JCE-PIM JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

Simulation of the Impact of Blue-Green Infrastructure Implementation on Surface Runoff Using the Storm Water Management Model in the University of North Sumatera

Diky Ardana [1*], Robi Arianta Sembiring [1*], Ivan Indrawan [1*], Emma Patricia Bangun [1]

[1] *Department of Civil Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan, 20155, Indonesia*

*Corresponding Author: dikyardana2005@gmail.com, robisembiring@usu.ac.id

ARTICLE INFO

Article history:
Received 30 July 22026
Revised 13 August 2026
Accepted 16 August 2026
Available online 31 August 2026

How to cite:
D. Ardana, R.A. Sembiring, I. Indrawan, E.P. Bangun. Simulation of the Impact of Blue-Green Infrastructure Implementation on Surface Runoff Using the Storm Water Management Model in the University of North Sumatera. Journal of Civil Engineering and Public Infrastructure Management. 2026. 1(3):24-34.

ABSTRACT

Land use changes in urban areas have increased impervious surfaces, resulting in higher surface runoff and greater pressure on drainage systems. As an educational area dominated by buildings, roads, and parking facilities, the Universitas Sumatera Utara (USU) campus has the potential to generate significant runoff that may contribute to urban flooding. This study evaluates the effects of Green Roof, Permeable Pavement, and their combination on surface runoff in the Outlet 2 drainage catchment using the EPA Storm Water Management Model (SWMM). Rainfall data were obtained from the BBMKG Region I Medan, Tanjung Selamat, and Tuntungan stations. Hydrological analyses included frequency analysis, the Chi-Square goodness-of-fit test, the Mononobe method, and the Alternating Block Method (ABM). Four simulation scenarios were evaluated for 2-year and 5-year return periods: existing conditions, Green Roof, Permeable Pavement, and their combination. Under existing conditions, total surface runoff reached 18.570 × 10^6 L and 21.360 × 10^6 L, with average outfall flows of 1.142 m^3/s and 1.208 m^3/s for the 2-year and 5-year return periods, respectively. The combined implementation produced the greatest runoff reduction, decreasing total surface runoff by 28.76% and 25.00%, while Green Roof was more effective in reducing average outfall flow and Permeable Pavement achieved greater reductions in runoff and flooding volumes. These findings demonstrate that combining both BGI practices provides the most effective strategy for improving urban drainage performance.

Keywords: *Blue-Green Infrastructure*, *Green Roof*, *Permeable Pavement*, *Storm Water Management Model* (SWMM), *Surface Runoff*.

1. Introduction

Rapid urbanization and land-use changes have significantly increased the extent of impervious surfaces in urban areas, resulting in higher surface runoff and increasing the risk of urban flooding [1], [2]. Conventional drainage systems are often designed to convey stormwater rapidly to receiving waters, but they frequently become insufficient under increasing runoff volumes caused by urban development and extreme rainfall events [3]. Consequently, sustainable stormwater management approaches have become increasingly important to reduce runoff generation while improving the hydrological performance of urban drainage systems [3].

Blue-Green Infrastructure (BGI) has emerged as a sustainable approach to urban stormwater management by integrating natural and engineered systems that promote rainfall retention, infiltration, storage, and evapotranspiration [4], [5]. Various BGI practices, including Green Roof, Permeable Pavement, Rain

JCE-PIM | JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

Garden, Bioretention, and Infiltration Trench, have been widely implemented to mitigate surface runoff and reduce flood risk [4], [5]. Among these practices, Green Roof primarily functions as a storage-based facility by temporarily retaining rainfall on rooftops, whereas Permeable Pavement promotes infiltration by allowing stormwater to infiltrate into the underlying soil [3], [4]. The combination of these two practices is expected to provide complementary hydrological benefits through different runoff control mechanisms [4].

Despite its potential, the development and implementation of BGI in urban areas face several challenges. BGI implementation requires integration with existing drainage systems, appropriate spatial planning, sufficient technical knowledge, long-term operation and maintenance, and coordination among different stakeholders. In addition, differences in local climate, soil conditions, land availability, urban density, and institutional capacity can affect the performance and feasibility of BGI across cities. Previous studies have emphasized that the transition toward blue-green urban flood resilience requires not only technical solutions but also appropriate planning, governance, and coordination among stakeholders [6], [7]. These challenges are particularly relevant in developing countries, where infrastructure priorities, technical capacity, and financial resources may limit the widespread adoption of BGI [8].

The effectiveness of BGI has been quantified in several previous studies, although the magnitude of reduction varies depending on the type, implementation area, rainfall characteristics, and spatial configuration of the infrastructure. Liu et al. [9] reported that integrated green infrastructure scenarios reduced total runoff by approximately 85–100% and peak flow by 92.8–100% in a community-scale study in Beijing, while the effectiveness of individual facilities was more limited, particularly under larger storm events. Wu et al. [10] found that green roofs reduced annual discharge volume by approximately 7–11%, whereas permeable pavement achieved a runoff reduction of approximately 58%; the combination of BGI measures achieved an overall runoff reduction of approximately 76%. In an Indonesian residential area, Yuono et al. [11] reported runoff-volume reductions ranging from approximately 18.23–18.56% for the minimum Low Impact Development (LID) configuration to 25.35–30.63% for the maximum configuration, with greater reductions generally observed for lower return-period rainfall events. These findings indicate that BGI performance is strongly influenced by the type and scale of implementation, rainfall characteristics, and the combination of different BGI functions.

The effectiveness of BGI implementation can also be evaluated using hydrological and hydraulic models capable of representing rainfall-runoff processes, infiltration, drainage-network response, and alternative land-use configurations. Storm Water Management Model (SWMM) by The United States Environmental Protection Agency (EPA) is widely used for urban drainage and LID analysis because it can represent runoff generation, infiltration, hydraulic routing, and the performance of decentralized stormwater controls [3]. Previous studies have also applied SWMM-based approaches to evaluate LID performance under different design rainfall conditions, demonstrating its usefulness for quantifying runoff-volume and peak-flow reductions [11]. More advanced modelling approaches, such as coupled 1D–2D PCSWMM, have also been used to assess BGI performance under climate change and drainage-system failure conditions [12]. Therefore, SWMM provides a practical modelling framework for evaluating alternative BGI scenarios before physical implementation, particularly when the objective is to compare hydrological responses under consistent rainfall and catchment conditions.

In Indonesia, the application of BGI is relevant to the existing framework for sustainable urban drainage and rainwater management. The Indonesian government has established regulations concerning urban drainage systems and rainwater management at buildings and their plots. Minister of Public Works and Housing Regulation No. 11/PRT/M/2014 addresses rainwater management at buildings and their plots, including the need to manage and utilize rainwater to maintain hydrological conditions and reduce flood risk [13]. In addition, Minister of Public Works and Housing Regulation No. 12/PRT/M/2014 provides a framework for the planned and integrated implementation of urban drainage systems [14]. Although these regulations do not specifically establish BGI as a single infrastructure category, their emphasis on rainwater management and integrated urban drainage provides a policy context that is compatible with the objectives of BGI implementation.

Universitas Sumatera Utara (USU) is characterized by extensive buildings, roads, and parking areas that contribute to a high proportion of impervious surfaces. These conditions increase the potential for significant

JCE-PIM | JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

surface runoff during rainfall events and place additional pressure on the campus drainage system. As a large university campus with extensive built-up areas, USU represents an appropriate case study for evaluating the application of BGI practices in reducing urban surface runoff. Moreover, the campus setting provides an opportunity to evaluate BGI within an existing built environment where land availability and the interaction between buildings, paved areas, and drainage infrastructure must be considered in determining appropriate implementation strategies.

Previous studies have demonstrated that BGI can substantially reduce runoff and flood-related impacts, while the effectiveness of individual measures varies according to their hydrological functions and implementation conditions [8]–[11]. Studies have also shown that combining BGI measures with different functions can provide greater benefits than individual measures by integrating storage, infiltration, and other runoff-control mechanisms [6], [10]. However, studies comparing Green Roof, Permeable Pavement, and their combined implementation within a university campus using the EPA SWMM remain limited, particularly in Indonesia. In addition, limited attention has been given to comparing runoff volume, average outfall flow, and flooding volume simultaneously under different return periods. Therefore, a quantitative assessment of alternative BGI configurations within an existing campus drainage system is needed to support site-specific infrastructure planning and management.

Therefore, this study evaluates the effects of Green Roof, Permeable Pavement, and their combined implementation on surface runoff within the Outlet 2 drainage catchment of Universitas Sumatera Utara using the EPA SWMM. Simulations were conducted under existing conditions and three BGI implementation scenarios for 2-year and 5-year return periods. The study specifically compares total surface runoff, average outfall flow, and flooding volume to identify the relative and combined effectiveness of the selected BGI practices. The findings are expected to provide quantitative evidence for supporting site-specific stormwater management and infrastructure planning in university campuses and other urban areas with similar land-use and drainage characteristics.

2. Method

This study employed a quantitative hydrological modeling approach to evaluate the effectiveness of BGI in reducing surface runoff within the USU campus. Hydrological simulations were conducted using the EPA SWMM Version 5.2, which is widely used to simulate urban drainage systems and evaluate LID practices [3]. The research methodology consisted of study area identification, data collection, hydrological analysis, SWMM model development, simulation of BGI scenarios, and performance evaluation.

2.1 Study Area

The study was conducted within the USU campus, Medan, North Sumatra, Indonesia. The campus covers approximately 116 ha and represents various urban land-use characteristics, making it suitable for evaluating urban runoff mitigation through BGI implementation with the analysis focused on the Drainage Outlet 2 catchment covering approximately 21.7 ha. Rainfall data were collected from three surrounding rainfall stations, namely BBMKG Region I Medan, Tanjung Selamat, and Tuntungan. The analysis focused on Drainage Outlet, which represents the dominant impervious area within the campus drainage system.

The drainage flow direction and catchment boundaries were determined based on differences in elevation at drainage junctions. Each drainage outlet was assumed to function independently, with no backflow occurring between drainage catchments. This delineation was used to define the contributing area represented in the SWMM model and to establish the drainage network boundaries for the simulation. The drainage system of the Universitas Sumatera Utara campus is presented in Figure 1, while the specific study area within the Drainage Outlet 2 catchment is presented in Figure 2.

JCE-PIM JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

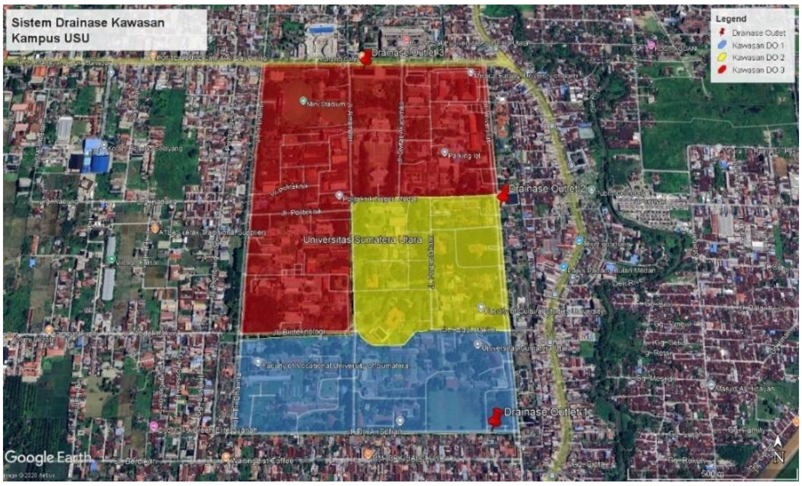

Figure 1 Drainage System of the Universitas Sumatera Utara Campus

Figure 2. Study Area of Drainage Outlet 2

2.2 Data Collection and Hydrological Analysis

Both primary and secondary data were utilized in this study. Primary data included land-use classification, topographic conditions, and the existing drainage network, while secondary data consisted of historical rainfall records, land-use area, and technical specifications of the selected BGI facilities.

The rainfall data were analyzed to obtain design rainfall for the SWMM simulations. Frequency analysis was performed using the Gumbel, Normal, Log-Normal, and Log-Pearson Type III distributions. The goodness-of-fit of the probability distributions was evaluated using the Chi-Square test. The Normal distribution was selected because it produced the lowest calculated Chi-Square value among the accepted distributions. Design rainfall intensity was subsequently calculated using the Mononobe method, while the temporal distribution of rainfall was developed using the Alternating Block Method (ABM). The resulting design hyetographs were used as rainfall inputs for the SWMM simulations.

2.3 SWMM Simulation

The SWMM model was developed to represent the existing drainage system within the Drainage Outlet 2 catchment by defining subcatchments, drainage conduits, junctions, outfalls, and hydrological parameters. The collected field and secondary data were converted into the input format required by SWMM. Green Roof and Permeable Pavement were selected as the BGI practices because they represent storage-based and infiltration-based stormwater control measures, respectively [4], [5]. The Green Roof and Permeable Pavement also represent two different types of BGI. Green Roof represents

JCE-PIM
JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

the detention type of BGI and Permeable Pavement represent Infiltration type of BGI. Four simulation scenarios were evaluated, consisting of (1) existing conditions, (2) Green Roof implementation, (3) Permeable Pavement implementation, and (4) the combined implementation of both BGI practices.

The Horton infiltration model was adopted to represent infiltration processes. The selection was based on the predominantly urban characteristics of the study area and the relatively high proportion of impervious surfaces. In addition, the soil characteristics required for the Green-Ampt method were not available in sufficient detail. The Horton parameters consisted of a maximum infiltration rate of 75 mm/h, minimum infiltration rate of 10 mm/h, decay constant of 4 h^{-1}, and drying time of 7 days.

2.4 Model Verification

Model verification was conducted using the continuity error reported by SWMM. The verification focused on runoff and flow-routing continuity to assess whether the water balance remained within an acceptable range during the simulations. No field-based calibration was performed because the study was limited to simulation-based assessment using SWMM. The acceptance criteria used to evaluate the SWMM continuity error are presented in Table 1.

Table 1. Model Acceptance Criterion

Error Value	Model Status
<1%	Very good
1–5%	Good
5–10%	Acceptable
>10%	Needs Further Review

2.5 Performance Comparison

The performances and the effectiveness of each scenario was evaluated by comparing the simulation outputs with the existing condition. The evaluation focused on total surface runoff, average outfall flow, and flooding. The percentage reduction of each parameter was calculated relative to the existing condition to identify the relative performance of green roof, permeable pavement, and their combined implementation and the most effective BGI implementation strategy for improving drainage system performance.

3. Results and Discussion

3.1 Study Area and Model Development

The study was conducted in the Drainage Outlet 2 catchment of the Universitas Sumatera Utara campus, Medan, Indonesia. The study area was divided into several subcatchments according to land-use characteristics and planned BGI implementation. Green Roof was assigned to selected building-roof subcatchments, while Permeable Pavement was applied to designated paved areas. Remaining pervious and impervious subcatchments were maintained under existing conditions. Junctions representing drainage nodes were incorporated into the SWMM model to simulate runoff routing throughout the drainage network. The spatial distribution of the selected BGI practices within the study area is presented in Figure 3. And the drainage flow direction within the Drainage Outlet 2 catchment are presented in Figure 4.

JCE-PIM
JOURNAL OF CIVIL ENGINEERING AND
PUBLIC INFRASTRUCTURE MANAGEMENT

Figure 3. BGI Distribution Map

Figure 4. Flow Map of Drainage Outlet 2

3.2 Hydrological Analysis

The hydrological analysis was conducted to obtain the design rainfall required for the SWMM simulations. The annual maximum rainfall data from the BBMKG Region I Medan, Tanjung Selamat, and Tuntungan stations were analyzed using several probability distributions. The Chi-Square goodness-of-fit test indicated that the Normal distribution provided the lowest calculated Chi-Square value among the accepted distributions and was therefore selected for determining the design rainfall. The results of the Chi-Square goodness-of-fit test for the evaluated probability distributions are presented in Table 2. The resulting design rainfall was subsequently transformed into rainfall intensity using the Mononobe method and distributed temporally using the ABM to make the model more realistic before being applied to the SWMM model.

Table 2. Chi-Square Goodness-of-Fit Test Results

Distribution	χ^2calc	χ^2crit	Decision
Gumbel	4	5.991	Accepted
Normal	1	5.991	Accepted
Log Normal	3	5.991	Accepted
Log Pearson III	6	3.841	Rejected

JCE-PIM
JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

3.3 SWMM Modelling

The developed model using EPA SWMM Version 5.2. represented the existing drainage system of the Drainage Outlet 2 catchment, including subcatchments, junctions, conduits, outfalls, and LID controls. Each subcatchment was assigned hydraulic parameters based on land-use characteristics, including area, slope, impervious percentage, Manning's roughness coefficient, depression storage, and Horton infiltration parameters. The drainage network geometry was established using field survey data and the existing drainage layout [3].

Two types of Blue-Green Infrastructure (BGI) practices were incorporated into the SWMM model, namely Green Roof and Permeable Pavement, using the LID Control module. Green Roof was implemented on selected building rooftops to increase rainfall storage and delay runoff generation, while Permeable Pavement was applied to paved areas to enhance infiltration and reduce direct surface runoff [4], [5].

Four simulation scenarios were developed to evaluate the hydrological performance of each BGI implementation:

1. Existing condition (without BGI);
2. Green Roof implementation;
3. Permeable Pavement implementation; and
4. Combined Green Roof and Permeable Pavement implementation.

Each scenario was simulated under the 2-year and 5-year design rainfall conditions using identical rainfall inputs. The simulation outputs included total surface runoff, average outfall flow, flooding volume, and LID performance, which were subsequently analyzed to determine the effectiveness of each BGI scenario. The distribution of junctions and conduits used to represent the drainage network in the SWMM model is presented in Figure 5.

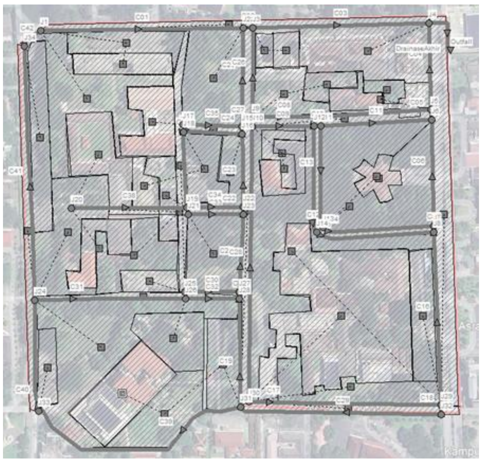

Figure 5. Distribution Map of Junction and Conduit

3.4 Model Verification

The developed SWMM model was validated through model verification and consistency analysis of the simulation outputs. Model validation was conducted by examining the continuity error reported by SWMM to ensure that the hydrological processes were represented properly throughout the simulation period. The continuity errors for both runoff and flow routing were within the acceptable range recommended in the SWMM Reference Manual, indicating that the developed model produced stable and reliable simulation results [3].

Furthermore, the simulated runoff characteristics were evaluated against the expected hydrological response of each BGI practice. Green Roof demonstrated greater effectiveness in reducing average

JCE-PIM JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

outfall flow because of its temporary rainfall storage capacity, whereas Permeable Pavement achieved larger reductions in runoff volume through enhanced infiltration. The combined implementation of both BGI practices consistently produced the highest reduction in total surface runoff and flooding volume for both return periods. These simulation trends are consistent with the findings reported in previous studies on Blue-Green Infrastructure performance [4], [15].

The consistency between the simulation outputs and the expected hydrological behavior indicates that the developed SWMM model is suitable for evaluating alternative BGI implementation scenarios within the Universitas Sumatera Utara campus. The continuity error values obtained for runoff and flow routing under each simulation scenario are summarized in Table 3.

Table 3. SWMM Model Verifications

Scenarios	Periode	Runoff Value	Flow Routing Value	Status
Existing	2	-3,49%	1,25%	Good
	5	-1,25%	1,16%	Good
Green Roof	2	-1,99%	1,43%	Good
	5	-2,03%	1,30%	Good
Permeable Pavement	2	-1,95%	1,47%	Good
	5	-2,71%	1,35%	Good
Combination Both BGI	2	-0,50%	1,75%	Good
	5	-1,27%	1,58%	Good

3.5 Simulation Results

Four simulation scenarios were evaluated, consisting of the existing drainage condition, Green Roof implementation, Permeable Pavement implementation, and the combined implementation of both BGI practices. Simulations were performed for the 2-year and 5-year return periods to assess the hydrological performance of each scenario.

Under the existing condition, the SWMM simulation produced a total surface runoff of 18.570 × 10^6 L and an average outfall flow of 1.142 m^3/s for the 2-year return period. Under the 5-year return period, the total surface runoff increased to 21.360 × 10^6 L, while the average outfall flow reached 1.208 m^3/s. These results indicate that increasing rainfall magnitude substantially increases runoff generation within the study area.

Implementation of the Green Roof scenario reduced total surface runoff by 13.14% for the 2-year return period and 11.47% for the 5-year return period. Meanwhile, Permeable Pavement achieved greater runoff reduction, with decreases of 15.56% and 13.53% for the respective return periods. The combined implementation of Green Roof and Permeable Pavement produced the best overall performance by reducing total surface runoff by 28.76% for the 2-year return period and 25.00% for the 5-year return period. These findings demonstrate the complementary hydrological functions of storage- and infiltration-based BGI practices in urban drainage management. The runoff reduction results for the three BGI scenarios are summarized in Table 4.

JCE-PIM JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

Table 4. Summary of SWMM Simulation Results

Scenario	Runoff Reduction (2-year)	Runoff Reduction (5-year)
Green Roof	13.14%	11.47%
Permeable Pavement	15.56%	13.53%
Green Roof + Permeable Pavement	28.76%	25.00%

3.6 BGI Performance and Effect of Return Period

The comparison between return periods indicates that BGI effectiveness generally decreased under the 5-year rainfall event. The reduction in total runoff decreased from 13.14% to 11.47% for green roof and from 15.56% to 13.53% for permeable pavement. Similarly, the combined scenario decreased from a 28.76% reduction under Q2 to 25.00% under Q5. This reduction in performance indicates that the capacity of BGI systems becomes increasingly constrained under larger rainfall events.

The BGI performance assessment further indicates that the green roof storage layer began to approach saturation under the higher-intensity Q5 event. Once the available storage capacity was exceeded, a greater portion of rainfall contributed to surface outflow. Meanwhile, permeable pavement continued to provide infiltration losses, indicating that its infiltration function remained active during the simulation. Nevertheless, the overall performance of the combined scenario also decreased under Q5, suggesting that both retention and infiltration capacities become increasingly challenged as rainfall intensity and volume increase.

3.7 Discussion and Comparison with Previous Studies

Previous studies have generally evaluated BGI effectiveness primarily based on runoff volume reduction. However, the simulations in this study demonstrate different results, indicating that each BGI practice contributes differently to urban runoff mitigation depending on its hydrological function.

The difference is related to the distinct hydrological mechanisms of the two interventions. Green roof primarily functions as a temporary storage system, which attenuates and delays runoff release, whereas permeable pavement primarily promotes infiltration and therefore contributes more directly to reducing runoff volume. Although each practice individually improved drainage performance, the combined implementation consistently produced the greatest reduction in surface runoff under both return periods.

The superior performance of the combined scenario indicates that integrating storage-based and infiltration-based BGI practices provides complementary benefits. Green Roof attenuates the runoff hydrograph by temporarily retaining rainfall, while Permeable Pavement promotes infiltration into the underlying soil, reducing the volume of water entering the drainage network. Consequently, combining both practices is more effective than implementing either practice individually for improving urban drainage performance within the Universitas Sumatera Utara campus.

Furthermore, the simulation results reveal that the effectiveness of BGI decreases slightly as the return period increases. This behavior is expected because larger rainfall events exceed the storage and infiltration capacities of the implemented BGI facilities. Nevertheless, the combined scenario continued to provide substantial runoff reduction even under the 5-year return period, demonstrating its potential as a sustainable stormwater management strategy for university campuses and urban areas with similar land-use characteristics.

4. Conclusion

This study evaluated the effectiveness of Blue-Green Infrastructure (BGI) implementation in reducing surface runoff within the Drainage Outlet 2 catchment of the Universitas Sumatera Utara (USU) campus using the EPA Storm Water Management Model (SWMM).

The study addressed the potential increase in surface runoff associated with the extensive built-up areas

JCE-PIM JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

of the campus by evaluating three BGI implementation scenarios, namely Green Roof, Permeable Pavement, and their combined implementation. The simulations were conducted for 2-year and 5-year return periods to assess the hydrological response under different rainfall magnitudes.

The results demonstrate that the effectiveness of BGI depends on the hydrological function of each practice and the indicator used for performance evaluation. Green Roof provided a greater reduction in average outfall flow, while Permeable Pavement achieved greater reductions in total runoff and flooding volume. The combined implementation consistently produced the highest overall performance, reducing total surface runoff by 28.76% and 25.00% for the 2-year and 5-year return periods, respectively, while also providing the greatest reduction in flooding volume. These findings indicate that integrating storage-based and infiltration-based BGI practices provides complementary benefits and is more effective than implementing either practice individually. The results also show that BGI effectiveness generally decreases under higher return-period rainfall, indicating the importance of considering rainfall magnitude and the functional capacity of BGI facilities in infrastructure planning.

This study was limited to SWMM-based simulation without field-based calibration and validation. Therefore, the results should be interpreted within the modeled conditions and assumptions of the study area. Future studies should incorporate field observations, evaluate additional BGI configurations, and assess their performance under a wider range of rainfall and catchment conditions. The findings provide a quantitative basis for site-specific stormwater management and sustainable drainage planning in university campuses and urban areas with similar characteristics.

Future studies are recommended to investigate additional BGI practices, evaluate larger drainage catchments, and incorporate field-based model calibration and validation to further improve the reliability of SWMM simulations.

5. Acknowledgements

The authors would like to express their sincere gratitude to everyone who help the author to complete this research, especially colleagues and friends who provided valuable support, assistance, and encouragement throughout the research process. Conflict of Interest

6. Conflict of Interest

The authors of this work, whose names are stated below, attest to the absence of conflicts of interest.

Diky Ardana

References

[1] Wu et al. (2024). *Assessing the performance of blue-green solutions through a fine-scale water balance model for an urban area.* https://doi.org/10.1016/j.scitotenv.2024.174750

[2] IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability.* https://doi.org/10.1017/9781009325844

[3] U.S. Environmental Protection Agency (EPA). (2022). *Storm Water Management Model (SWMM) Reference Manual.*

[4] Ariyarathna et al. (2023). *Blue-Green Infrastructure for Sustainable Stormwater Management.* https://doi.org/10.3390/architecture3030025

[5] Versini et al. (2018). *Blue-Green Infrastructure and Urban Hydrology. https://doi.org/10.1016/j.landurbplan.2018.02.001*

[6] O'Donnell et al. (2020) — *The blue-green path to urban flood resilience. https://doi.org/10.2166/bgs.2019.199*

JCE-PIM | JOURNAL OF CIVIL ENGINEERING AND PUBLIC INFRASTRUCTURE MANAGEMENT

[7] McNabb et al. (2024) — *Unlocking urban blue-green infrastructure: an interdisciplinary literature review analysing co-benefits and synergies between bio-physical and socio-cultural outcomes. https://doi.org/10.2166/bgs.2024.00*

[8] Joshi et al. (2024) — *Blue-Green Infrastructure for Sustainable Urban Settlements: Implications for Developing Countries Under Climate Change. https://doi.org/10.1007/978-3-031-62293-9*

[9] Liu, Wen, Weiping Chen, and Chi Peng (2014). *Assessing the Effectiveness of Green Infrastructures on Urban Flooding Reduction: A Community Scale Study. https://doi.org/10.1016/j.ecolmodel.2014.07.012*

[10] Xuan wu. (2024). *Assessing the Performance of Blue-Green Solutions Through A Fine-Scale Water Balance Model for An Urban Area.* https://doi.org/10.1016/j.scitotenv.2024.174750

[11] Agus L. Yono. (2024). *Simulasi Pengendalian Limpasan Permukaan dengan Penerapan Low-Impact Development di Kawasan Perumahan.* https://doi.org/10.35139/cantilever.v13i2.400

[12] S. N. Mugume and L. P. Nakyanzi, "Evaluation of effectiveness of Blue-Green Infrastructure for reduction of pluvial flooding under climate change and internal system failure conditions," *Blue-Green Systems*, vol. 6, no. 2, pp. 264–292, 2024. https://doi.org/10.2166/bgs.2024.030

[13] Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia, *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 11/PRT/M/2014 tentang Pengelolaan Air Hujan pada Bangunan Gedung dan Persilnya*, Jakarta, Indonesia, 2014.

[14] Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia, *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 12/PRT/M/2014 tentang Penyelenggaraan Sistem Drainase Perkotaan*, Jakarta, Indonesia, 2014.

[15] Andrusenko, Ekaterina. (2025). *Estimating the Impact of Blue-Green Infrastructure on Household Water Demand.* https://doi.org/10.2166/wst.2025.088