainage capacity of 10,167 m³, while the existing system can only accommodate 8,069 m³. This results in an excess runoff volume of 1,558 m³, with a flood discharge of 335,016 m³/hour. Therefore, a green infrastructure-based solution is required to manage rainwater effectively without requiring extensive additional land. One viable alternative is the infiltration well system, which functions to reduce surface runoff and enhance rainwater infiltration into the soil.

Compared to other drainage systems, such as retention ponds or rainwater harvesting, infiltration wells are considered more effective and efficient in managing surface runoff. Rainwater storage systems require large land areas, while rainwater utilization systems demand complex treatment technology and high costs. Infiltration wells offer advantages due to their relatively simple

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construction and minimal land requirements. Additionally, the application of porous-walled infiltration wells can enhance infiltration efficiency without significantly obstructing water flow [4]. According to Sunjoto's theory, the effectiveness of infiltration wells in reducing surface runoff depends on the balance between infiltration discharge (Qi) and runoff discharge (Qr). The optimal design of infiltration wells must consider hydrological factors, such as soil characteristics and rainfall intensity, as well as hydraulic factors, including infiltration capacity and well dimensions. A calculation method that comprehensively accounts for existing conditions is required to achieve a more accurate design. Modelling software, such as EPA SWMM (Environmental Protection Agency – Storm Water Management Model), can analyze the interaction between drainage systems and water infiltration in greater detail. With its Low Impact Development (LID) feature, this software enables more precise simulations of the effectiveness of porous-walled infiltration wells in reducing surface runoff [5].

Several previous studies have demonstrated the effectiveness of EPA SWMM modelling in designing rainwater management infrastructure. Research conducted by Haqqin et al. [6] revealed that implementing infiltration wells using the LID feature in EPA SWMM 5.1 successfully reduced rainwater runoff by 25–40%. However, most previous studies have not specifically focused on optimizing porous-walled infiltration wells in urban campus environments with land-use constraints. Therefore, considering the hydrological conditions and land limitations at Campus I of Universitas Negeri Malang, this study introduces a novel approach by integrating site-specific permeability data with EPA SWMM 5.2 simulations to develop an optimized design for porous-walled infiltration wells. Unlike prior research, this study incorporates detailed soil permeability analysis obtained through laboratory testing, allowing for a more accurate representation of infiltration capacity. Through this approach, it is expected that an optimal infiltration well design can be developed to reduce surface runoff and enhance water infiltration capacity within the campus environment.

2. Materials and methods

This research was conducted within the higher education environment of State University of Malang, located at Jalan Semarang No. 5, Sumbersari Subdistrict, Lowokwaru District, Malang City, East Java. The reviewed site data includes a campus area map, a land-use map, and an existing campus drainage network plan.

According to the Malang City Spatial Plan (2010–2030), Campus I of Universitas Negeri Malang, located in Sumbersari Subdistrict, is classified as a high-risk flood area. Therefore, an in-depth study on rainwater management infrastructure is required. The research location map is presented in Figure 1.

2.1. Data collection

Those are the necessary data collection for this research:

1. Soil permeability coefficient data for Campus I of Universitas Negeri Malang (Primary Soil Permeability Test Data).
2. Rainfall data from Sukun, Dau, and Blimbing rain gauge stations (2014–2023) provided by the Public Works Department of East Java.
3. Rainfall data from the Hydrology Laboratory Rain Gauge Station at Universitas Brawijaya (2014–2023) provided by Hydrology Laboratory, Water Resources Engineering, Universitas Brawijaya.
4. Land-use map of Campus I, Universitas Negeri Malang (Department of Civil Engineering and Planning, Universitas Negeri Malang).
5. Soil type map of Campus I, Universitas Negeri Malang [7].
6. Existing drainage channel data of Campus I, Universitas Negeri Malang [3].

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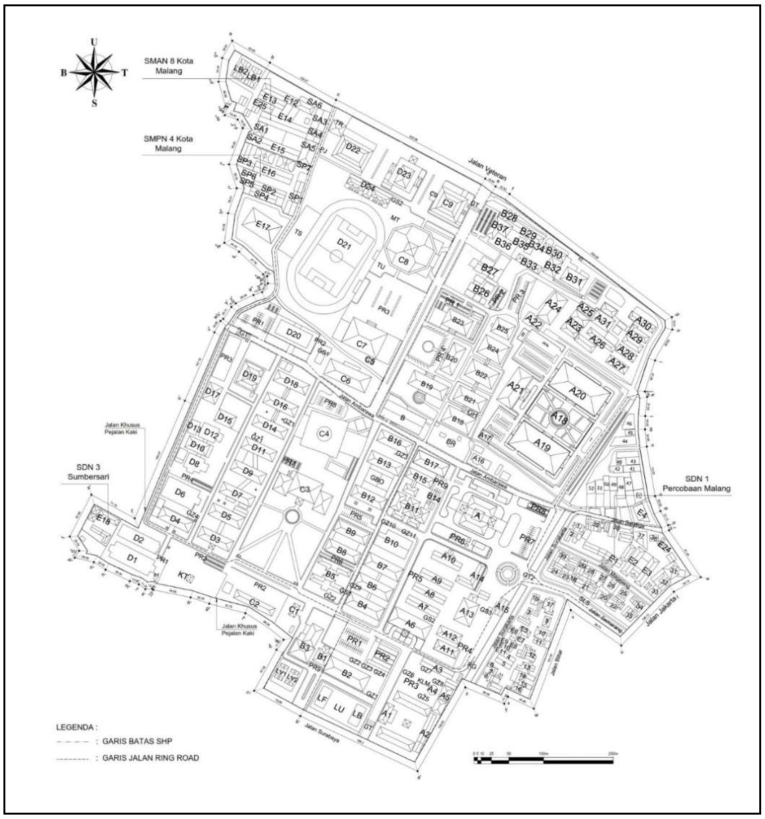

Figure 1. State University of Malang Area Map
Source: State University of Malang, 2024

2.2. Methodology

The calculation of hydrological analysis using the Rational Method assisted by EPA SWMM 5.2 hydrological simulation software to simulate the maximum rainfall event at the study site. The following are some of the research analysis methods carried out:

1. The soil permeability testing of the study location was obtained through the results of the soil permeability test with the Falling Head Permeability Test Method conducted at the Soil Mechanics Laboratory, Department of Civil Engineering and Planning, Faculty of Engineering, State University of Malang.
2. Regional rainfall analysis using the Thiessen Polygon method.
3. Data consistency test uses the RAPS (rescaled adjusted partial sums) method.
4. Frequency and probability analysis by conducting a distribution test first for the distribution parameters of Gumbel, Normal, Log-Normal and Log-Pearson type III to meet the requirements of the statistical parameters of each frequency analysis method, then a statistical test was carried out on the distribution method accepted in the previous distribution test.
5. Distribution match test with Chi-Square method and Smirnov-Kolmogorov method.
6. Rain intensity analysis of the *Mononobe* method.
7. Calculation of runoff discharge Rational Method.
8. The analysis of the calculation of the model and dimensions of infiltration wells was carried out according to the previous research method, namely the Azizah & Sunjoto [8] method.
9. Analysis of the Number and Distribution of Porus Wall Infiltration Wells using EPA SWMM 5.2 software simulation analysis using LID (Low Impact Development) tools of the infiltration trench method.

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3. Results and Discussion

3.1 Soil Permeability Test

The purpose of the soil permeability test is to determine the rate of water flow through soil samples taken from six different points in four different areas within Campus I of the State University of Malang. This test refers to the Indonesian National Standard (SNI) 03-6870:2002 which regulates the water pass test procedure for fine-grained soils with high decreasing pressure [9]. Soil samples were taken from various locations to obtain a comprehensive picture of the soil permeability characteristics in the area. Details regarding the sampling location and the area being reviewed are shown in Figure 2.

Figure 2. Distribution of Soil Sampling Locations
Source: Google Earth, 2024

Through the results of testing and calculating the soil permeability value, it was obtained that the soil permeability value in the Campus I area of the State University of Malang is included in the classification of the soil permeability value rather quickly (3.6 – 36 cm/hour) which is by the technical requirements for the implementation of infiltration wells by SNI 8456 of 2017 where at least the soil structure must have a soil permeability coefficient value of > 2 cm/hour. The results of soil permeability testing in the campus area I of the State University of Malang are in Table 1.

Table 1. Results of Soil Permeability Testing Campus I UM

Area Code	Sample Number	Soil Permeability Value (cm/hours)
Area 1	GRACAK-1	3,812
Area 2	GKB-2	3,494
Area 3	FIS-3	3,836
Area 3	GRBSBY-3	3,694
Area 4	PTIK-4	3,711
Area 4	FEB-4	3,713
Average Soil Permeability Coefficient at UM		3,710
		~ 0,0000103 m/second

Source: Analysis and Calculation Result Excel, 2024

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3.2 Hydrology Analysis

3.2.1 Regional Rainfall Analysis

This study uses the Thiessen Polygon Method to analyses regional rainfall. In this study, four nearest rain stations from the study location were used as shown in Table 2.

Table 2. Maximum Rainfall Data of stations used (mm)

Years	UB Hydrology Lab Rain Station (P_A)	Sukun Rain Station (P_B)	Dau Rain Station (P_C)	Blimbing Rain Station (P_D)
2014	116	134	100	125
2015	111	170	65	96
2016	118	122	75	64
2017	103	132	105	104
2018	111	132	95	97
2019	97	135	93	82
2020	114	125	145	97
2021	90	133	95	123
2022	99	82	105	115
2023	281	134	80	102

Source: Public Works Department of East Java & Hydrology Laboratory Brawijaya University, 2024

Thiessen Polygon analysis uses the help of ArcMap software version 10.8. The output of the Arcmap analysis will produce the area of influence (km^2) based on polygons formed following the distribution of the coordinates of the specified rain station points. The results of the analysis of the area of influence of all rain stations are in Table 3.

Table 3. Area of Influence of Rain Station

No	Rain Station	X Coordinate	Y Coordinate	wide (km^2)
1	UB HYDROLOGY LAB	112,614	-7,952	17,691 (K_A)
2	SUKUN	112,618	-7,996	48,915 (K_B)
3	DAU	112,593	-7,925	8,072 (K_C)
4	BLIMBING	112,644	-7,955	36,399 (K_D)
Total				**111,077 (K_{Total})**

Source: Analysis and ArcMap 10.8, 2024

Based on the area of influence in Table 3, we can determine the maximum rainfall value each year for all rain stations evenly. Where the calculation of regional rainfall resulted in an average rainfall value of 116.8 mm at the study location. The results of the calculation of the maximum average rainfall of the Thiesen Polygon are shown in Table 4.

Table 4. Thiessen Polygon Maximum Rainfall

Years	$P_A.K_A$ (UB)	$P_B.K_B$ (Sukun)	$P_C.K_C$ (Dau)	$P_D.K_D$ (Blimbing)	P_{max} (mm)
2014	6554,568	807,221	4549,925	2052,130	125,713
2015	8315,497	524,694	3494,343	1963,676	128,723

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Years	$P_A.K_A$ (UB)	$P_B.K_B$ (Sukun)	$P_C.K_C$ (Dau)	$P_D.K_D$ (Blimbing)	P_{max} (mm)
2016	5967,592	605,416	2329,562	2091,050	98,973
2017	6456,739	847,582	3785,538	1825,688	116,276
2018	6456,739	766,860	3530,742	1963,676	114,497
2019	6603,483	750,715	2984,751	1707,160	108,448
2020	6114,336	1170,470	3530,742	2016,748	115,526
2021	6505,653	766,860	4477,127	1592,170	120,113
2022	4011,004	847,582	4185,931	1751,387	97,193
2023	6554,568	645,777	3712,739	4975,354	143,040
Average ($\bar{x}$)					116,850

Source: Analysis and Calculation Result Excel, 2024

3.2.2 Data Consistency Test

Data consistency testing was carried out using the Rescaled Adjusted Partial Sums (RAPS) Method. In this test, the confidence levels used were 90%, 95%, and 99%. The results of the analysis of rainfall data consistency test with the RAPS method are presented in Table 5.

Table 5. RAPS Test Results

α	$Q/n^{0,5}$ Critical	$R/n^{0,5}$ Critical	$Q/n^{0,5}$ Count	$R/n^{0,5}$ Count	Description (Q / R Count ≤ Q / R Critical)
99%	1,29	1,38	0,635	0,621	**Consistent**
95%	1,14	1,28			**Consistent**
90%	1,05	1,21			**Consistent**

Source: Analysis and Calculation Result Excel, 2024

Based on Table 5, the rainfall data was declared valid at all confidence levels tested (90%, 95%, and 99%). because the $Q/n^{0,5}$ and $R/n^{0,5}$ values are calculated not to exceed the critical values at various levels of confidence:

At a 90% confidence level, the critical value for $Q/n^{0,5}$ is 1,05 and for $R/n^{0,5}$ is 1,21. Because Q = 0,635 < 1,05 and R = 0,621 < 1,21. then the data is declared consistent.

At a 95% confidence level, the critical value for $Q/n^{0,5}$ is 1,14 and for $R/n^{0,5}$ is 1,28. Since Q = 0,635 < 1,14 and R = 0,621 < 1,28 the data remained consistent.

At a 99% confidence level, the critical value for $Q/n^{0,5}$ is 1,29 and for $R/n^{0,5}$ is 1,38. With the results Q = 0,635 < 1,29 and R = 0,621 < 1,38, the data was also declared consistent.

3.2.3 Frequency and Probability Analysis

The frequency and probability analysis in this study was carried out using four statistical methods, namely Normal, Log-Normal, Gumbel, and Log-Pearson Type III. Before conducting frequency analysis, an important first step is to conduct a data distribution test as shown in Table 6.

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Table 6. Distribution Test Results

Distribution	***Normal***		***Log-Normal***		***Gumbel***		***Log-Pearson* Type III**
Requirement	Cs	Ck	Cs	Ck	Cs	Ck	Cs
	0	3	2	4	1,14	5,4	$\neq 0$
Result	Cs	Ck	Cs	Ck	Cs	Ck	Cs
	0,3	4,2	0,055	3	0,3	4,2	0,055
Description	**Not Fulfilled**		**Not Fulfilled**		**Not Fulfilled**		**Fulfilled**

Source: Analysis and Calculation Result Excel, 2024

Based on Table 6, the Log-Pearson type III distribution **meets the requirements** of the data distribution test according to the requirements of the statistical parameter test (Cs = 0.055), while the three other methods such as the Normal, Log-Normal and Gumbel distributions do not meet the requirements of the distribution test because the skewness and kurtosis values are not close to the distribution requirements.

Since the Log-Pearson type III distribution meets the requirements of the distribution test, the calculation of the design rainfall in millimeters (mm) with recalculation periods (2, 5, 10, 25.50 and 100 years) can be carried out according to Table 7.

Table 7. Results of Pearson Log Type III Rainfall Frequency Analysis

***Log-Pearson* Type III**		
Tr	KTr	RTr
(Years)		(mm)
100	2,366	153
50	2,083	148
25	1,770	143
10	1,287	135
5	0,839	128
2	-0,009	116

Source: Analysis and Calculation Result Excel, 2024

3.2.4 Distribution Fit Test

(1) *Chi-Square* Method

The Chi-Square test is used to determine whether the selected distribution is able to Figure the statistical distribution from the analysis data sample. The distribution test of the Chi-Square method is shown in Table 8.

Table 8. Results of the Chi-Square Method Distribution Fit Test

Class	**KTR**	**RTR**	**Limit Value of Class**			**Ei**	**Oi**	**((Ei-Oi)^2)/Ei**
1	0,842	128,17		>	128,17	2	2	0
2	0,132	117,94	117,94	-	128,17	2	2	0
3	-0,776	106,04	106,04	-	117,94	2	4	2
4	-1,734	94,78	94,78	-	106,04	2	2	0
5	-2,286	88,84		<	88,84	2	0	2
			Total			**10**	**10**	**4**
							X^2	**4**
							Xh^2	**5.991**
								Represented

Source: Analysis and Calculation Result Excel, 2024

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The division of observation data can be adjusted to the number of distribution classes (K = 5) so that the Chi-Critical extraction (Xh^2) can be determined according to the degree of chi-square confidence, the Chi-Critical value (Xh^2) = 5,991 for dk = 2 and α = 5%. Since Chi-Count ($X^2 = 4$) < *Chi-Critical* ($Xh^2 = 5{,}991$), the distribution equation of the Chi-Square method for rainfall designed by the Log-Pearson method type III is **acceptable**.

(2) *Smirnov-Kolmogorov* Method

The non-parametric fit test or Smirnov-Kolmogorov does not use a specific distribution function so that the degree of confidence or significance can be determined according to the Smirnov-Kolmogorov critical value table using a critical value of 5%. The value of $\Delta p_{Critical}$= 0,410 was obtained. Thus, the interpretation of the match test was obtained with the results of Δp_{max} < $\Delta p_{Critical}$. he results of the calculation of the Smirnov-Kolmogorov method distribution match test on the Log-Pearson type III distribution method, are shown in Table 9.

Table 9. Results of the Distribution Compatibility Test of the Smirnov-Kolmogorov Method

No.	Years	Rmax	Ri	P (A)	f (t) (B)	P' (C)	ΔP (D)
1	2014	125,713	143,040	0,091	1,905	0,020	0,071
2	2015	128,723	128,723	0,182	0,864	0,181	0,001
3	2016	98,973	125,713	0,273	0,645	0,244	0,029
4	2017	116,276	120,113	0,364	0,237	0,387	0,023
5	2018	114,497	116,276	0,455	-0,042	0,536	0,082
6	2019	108,448	115,526	0,545	-0,096	0,558	0,013
7	2020	115,526	114,497	0,636	-0,171	0,587	0,049
8	2021	120,113	108,448	0,727	-0,611	0,746	0,018
9	2022	97,193	98,973	0,818	-1,301	0,912	0,093
10	2023	143,040	97,193	0,909	-1,430	0,930	0,021
Total			1168,502			Δp_{max}	**0,093**
Average (Rt)			116,850			$\Delta p_{Critical}$	**0,410**
Total Data (n)			10			**Represented**	
Standard Deviation (Sd)			13,745				

Source: Analysis and Calculation Result Excel, 2024

Based on Table 9, the results of Δp_{max} (0,093) < $\Delta p_{Critical}$ (0,410) was obtained. So that the rainfall data of the Log-Pearson type III distribution method can be **accepted**.

3.2.5 Rainfall Intensity Analysis

Intensity Duration Frequency (IDF) analysis used a 2-year repetition period on the rainfall data of the Log-Pearson method type III obtained in the frequency analysis of 116 mm. The analysis calculation is shown in Table 10.

Table 10. Log-Pearson type III Rainfall Intensity Mononobe Method

T (Minute)	T (Hours)	Return Period (Years)		
		2	5	10
5	0,083	210,792	232,817	245,389
10	0,167	132,790	146,666	154,585

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T (Minute)	T (Hours)	Return Period (Years)		
		2	5	10
20	0,333	83,653	92,394	97,383
40	0,667	52,698	58,204	61,347
60	1	40,216	44,418	46,817
90	1,5	30,691	33,897	35,728
120	2	25,335	27,982	29,493

Source: Analysis and Calculation Result Excel, 2024

Referring to the calculation results in Table 10, it was found that with the intensity of rainfall over the 2-year period, the maximum daily rainfall of the Log-Pearson method type III was **116 mm**, resulting in a maximum rainfall intensity of 2 hours of **25.335 mm**.

3.2.6 Runoff Discharge

The calculation of runoff discharge is carried out by the Rational Method. The results of the runoff discharge analysis in the Campus I area of the State University of Malang are shown in Table 11.

Table 11. Results of Runoff Discharge Analysis

Runoff Coefficient (C) (1)	*Mononobe* (I) (2)	Area (A) (3)	Rational Method (4)	
	mm/hours	km^2	m^3/sec	m^3/hrs
0,95	**25,335**	**0.000552**	**0,00370**	**13,306**

Source: Hydrology Analysis of *Mononobe* Method, 2024

Referring to the calculation results in Table 11, it was found that the runoff discharge that occurred at Campus I of the State University of Malang was **0.00370 m^3/second** or **13.306 m^3/hour.**

3.3 Model and Dimensions Analysis of Porous Walls Infiltration Wells

Infiltration wells applied at the mandatory study location following the standard requirements of SNI 8456-2017, where the cross-sectional size of rainwater infiltration wells is determined to be 80 cm to 100 cm [4]. In this study, the well was implemented using the construction of porous concrete infiltration walls according to the concrete SCG catalogue which provides porous wall infiltration well construction materials. The well is applied with initial pre-dimensionality using a diameter of 1 meter (r = 0.5 m) with a concrete thickness of 9 cm. In this study, the geometric factor was determined according to 4 different researchers, of which 2 of them had the highest geometric factor (F) value, Sunjoto produced a geometric factor value of **F = 4.787 m**, while Azizah [8] got a geometric factor value of **F = 3.243 m**.

The Sunjoto and Azizah [8] wells model each have a porous wall element in the bottom structure of the well, the value of the height of the porous wall (L) is determined according to Azizah's research, where the effective height for the porous wall in the infiltration well of the concrete slab wall model is 70 cm. Analysis of well infiltration discharge in 2 models of geometric factors with well radius (R) of 0,5 m and height of porous wall (L) of 0,7 m according to Sunjoto's theory (Q=F.K.H) where the value of groundwater level (H) is obtained from the results of Ansyorie's [7] research in the study location area that the groundwater level is 4,8 meters, then the calculation of well infiltration discharge is as follows:

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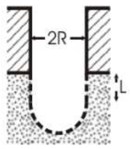
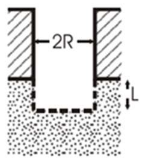
(a) Infiltration Discharge of Sunjoto Wells Model



Q = F x K x H
Q = 4,787 m x 0,0000103 m/second x 4,8 m
Q = 0,000237 m^3/second ~ 0,8525 m^3/hours

(b) Infiltration Discharge of Azizah Wells Model



Q = F x K x H
Q = 3,243 m x 0,0000103 m/second x 4,8 m
Q = 0,000160 m^3/second ~ 0,5775 m^3/hours

To find the optimal depth of the porous wall infiltration well, the formula used is the Sunjoto formula with the principle of dynamic balance and the integration method for empty wells (Hollow Wells), with T or the dominant duration of rain (j) adjusted to the previous researcher, which is 5 hours [10].

(a) Optimal Depth of Sunjoto Wells Model

$$H = \frac{Q}{F.K}\left[1 - \exp^{\left(\frac{-F.K.T}{\pi.R^2}\right)}\right]$$

$$H = \frac{0{,}8525\ m3/hours}{4{,}787\ m\ \times 0{,}0000103\ m/s}\left[1 - \exp^{\left(\frac{-\ 4{,}787\ m\ \times 0{,}0000103\ m/s\ \times 5\ hours}{\pi.0{,}5^2}\right)}\right]$$

$$\mathbf{H = 3{,}251\ m}$$

(b) Optimal Depth of Azizah Wells Model

$$H = \frac{Q}{F.K}\left[1 - \exp^{\left(\frac{-F.K.T}{\pi.R^2}\right)}\right]$$

$$H = \frac{0{,}5575\ m3/hours}{3{,}243\ m\ \times 0{,}0000103\ m/s}\left[1 - \exp^{\left(\frac{-\ 3{,}243\ m\ \times 0{,}0000103\ m/s\ \times 5\ hours}{\pi.0{,}5^2}\right)}\right]$$

$$\mathbf{H = 2{,}569\ m}$$

Based on the results of the calculation of the height of the well (H) above, it was obtained that the porous wall infiltration well with a cross-sectional width of 1 meter using the Sunjoto method has an optimal depth of 3.2 meters, deeper than using the Azizah method which is optimal at a depth of 2.5 meters.

The Sunjoto well model and the Azizah well model [8], are two well models that are suitable for implementing their construction design at the study site, namely Campus I of the State University of Malang, the Sunjoto Model with a diameter of 1 meter is determined using a depth of 3.7 meters (3 meters of conventional concrete bridges + 0.7 meters of porous concrete bridges) which are able to absorb runoff of 0.8525 m^3/hours as modelled in Figure 3.

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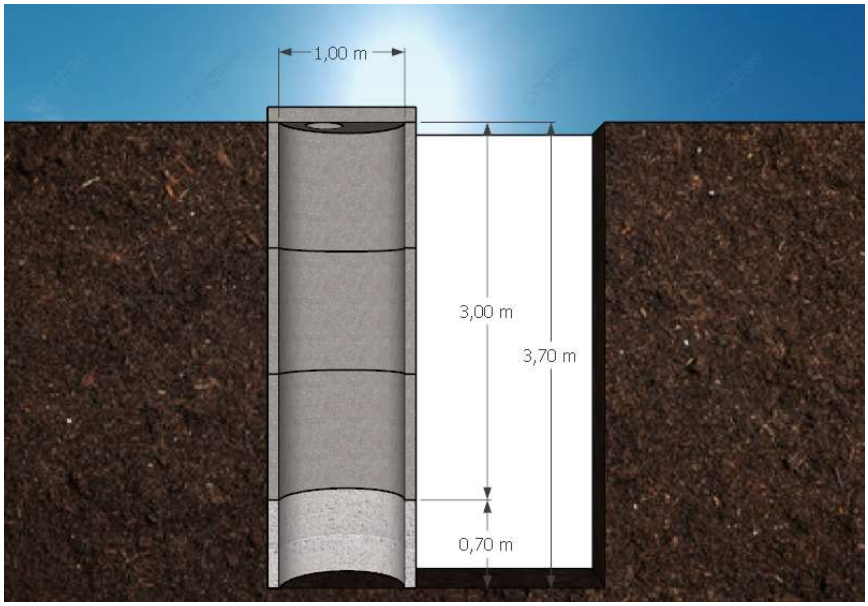

Figure 3. Design of Sunjoto Model Infiltration Well
Source: 3D Modeling Results in SketchUp Application, 2024

Meanwhile, if using the infiltration well model of the Azizah model [8] with a diameter of 1 meter and a depth of 2.7 meters (2 meters of conventional concrete bridge, + 0.7 meters of porous concrete bridge), which is able to absorb runoff of 0.5775 m^3/hour as modelled in Figure 4.

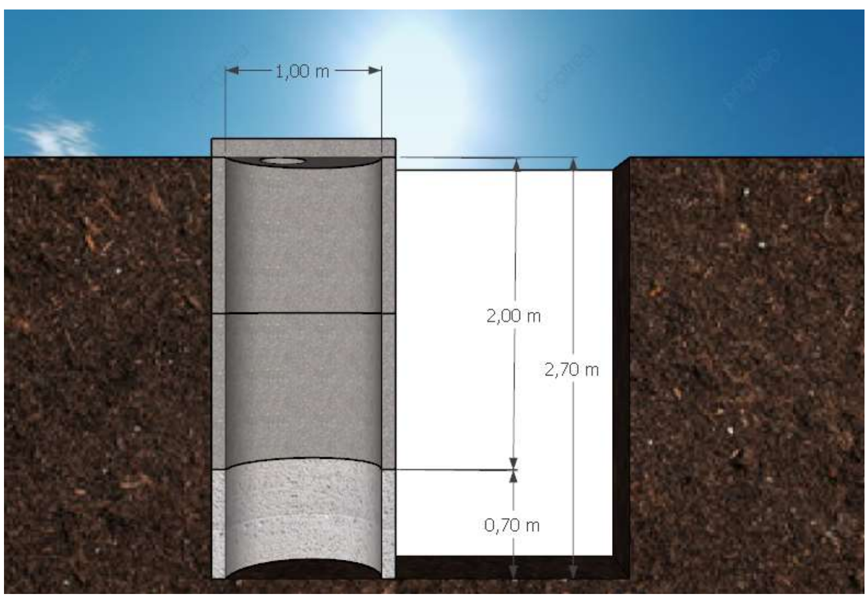

Figure 4. Design of Azizah Model Infiltration Well
Source: 3D Modeling Results in SketchUp Application, 2024

Although the Sunjoto model has a larger absorption capacity, the Azizah model is more efficient in terms of construction and practicality. The Sunjoto model requires a vertical semicircular well bed (U-letter) with a depth of 3.7 meters, while the Azizah model uses a shallower flat well bed with a depth of 2.7 meters, making it easier to implement as shown in Table 12.

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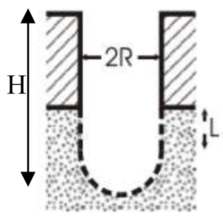
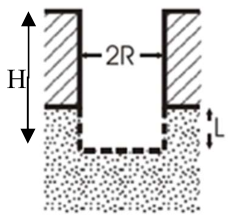
Table 12. Comparison of Well Construction of Azizah & Sunjoto

Applied Well Model	Well Depth (H)	Well Diameter (R)	Reservoir able Infiltration Discharge (Q_{Sumur})
 Sunjoto	3,7 meters	1 meter	0,8525 m^3/hours
 Azizah	2,7 meters	1 meter	0,5775 m^3/hours

Source: Hydrology and Model Analysis of Infiltration Wells, 2024

With a cross-sectional width of 1 meter, the Azizah model requires an arrangement of three concrete bushes (two conventional and one porous) per unit. This model is also able to absorb the main runoff discharge of the campus of 13,306 m^3/hours. To support the implementation, the Azizah model is designed using SCG concrete wall, equipped with a cover, plates, a 4-inch diameter PVC pipe system, and a control basin according to SNI 8456-2017 standards [11]. By considering the infiltration efficiency, ease of construction, and compliance with SNI standards, the Azizah model is more suitable to be applied at Campus I of the State University of Malang as a solution to overcome surface runoff.

3.4 Analysis of Distribution and Number of Porous Wall Infiltration Wells

In the initial stage of software-based hydraulic analysis, modelling of the drainage system of the study site was carried out. This process aims to realistically represent the hydrology and drainage system into hydraulic analysis software [12]. Details of modelling the UM campus drainage system in EPA SWMM 5.2.

The simulation results show the surface runoff pattern, channel capacity, and waterlogging critical points in the study area. Using EPA SWMM 5.2-based hydraulic simulation software, these results are visualized through tables and graphs describing the flow in each channel. After the running process is completed, the results of Continuity error in both Surface Runoff and Flow Routing which have a stable value of between 0.00% - 0.18%, an error value that is close to zero is an indicator that the SWMM model has accurately Figured the hydrological conditions of the study location. Based on the initial simulation, it was found that 3 critical points of drainage channels were inadequate to channel rainwater at the study site, as shown in Figure 5 with the location of the flood.

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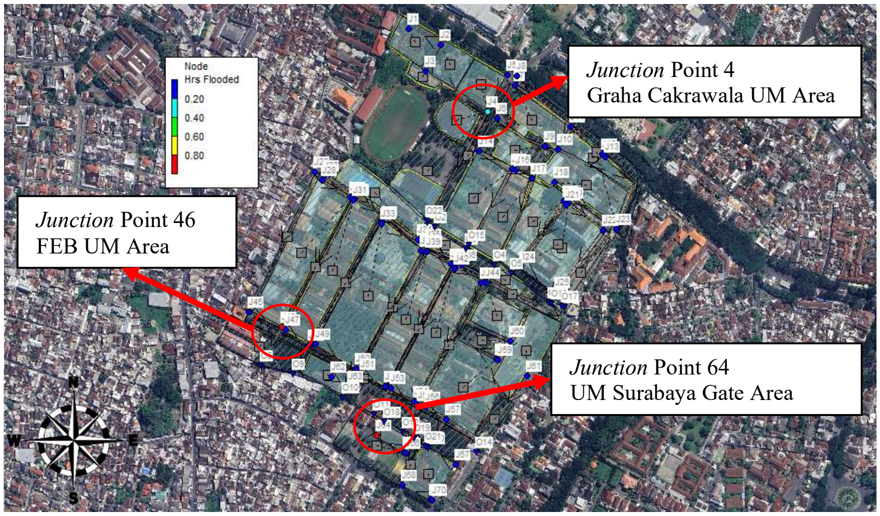

Figure 5. Results of Flood Location Points in EPA SWMM 5.2 Simulation
Source: Wells Distribution Analysis in EPA SWMM 5.2 Application, 2024

The Flooding node that appeared in the simulation results showed that the existing drainage was not able to drain all the rainwater flow during extreme hours of rainfall [13]. Flood stains or flood points from the simulation results of EPA SWMM 5.2 software are shown in Table 13.

Table 13. Results of Hydrology Analysis of Campus I State University of Malang

Results of EPA SWMM Simulation Before Infiltration Well Application			
Flooding Location	J4 (Graha Cakrawala)	J46 (FEB)	J64 (Gate Surabaya)
Flow Rate (cm/s)	0,077	0,209	0,26
Time of Overflow (Local Time* : WIB*)	14.00	13.58	14.00
Duration of Overflow (Hours)	0,055	0,98	1,00
Flood Volume (m³)	58	380	140

Source: Drainage Hydraulics Analysis of EPA SWMM 5.2 Application, 2024

With a total flood volume of 578 m^3 spread over the three flood points above, the location point will be used as the implementation point of the Azizah's [8] porous wall infiltration well. However, the number and division will be determined by the following calculation:

The number of infiltration wells needed for the Azizah model is calculated using the Sunjoto Equation according to the requirements of SNI 8456 of 2017 where the Q (Debit) used is the runoff discharge (Qr) at the study location, which is **13,306 m^3/hours**.

$$H = \frac{Q}{F.K}\left[1 - \exp^{\left(\frac{-F.K.T}{\pi.R^2}\right)}\right]$$

$$H = \frac{13{,}190\ \mathrm{m3/hours}}{3{,}243\ \mathrm{m}\ \times 0{,}0000103\ \mathrm{m/s}}\left[1 - \exp^{\left(\frac{3{,}243\ \mathrm{m} \times 0{,}0000103\ \mathrm{m/s} \times 5\ \mathrm{hours}}{\pi.0{,}5^2}\right)}\right]$$

$$\mathbf{H = 58,66\ m}$$

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Based on these results, **24 wells** can be made with a depth (H) = 2.7 meters (2 meters of conventional concrete walls + 0.7 meters of porous concrete walls), 1 meter in diameter. according to the SNI 8456 formula of 2017 as in the calculation below.

0,5775 m^3/hours x 24 Wells = **13,860 m^3/hours**

The total implementation of 24 infiltration wells for the Azizah model [8] can accommodate all runoff discharge in the campus I area of the State University of Malang according to the results of the runoff discharge analysis in the UM Campus I area (**13,860 m^3/hours > 13,306 m^3/hours**).

To divide the number of wells into three different locations based on flood discharge, the method that can be used is the proportional division method. The number of wells in each location is calculated based on the proportion of flood discharge of each location to the total flood discharge. Here are the calculation steps:

1. Calculate the proportion of flood discharge (Flood Volume) according to Table 13, for each location to the total flood discharge:

$$Location\ Proportion = \frac{Location\ Flood\ Discharge}{Total\ Flood\ Discharge}$$

$$Graha\ Cakrawala\ UM\ Area = \frac{58\ m^3}{578\ m^3} = 0{,}1003$$

$$FEB\ UM\ Area\ = \frac{380\ m^3}{578\ m^3} = 0{,}6574$$

$$Surabaya\ UM\ Gate\ Area = \frac{140\ m^3}{578\ m^3} = 0{,}2423$$

2. Multiply this proportion by the total number of wells (24 pieces) to determine the number of wells in each location:

$$Jumlah\ Sumur\ Lokasi = Proporsi\ Lokasi\ \times 24$$

$Graha\ Cakrawala\ UM\ Area = 0{,}1003\ \times 24$ = 2,4 ~ 2 wells

$FEB\ UM\ Area = 0{,}6574\ \times 24 = 15{,}7$ ~ 16 wells

$Surabaya\ Gate\ UM\ Area = 0{,}2423\ \times 24$ = 5,8 ~ 6 wells

The distribution of porous wall infiltration wells in the Campus I Area of the State University of Malang is modelled according to Figure 6.

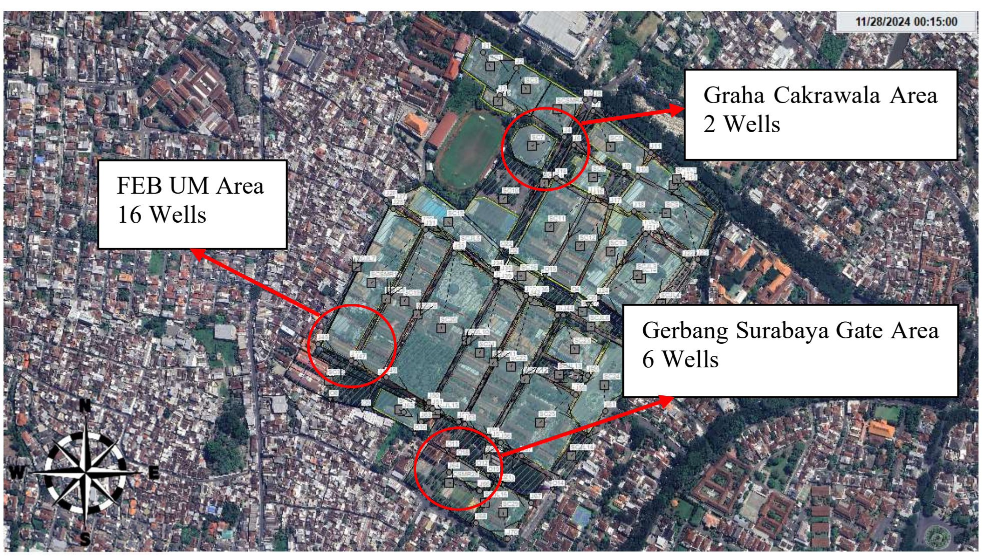

Figure 6. Distribution of Infiltration Wells at Campus I of State University of Malang
Source: Wells Distribution Analysis in EPA SWMM 5.2 Application, 2024

The LID (Low Impact Development) tool, namely the Infiltration Trench feature, which represents infiltration wells as rainwater management infrastructure, can provide results that the

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application of **24 porous wall** infiltration wells of the Azizah model [8] at 3 flood points (Graha Cakrawala, FEB, Surabaya Gate) shows that the results of flood stains (node flooding) are only left at 1 point with a very small flood volume (0.000 m^3, or it is considered that there is no flood at all). The reduction of runoff that can be reduced by the Azizah model well [8] is 106.255 mm or equivalent to 10.62 cm, according to the results of the LID Infiltration trench simulation in Table 14.

Table 14. Results of the Azizah Model Infiltration Well Runoff Reduction

Analysis Results of EPA SWMM Simulation After the Azizah Model Infiltration Well [8] was Applied to the LID Analysis	
Flooding Location	J46 (FEB UM)
Flow Rate (cm/s)	0,005
Time of Overflow (Local Time* : WIB*)	14.00
Duration of Overflow (Hours)	0,01
Flood Volume (m^3)	0,000
Surface Runoff (mm)	106,255

Source: Low Impact Development (LID) Analysis in EPA SWMM 5.2 Application, 2024

4. Conclusion

Model and dimensions of porous wall infiltration wells that are suitable to be implemented at Campus I of the State University of Malang to reduce surface runoff is the Azizah model which is designed with a diameter of 1 meter using the construction of a flat well bottom at a depth of 2.7 meters consisting of a combination of conventional concrete bridges as high as 2 meters and porous concrete bridges as high as 0.7 meters.

Based on the analysis using EPA SWMM software version 5.2, as many as 24 porous wall infiltration wells are needed at Campus I of the State University of Malang, with the proportional distribution of wells as follows: 2 wells in Graha Cakrawala, 16 wells in the Faculty of Economics and Business, and 6 wells at the Surabaya UM Gate. The application of this system is able to reduce surface runoff at Campus I of the State University of Malang by 13,306 m^3/hours.

Based on this overall research, it produces the following suggestions:

Campus I of the State University of Malang is expected to adopt the results of this research as a guideline in planning and building a surface runoff management system in the form of porous wall infiltration wells.

Maintenance aspect of infiltration wells needs to be considered to ensure that their performance remains optimal in reducing surface runoff. Systematic maintenance, such as sedimentation cleaning, and checking for blockages is important so that infiltration wells can function effectively.

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