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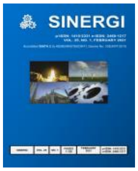

# Drainage system analysis using Storm Water Management Model (SWMM) in flood mitigation efforts in the valley area

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***Abstract***
*This research takes place in the North Siantar Subdistrict of Pematangsiantar City, where issues with the drainage system result in frequent flooding in the valley area. Previously, this phenomenon has not been extensively researched. The study aims to analyze infiltration wells on Bah Tongguran Street in the North Siantar Subdistrict of Pematangsiantar City through existing drainage simulation using SWMM software. Water pooling at this location leads to floods due to insufficient drainage capacity, exacerbated by the valley-shaped land contour and high population density. The simulation results, utilizing SWMM software with the Gumbel method for rainfall distribution and a 5-year return period, revealed that the channels on both sides of Bah Tongguran Street cannot accommodate rainwater discharge. The dimensions of the existing drainage channel are b = 0.3 and h = 0.45. To address this issue, we propose the construction of infiltration wells with a diameter of 1.4 meters and a depth of 1.5 meters. The analysis determined that the infiltration wells would be 24 wells on the left and 21 on the right. These infiltration wells will be constructed using concrete pipes, with an effectiveness rate of 65% for the left side and 58% for the right. Through this intervention, our research aims to serve as a reference for planners designing infiltration wells in valley areas and as a resource for other researchers developing sustainable flood mitigation technologies.*

***Keywords:***
*Drainage;*
*Flood;*
*Infiltration Wells;*
*SWMM;*
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## INTRODUCTION

Until now, no one has discussed infiltration wells as an alternative to flooding in valley areas inhabited by people. Essentially, valley areas have lower contours compared to the surrounding regions. Previous studies on planning infiltration wells are generally common, such as those conducted by Zainal [1] in residential areas, Molya [2] as an alternative to Eco-Drainage, and Nyoto [3] in the city of Jakarta. These studies focused on general research areas and were not specific to valley regions.

Flood management in valley areas requires a nuanced understanding of drainage capacity, Juliastuti [4], vulnerability assessment, Eryani [5], and real-time monitoring, Adriansyah [6]. Research has shown that deficiencies in drainage capacity, such as those identified in the analysis of residential drainage systems, highlight the need for alternative solutions like infiltration wells. Studies on flood vulnerability, using various indicators, provide insights into how environmental factors affect flood risks, which is crucial for effective well placement.

Additionally, advancements in flood early warning systems, utilizing wireless sensors, can enhance the management of flood events, informing the strategic placement and operation of infiltration wells. Soil infiltration rate tests, such as those conducted in the Kathmandu Valley, further underline the importance of local conditions in determining well effectiveness. Integrating these approaches can optimize flood management strategies in valley regions, addressing the unique challenges posed by their topography [7]. Additionally, there is a scientific report on hydrogeological research in the southeastern part of New York. This research, conducted by the U.S. Geological Survey (USGS) in collaboration with the New York State Department of Environmental Conservation and the New York State Department of Health, aims to protect groundwater sources used for public water supply in several villages and communities in the region [8].

However, there is still no research specifically addressing the use of infiltration wells in valley areas to mitigate floods. These studies are interconnected, as the use of infiltration wells is influenced by soil permeability. If soil infiltration conditions are impermeable, the use of infiltration well technology cannot be applied. Moreover, if groundwater conditions are less than half a meter from the soil surface, infiltration wells will not be effective. Furthermore, if the groundwater level is too high, infiltration wells run the risk of being contaminated by surface water that may be polluted by waste or pollutants [9].

The study was carried out in the North Siantar Subdistrict, Pematangsiantar City, specifically chosen to assess drainage channels in response to recurrent waterlogging and flooding. Based on the geographic location of the study in Figure 1, the city of Pematangsiantar is situated between the latitudes 2°53'20" – 3°01'00" N and the longitudes 99°1'10" – 99°6'35" E. The area of study for this research is in the Siantar Utara District of Pematangsiantar, covering an area of 3.65 km². Furthermore, the valley that experienced flooding in this study is situated in the Siantar Utara District, on Bah Tongguran Street. At this location, there are tertiary drainage channels on both the right and left sides of the road, with dimensions of width = 0.30 m and height = 0.45 m, and a channel length of 208.66 m, encompassing an area of 1.84 hectares. This area is designated for residential use.

The areas prone to flooding in the North Siantar Subdistrict include Bah Tongguran Street. Residents living around Bah Tongguran Street reported that the water level reached the calf of an adult, approximately 15-30 cm, and the flooding was characterized by stagnation without any flow. Flooding in drainage channels resulted in road closures and disruptions to passing vehicles, endangering road users.

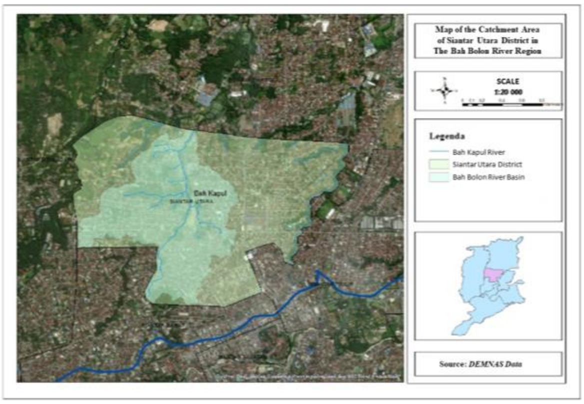

Figure 1. Location of Study [10]

Furthermore, it forced businesses around the area to close to prevent water damage, leading to financial losses. Citizens said that the flood depth on Bah Tongguran Street ranged from 15-20 cm, covering an area of 296 m².

The North Siantar Subdistrict is a densely populated commercial area with drainage issues that need to be addressed to prevent flood-related losses and disruptions to community activities. Therefore, this study aims to evaluate the performance of the drainage system by conducting hydrological and hydraulic analyses and simulating flow profiles using Storm Water Management Model 5.1 (SWMM) software to determine whether the capacity of the drainage channels is still able to accommodate the generated flow and runoff. This research also aims to identify methods for managing excess water and addressing flood issues in flood-prone areas of the North Siantar Subdistrict.

## METHOD

The methodology of this research involves hydrological analysis, which includes calculating the average rainfall using an algebraic method with a 5-year return period [11].

The research flowchart shown in Figure 2 begins with problem formulation, followed by a literature review and data collection (both primary and secondary), which form the basis for the analysis of rainfall, flood discharge, and channel dimensions. Subsequently, an evaluation using SWMM determines the need for channel dimension improvements or infiltration well planning. If no issues are identified, conclusions and recommendations are developed.

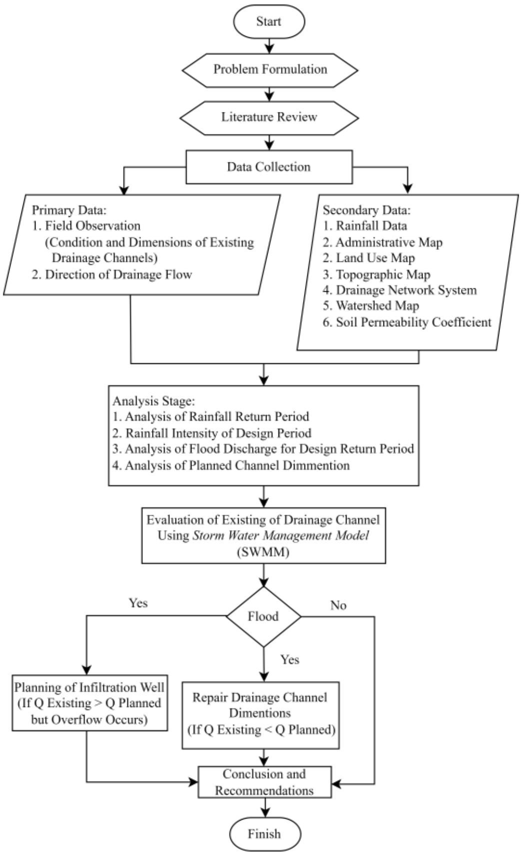

Figure 2. Flowchart of Research

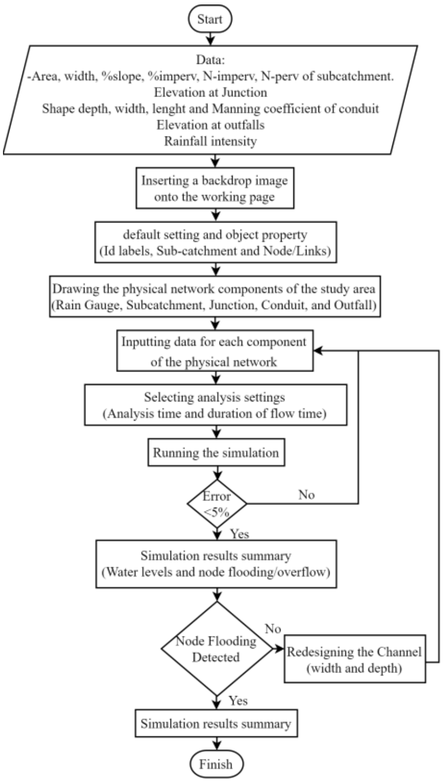

Figure 3. Flowchart of SWMM 5.1 Modeling

The flowchart for SWMM 5.1 modeling in Figure 3 begins with inputting data on area, elevation, and channel characteristics, followed by adding a backdrop image and setting object properties. Next, the physical network is drawn, component data is entered, and analysis settings are selected. Run the simulation; if the error is <5%, re-enter the data. If not, review the simulation results and redesign the channel if node flooding occurs.

Analyzing rainfall frequency using normal, log-normal, Log Pearson III, and Gumbel methods, calculating rainfall intensity using the monobe method, and determining the design flood discharge using the rational method [12]. Hydraulic analysis is conducted by calculating the capacity of the drainage channels and simulating the hydrological and hydraulic processes using the Storm Water Management Model (SWMM) [13] software. Furthermore, improvements will be made to the flooded channels by redesigning the drainage system, and planning infiltration wells for these improvements.

## RESULTS AND DISCUSSION

### Validation of Rainfall

Based on the calculation results in Table 1, the value of Q/√n [14] < critical Q is 0.69 < 1.14 and the value of R/√n [14] < critical Q is 0.93 < 1.28 with a 95% probability [15]. Therefore, the rainfall data for Bangun and Marihat is considered valid.

Table 1. Results of Validation Calculation for Rainfall Data in Bangun and Marihat

| Year | Xi | Sk* | $SD^2$ | Sk** |
|---|---|---|---|---|
| **2012** | 110.7 | 34.54 | 119.30 | 2.19 |
| **2013** | 72.1 | -4.06 | 1.65 | -0.26 |
| **2014** | 69.9 | -6.26 | 3.92 | -0.40 |
| **2015** | 75.4 | -0.76 | 0.06 | -0.05 |
| **2016** | 65.5 | -10.66 | 11.36 | -0.67 |
| **2017** | 69.5 | -6.66 | 4.44 | -0.42 |
| **2018** | 64.5 | -11.66 | 13.60 | -0.74 |
| **2019** | 64 | -12.16 | 14,79 | -0.77 |
| **2020** | 67 | -9.16 | 8.39 | -0.58 |
| **2021** | 103 | 26.84 | 72.04 | 1.70 |
| **Average** | 76.16 | **Total** | 249.54 | |
| **Dev. Std.** | 15.8 | **Q** | 2.19 | |
| **Sk**max** | 2.19 | **R** | 2.96 | |
| **Sk**min** | -0.77 | | | |
| **$Q/(n^{0.5})$** | **0.69** | With a Probability of 95% | | Accepted |
| **$R/(n^{0.5})$** | **0.93** | With a Probability of 95% | | Accepted |

### Rainfall Distribution

Based on the calculation results of rainfall dispersion using the algebraic method in Table 2, it is concluded that the distribution types meeting the criteria are Gumbel and Log Pearson III. Gumbel's criteria are Cs ≤ 1.14 (0.63) and Ck ≤ 5.4 (3.37), while Log Pearson III meets additional unspecified values.

### Distribution Goodness-of-Fit Test

On the one hand, in Table 3, the Gumbel and Log Pearson III distributions both meet the criteria, with a calculated maximum ΔP of 3 against a critical maximum ΔP of 5.99. Therefore, both distributions pass the Chi-Square goodness-of-fit test. Furthermore, in Table 4, the Gumbel distribution meets the criteria with a calculated maximum ΔP of 0.063 against a critical maximum ΔP of 0.41. In contrast, the Log Pearson III distribution does not meet the criteria, with a calculated maximum ΔP of 0.895 exceeding the critical maximum ΔP of 0.41 [18][19].

### Calculation of Rainfall Intensity

Calculation of rainfall intensity using the data that passed the previous test, which is the Gumbel distribution, using the Mononobe method [20].

Table 2. Results of Rainfall Dispersion Calculation

| Distribution Type | Requirement [16][17] | Result of Calculatior | Conclusion |
|---|---|---|---|
| **Normal** | Cs = 0 | 0.63 | Not Accepted |
| | Ck = 3 | 3.83 | |
| **Log Normal** | Cs = 3Cv | 0.31 | Not Accepted |
| | Cv = 0 | | |
| **Gumbel** | Cs ≤ 1.14 | **0.63** | **Accepted** |
| | Ck ≤ 5.4 | **3.37** | |
| **Log Pearson III** | In addition to the values above | - | Accepted |

Table 3. Summary of Chi-Square Goodness-of-Fit Test

| Probability Distribution | ΔP Calculated maximum | ΔP Critical Maximum | Description |
|---|---|---|---|
| **Gumbel** | 3 | 5.99 | Meets the criteria |
| **Log Pearson III** | 3 | 5.99 | Meets the criteria |

Table 4. Summary of Smirnov-Kolmogorov Goodness-of-Fit Test [18]

| Probability Distribution | ΔP Calculated maximum | ΔP Critical Maximum | Description |
|---|---|---|---|
| **Gumbel** | 0.063 | 0.41 | Meets the criteria |
| **Log Pearson III** | 0.895 | 0.41 | Doesn't meet the criteria |

Table 5. Results of Rainfall Intensity Calculation using the Mononobe method

| Duration | | Rainfall Intensity for Various Return Periods [21] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 25 | 50 | 100 |
| **Minute** | **Hour** | 60.9 | 74.4 | 83.4 | 94.7 | 103.1 | 111.4 |
| **5** | **0.083** | .10.7 | 135.2 | 151.5 | 172.1 | 187.3 | 202.5 |
| **10** | **0.167** | 69.7 | 85.2 | 95.4 | 108.4 | 118 | 127.5 |
| **15** | **0.25** | 53.2 | 65 | 72.8 | 82.7 | 90 | 97.3 |
| **30** | **0.5** | 33.5 | 40.9 | 45.9 | 52.1 | 56.7 | 61.3 |
| **60** | **1** | 25.6 | 31.2 | 35 | 39.8 | 43.2 | 46.8 |
| **120** | **2** | 21.1 | 25.8 | 28.9 | 32.8 | 35.7 | 38.6 |
| **720** | **12** | 12 | 14.7 | 16.4 | 18.6 | 20.3 | 21.9 |
| **1440** | **24** | 10.1 | 12.4 | 13.9 | 15.8 | 17.2 | 18.61 |

Table 5 presents rainfall intensity calculated using data validated by the Gumbel distribution test, employing the Mononobe method. For various return periods, the intensity (in mm/hour) varies across durations: for 2 minutes, it ranges from 60.9 (2-year return) to 111.4 (100-year return); for 5 minutes, from 110.7 to 202.5; and for 10 minutes, from 69.7 to 127.5. Longer durations show corresponding intensities: 15 minutes (53.2 to 97.3), 30 minutes (33.5 to 61.3), 60 minutes (25.6 to 46.8), 120 minutes (21.1 to 38.6), 720 minutes (12 to 21.9), and 1440 minutes (10.1 to 18.61). These values are crucial for estimating rainfall intensity across different durations and essential for urban drainage planning and flood management. The Mononobe method's results are utilized directly in SWMM 5.1's rain gauge application, ensuring accurate simulation and management of stormwater in urban environments based on reliable intensity data.

### Runoff Coefficient

The coefficient of runoff (C) is the ratio of peak runoff to rainfall intensity. The value of C is influenced by several main factors, including soil infiltration rate, slope of the land, vegetation cover, and rainfall intensity [22][23]. The flooded locations on Bah Tongguran roads consist of various land covers such as urban areas, residential areas, yards, and asphalt roads, with respective areas as shown in Table 6.

Table 6. Area and Coefficient of Runoff for Each Land Cover in Bah Tongguran

| Name | Asphalt Road ($km^2$) | Roof ($km^2$) | Yard ($km^2$) | Total "C" Area (km2) | Composite Value |
|---|---|---|---|---|---|
| | 0.95 | 0.9 | 0.1 | | |
| **Left Segment** | 0.001 | 0.0036 | 0.004 | 0.009 | 0.52 |
| **Right Segment** | 0.001 | 0.0040 | 0.004 | 0.009 | 0.54 |

Based on the calculation of the coefficient of runoff in Table 6, the coefficient of runoff for the left and right segments of Bah Tongguran road is 0.52 and 0.54, respectively.

## Calculation of Planned Discharge

Based on the calculated intensity in Table 7, the planned discharge for the left segment of Bah Tongguran road is 0.093 m³/s, with an intensity of 713.11, an area of 0.0091 km², and a C value of 0.52. The right segment's planned discharge is 0.079 m³/s, with an intensity of 561.58, an area of 0.0093 km², and a C value of 0.54.

## Hydraulic Analysis

The hydraulic analysis calculates the discharge capacity of the main drainage channel on Bah Tongguran Road, as illustrated in Table 8. For the left segment, the planned discharge (Qplan) is 0.093 m³/s, and the channel discharge (Qchannel) is 0.24 m³/s, indicating no flood. For the right segment, Qplan is 0.079 m³/s, and Qchannel is 0.17 m³/s, also indicating no flood. However, despite the channel's capacity, flooding occurs in Bah Tongguran because the valley area prevents water from flowing to the river.

## Modeling of Drainage Channel using Storm Water Management Model (SWMM)

The drainage channel modeling for Bah Tongguran Street is carried out with a 5-year return period. It consists of 2 sub catchments, 10 junctions, 10 conduits, and 2 outfalls. Subcatchments can be represented using the subcatchment button on the object toolbar. Based on the land use, the catchment area of Bah Tongguran Street consists of residential areas with asphalt roads. The N-impervious value for non-absorbent areas is 0.011, while the N-previous value for non-waterproof areas is 0.15, representing sparsely vegetated grassy land.

The top view of the drainage network schema for Bah Tongguran Street can be seen in Figure 4. The right segment is illustrated at points JC2, JC9, JC3, and JC4 from left to right, while the left segment is illustrated at points JC6, JC10, JC7, and JC8. Additionally, Figure 5 shows that at node JC7, which is in the valley and part of the main channel of the left segment of the drainage system on Bah Tongguran Street, this section is unable to handle the water flow during the 5-year return period. This occurs because the location is in a valley or concave contour, causing the water to be unable to flow and accumulate in that low-lying area. On the other hand, Figure 6 shows that node JC3 in the main channel of the right segment of the drainage system on Bah Tongguran Street, it also cannot accommodate water during the 5-year return period.

Table 7. Planned Discharge of Drainage Channel in Bah Tongguran

| | | |
|---|---|---|
| **Left Segment** | **Intensity** | **713.11** |
| | **Area km$^2$** | 0.0091 |
| | **C** | 0.52 |
| | **Q plan** | 0.093 |
| **Right Segment** | **Intensity** | 561.58 |
| | **Area km$^2$** | 0.0093 |
| | **C** | 0.54 |
| | **Q plan** | 0.079 |

Table 8. The comparison between the planned discharge (Qplanned) [24] and the channel discharge (Qchannel) [25]

| **Flood Point** | **Channel** | **Q plan** | **Q channel** | **Description** |
|---|---|---|---|---|
| **Bah Tongguran** | **Left Segment** | 0.093 | 0.24 | No Flood |
| | **Right Segment** | 0.079 | 0.17 | No Flood |

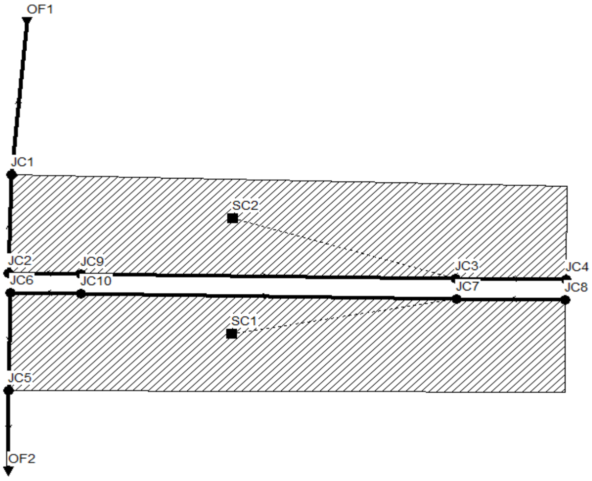

Figure 4. Drainage Network Schema for Bah Tongguran Street

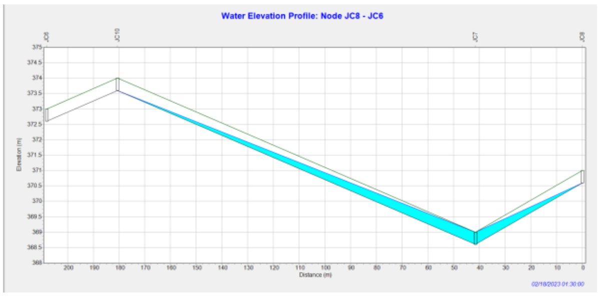

Figure 5. Running SWMM for the 5-year return period at nodes JC6, JC10, JC7, and JC8 sequentially from the left side of the figure.

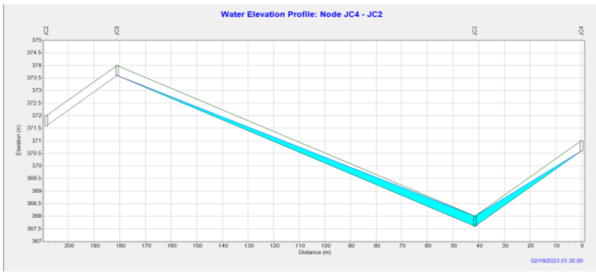

Figure 6. Running SWMM for the 5-year return period at nodes JC2, JC9, JC3, and JC4 sequentially from the left side of the figure

This is also due to the location being in a valley or contour resembling a basin, causing water to stagnate and accumulate in that valley area. Furthermore, there is no main river to carry the water away from nodes JC3 and JC7.

## Handling Alternative for Waterlogging Using Infiltration Wells

In this research, there is a flood location point on Bah Tongguran Road, which has a topography like a basin or valley, making it impossible to redesign the drainage channel in that area to prevent floods because water will continue to accumulate in the valley area. Based on hydraulic calculations, the channel's flow rate (Q) is found to be higher than the Q planned flow rate, so the dimensions of the drainage channel are not the cause of the floods on Bah Tongguran Road. Therefore, improvement can be made by planning infiltration wells to collect and infiltrate water back into the ground, thereby reducing the burden on the drainage system. The planned infiltration wells on Bah Tongguran Road using the Sunjoto method [26] are as follows:

a. Shallow infiltration wells have a diameter of 1.4 m.
b. The height of the infiltration wells is 1.5 m.
c. The well walls use concrete pipes with a wall thickness of 10 cm.
d. The cover of the infiltration wells uses concrete pipes with a thickness of 10 cm.
e. The infiltration wells are filled with coconut coir (ijuk) 10 cm and gravel 20 cm to filter the water that will be absorbed into the ground [27].
f. The inlet pipe size is 110 mm in diameter.
g. The overflow pipe size is 110 mm in diameter.
h. The control basin uses square-shaped brick pairs with a width of 30 cm, a depth of 35 cm, and a brick thickness of 10 cm.

## Type of Infiltration Wells

The detailed top view of the house featuring an infiltration well can be seen in Figure 7. The water entering the well is rainwater conveyed from the house gutter. The horizontal gutter is a half-circle with a diameter of 8 inches, and the vertical gutter has a diameter of 4 inches. The planned layout determination is adjusted according to the Indonesian National Standard (SNI) 03-2453-2002 [28]:

a. Distance from the house foundation to the infiltration well is 2 meters.
b. Distance from the foundation to the control tank is 100 cm.
c. Distance from the control tank to the infiltration well is 50 cm.
d. Distance from the infiltration well to the tree is 3 meters.

Based on Table 9, it is known that infiltration wells are planned with a diameter of 1.4 m and a depth of 1.5 m, totaling 24 wells on the left segment and 21 wells on the right segment of Bah Tongguran Road.

## Comparison of research results with previous studies

In contrast to previous research by Zainal [1], Molya [2], and Nyoto [3], which focused on infiltration wells in general urban or residential contexts, this study specifically highlights the unique challenges in valley areas, where conventional drainage systems are inadequate due to topographical constraints. While earlier studies established the basic effectiveness of infiltration wells in enhancing eco-drainage systems and urban flood management, they did not delve into the complexities posed by valley regions.

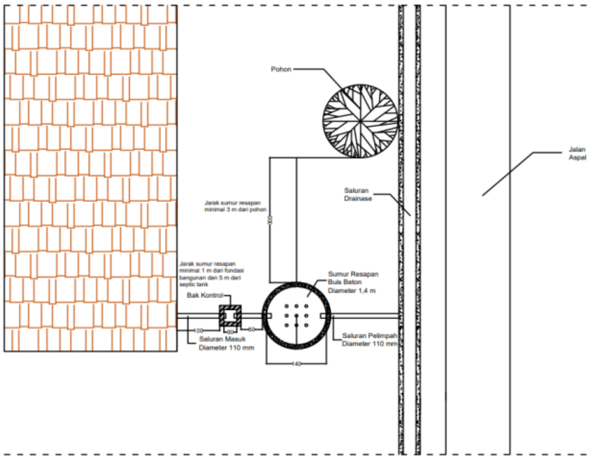

Figure 7. Top View of Infiltration Well Planning

Table 9. Infiltration Well Planning for Bah Tongguran Road.

| Location | Diameter (m) | H = 1.5 (m) | Number of Wells (Piece) |
|---|---|---|---|
| **Left Segment** | 1.4 | 1.5 | 24 |
| **Right Segment** | 1.4 | 1.5 | 21 |

For instance, Zainal's [1] study in residential areas did not consider the impact of topographical depressions on flood accumulation, nor did it address the specific design adaptations required for such environments. Similarly, Molya's [2] work on eco-drainage as an alternative solution did not tackle the particular issue of water stagnation in valleys, where water cannot easily escape due to the natural contour of the land. Additionally, Juliastuti's [4] research offered a nuanced understanding of drainage capacity but remained limited to urban contexts, lacking consideration of the more complex drainage challenges in valley areas.

The findings from this research, therefore, contribute a critical perspective on the application of infiltration wells in valley regions. Unlike general applications, the effectiveness of infiltration wells in valleys depends heavily on localized conditions, including soil permeability and groundwater levels. This research has demonstrated that with proper design adjustments, such as those applied on Bah Tongguran Road, infiltration wells can significantly mitigate flood risks even in challenging topographical conditions.

However, this study also highlights limitations not typically encountered in less topographically constrained areas, such as the risk of ineffective infiltration due to high groundwater levels or impermeable soil conditions, as noted in hydrogeological studies like those conducted by the USGS in New York.

Table10. Effectiveness of Infiltration Well [20][30]

| Well Capacity | Q planned ($m^3/s$) | Q well ($m^3/s$) | Q runoff ($m^3/s$) |
|---|---|---|---|
| **Left Segment** | 0.093 | 0.061 | 0.032 |
| **Right Segment** | 0.079 | 0.046 | 0.033 |

| Well Capacity | Effectiveness | Drainage Capacity |
|---|---|---|
| | **%** | **$m^3/s$** |
| **Left Segment** | 65 | 0.24 |
| **Right Segment** | 58 | 0.17 |

Figure 2. Site Plan of Infiltration Well

Eryani [5] research on vulnerability assessment also underscores the importance of in-depth contextual analysis, particularly in identifying areas most susceptible to flooding in valley regions.

Furthermore, Adriansyah [6] research focused on real-time monitoring using IoT technology has shown that the use of such technology can provide critical real-time data to monitor the effectiveness of infiltration wells in valley areas, aiding in more timely and accurate decision-making.

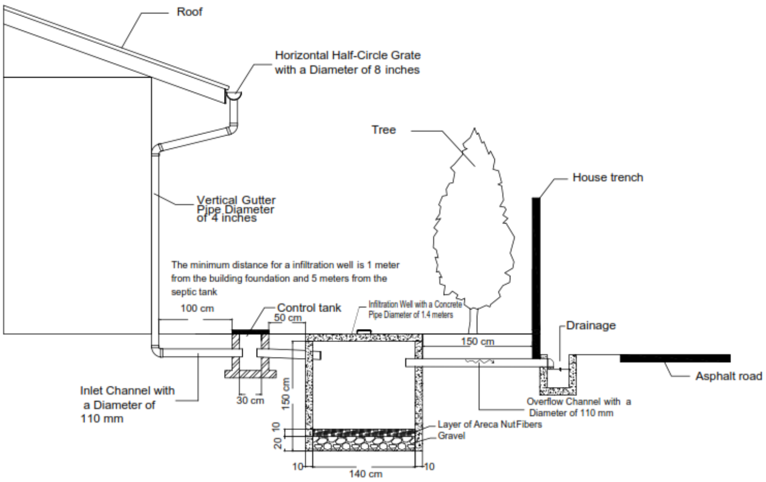

Figure 3. Cross Section of Infiltration Well

## CONCLUSION

The conclusion drawn from this study is based on hydrological and hydraulic calculations, as well as modeling using SWMM software. There are two channels identified that cannot accommodate rainfall discharge, namely the left and right segments of Bah Tongguran Road. The cross-sectional capacity of the channels in Siantar Utara District was determined using hydraulic calculations. The left and right segments of Bah Tongguran Road have capacities of 0.2369 m3/s and 0.1680 m3/s, respectively.

The flood control alternative for the left and right segments of Bah Tongguran Road involves planning the construction of 24 infiltration wells with a diameter of 1.4 m and a depth of 1.5 m in the left segment, and 21 wells in the right segment. The infiltration wells are planned using concrete pipes with an effectiveness of 65% in the left segment and 58% in the right segment, as shown in Table 10.

Figure 8 illustrates the site plan for the placement of infiltration well points, which are connected to the houses on Bah Tongguran Road. Additionally, Figure 9 shows the cross-section of the infiltration well. It can be seen that rainwater falling from the roof will be channeled through a downspout into a control tank, where roof sediments can first settle in the control tank. Subsequently, clean water flowing from the control tank is directed into the infiltration well.

From the infiltration well, the water will seep into the ground and become part of the groundwater storage. However, if there is an overflow in the infiltration well, the excess water will flow into the drainage system with the hope that it will gradually dry out as the drainage water returns to the infiltration well.

This study highlights the critical need for tailored design adaptations of infiltration wells in valley areas, addressing topographical challenges that were overlooked in previous research. While earlier studies confirmed the general effectiveness of infiltration wells, they did not consider the complexities unique to valleys, such as high groundwater levels and impermeable soils. This research demonstrates that with proper adjustments, these wells can significantly mitigate flood risks in challenging terrains. Future research should focus on developing advanced design models specifically for valley regions and integrating real-time monitoring systems to optimize the performance and adaptability of infiltration wells in diverse environmental conditions.

## REFERENCES

[1] Z. E. Zainal, “Infiltration wells for various house types in the Kuranji catchment area, Padang City,” *AIP Conference Proceedings*, vol. 2691. 2023, doi: 10.1063/5.0114963.

[2] R. Molya, “Infiltration Wells as an Alternative Eco Drainage System a Case Study in Mangkubumen Surakarta,” *Lecture Notes in Civil Engineering*, vol. 225. pp. 953–964, 2023, doi: 10.1007/978-981-16-9348-9_84.

[3] R. L. V Nyoto, “Infiltration Wells Program in Jakarta: Twitter Sentiment Analysis,” *2022 1st International Conference on Information System and Information Technology, ICISIT 2022*. pp. 352–357, 2022, doi: 10.1109/ICISIT54091.2022.9872911.

[4] Juliastuti, T. K. Wihartono, O. Setyandito, Y. Wijayanti, L. Safitri, and I. S. D. Sebayang, “The assessment of drainage performance in the residential area using SWMM,” *SINERGI*, vol. 27, no. 2, pp. 281–288, 2023, doi: 10.22441/sinergi.2023.2.016.

[5] I. G. A. P. Eryani, M. W. Jayantari, and S. Ramli, “Determination of flood vulnerability level based on different numbers of indicators using AHP-GIS,” *SINERGI*, vol. 28, no. 1, pp. 13–22, 2024, doi: 10.22441/sinergi.2024.1.002.

[6] A. Adriansyah, M. H. Budiutomo, H. Hermawan, R. I. Andriani, R. Sulistyawan, and A. U. Shamsudin, “Design of water level detection monitoring system using fusion sensor based on Internet of Things (IoT),” *SINERGI*, vol. 28, no. 1, pp. 191–198, 2024, doi: 10.22441/sinergi.2024.1.019.

[7] G. Shrestha, B. M. Shakya, M. B. Shrestha, and U. R. Khadka, “Water infiltration rate in the Kathmandu Valley of Nepal amidst present urbanization and land-use change,” *H2Open J.*, vol. 6, no. 1, pp. 1–14, 2023, doi: 10.2166/h2oj.2023.044.

[8] N. T. Corson-Dosch *et al.*, “Areas Contributing Recharge to Priority Wells in Valley-fill Aquifers in the Neversink River and Rondout Creek Drainage Basins, New York,” *USGS Science Investig. Rep.*, vol. 2022, pp. 1–50, 2022, doi: 10.3133/sir20215112.

[9] L. A. Stenvik, B. O. Hilmo, and B. S. Frengstad, “Elevated manganese concentrations in groundwater wells after longtime abstraction with bank filtration: developing and testing of a sorption model for Ringerike waterworks, Norway,” *Hydrogeology Journal*, vol. 30, no. 7, pp. 2059–2071, 2022, doi: 10.1007/s10040-022-02538-w.

[10] “DEMNAS.” Accessed: Oct. 09, 2023.

[Online]. Available: https://tanahair.indonesia.go.id/demnas/#/

[11] A. M. Al Ali, A. Salih, and A. Hassaballa, “Geospatial-Based Analytical Hierarchy Process (AHP) and Weighted Product Model (WPM) Techniques for Mapping and Assessing Flood Susceptibility in the Wadi Hanifah Drainage Basin, Riyadh Region, Saudi Arabia,” *Water (Switzerland)*, vol. 15, no. 10, 2023, doi: 10.3390/w15101943.

[12] R. Serang, “Overview of River over Drainage Channels in the Wailela River Watershed, Teluk Ambon District, Ambon City,” *International Journal of Advanced Engineering Research and Science (IJAERS)*, vol. 10, no. 2, pp. 029–047, 2023, doi: 10.22161/ijaers.102.4.

[13] S. Vahida and S. N. Sahoo, “Urban Flood Simulation in Erbil City by Using Storm Water Management Model (SWMM),” *Zanco J. Pure Appl. Sci.*, vol. 35, no. 5, pp. 1–11, 2023.

[14] L. B. Firdauzi and U. Suarma, “Analysis of Rainfall Variability and Shifts in Season in Relation to the Rice Cultivation Period in Sleman Regency,” *IOP Conference Series: Earth and Environmental Science (EES)*, vol. 1233, no. 1, p. 012052, 2023, doi: 10.1088/1755-1315/1233/1/ 012052.

[15] S. Bhattarai, P. B. Parajuli, and F. To, “Comparison of Flood Frequency at Different Climatic Scenarios in Forested Coastal Watersheds,” *Climate*, vol. 11, no. 2, 2023, doi: 10.3390/cli11020041.

[16] M. H. Imaaduddiin, W. Utama, C. Jasikur, W. Lestari, and A. N. Aini, “Potential for Renewable Energy Generation from Water Sources in the Batang River Area,” *Environ. Res. Eng. Manag.*, vol. 79, no. 1, pp. 80–89, 2023, doi: 10.5755/j01.erem.79.1.32482.

[17] U. Agustin and M. A. P. Siregar, “Frequency Analysis of Deli River Flood Distribution Plan Using the Gumbel Probability Distribution Method,” *Sinkron*, vol. 8, no. 3, pp. 1474–1485, 2023, doi: 10.33395/sinkron.v8i3. 12543.

[18] R. R. Sari, V. Dermawan, and E. N. Cahya, “Implementation of Building Information Modeling (BIM) on Drainage Channel Design in UB Forest Sumberwangi Area,” *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, vol. 14, no. 02, pp. 178–184, 2023.

[19] A. Satria perdana and W. Sejati, “Flood Water Level Simulation Bringin River, Semarang City By Using The HEC-RAS 6.3.1 Programming,” *APTISI Trans. Manag.*, vol. 7, no. 3, pp. 243–252, 2023, doi: 10.33050/atm.v7i3.2134.

[20] T. Kristiawan and A. P. Irawan, “Analysis of Annual Rainfall Distribution and Planned Rain Intensity at 11 (Eleven) Rain Post Stations in Serang District,” *International Journal of Entrepreneurship and Business Development (IJEBD)*, vol. 06, no. 05, pp. 945–958, 2023.

[21] Y. I. Sihombing, A. Rizaldi, M. Farid, N. F. Januriyadi, and I. R. Moe, “Jakarta’s 2020 New Year Flood Assessment with a Rainfall–Runoff–Inundation (RRI) Model,” *Environmental Sciences Proceedings,* vol. 25, no. 1, p. 100, 2023, doi: 10.3390/ecws-7-14317.

[22] A. F. A. Oraya, B. V. Alburo, M. K. S. Cauban, and J. B. Canene, “Roof Runoff Analysis: A Case for Cebu Technological University - Main Campus,” *IOP Conference Series: Earth and Environmental Science (EES)*, vol. 1184, no. 1, 2023, doi: 10.1088/1755-1315/1184/1/012015.

[23] V. R. T. Picado and L. C. B. Chavarria, “Methodology for the Calculation of the Runoff Coefficient with the Arrangement Tirado,” *Open Journal of Applied Sciences (OJAppS)*, vol. 13, no. 05, pp. 659–671, 2023, doi: 10.4236/ ojapps.2023.135052.

[24] M. Kencanawati, D. Iranata, and M. A. Maulana, “Hydrologic Modeling System HEC-HMS Application for Direct Runoff Determination,” *Journal of Human, Earth, and Future*, vol. 4, no. 2, pp. 153–165, 2023, doi: 10.28991/HEF-2023-04-02-02.

[25] A. N. O. Fikri, H. T. Tjendani, and W. Oetomo, “Analysis of urban drainage system to avoid rain water overflow on the access road to Juanda Airport,” *IOP Conference Series: Earth and Environmental Science (EES)*, vol. 1195, no. 1, pp. 0–8, 2023, doi: 10.1088/1755-1315/1195/1/012045.

[26] M. Imamuddin, B. Al Hanif, and A. D. Yuliansyah, “Utilization Of Rainwater To Reduce Water Runoff Discharge In The Kelapa Gading Pump Building Area Using The Sunjoto Method,” *International Journal of Civil Engineering and Infrastructure (IJCEI)*, vol. 1, no. 1, pp. 40–52, 2023, doi: 10.24853/ijcei.1.1.40-52.

[27] W. He *et al.*, “Nutrient removal performance and microbial community analysis of amended bioretention column for rainwater runoff treatment,” *Journal of Cleaner Production*, vol. 374, p. 133974, Nov. 2022, doi: 10.1016/j.jclepro.2022.133974.

[28] L. E. Hutabarat and I. V. Simanjuntak, “Using bio-pore infiltration hole to reduce flooding in densely population communities

of Jakarta and surrounding area," *IOSR Journal of Engineering (IOSR-JEN)*, vol. 12, no. 8, pp. 2278–8719, 2022, [Online]. Available: www.iosrjen.org

[29] M. Situmorang, S. Setiyadi, and L. E. Hutabarat, "Infiltration wells utilizing watershed conservation for flood prevention," *IOP Conference Series: Earth and Environmental Science (EES),* vol. 878, no. 1, 2021, doi: 10.1088/1755-1315/878/1/012056.

[30] C. Cahyono and P. A. Setyawan, "Drainage System Planning with Eco-Drainage Concept in Bumi Serpong Damai Housing Area (BSD)," *E3S Web Conf.*, vol. 388, 2023, doi: 10.1051/e3sconf/202338801003.