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Assessing the Effectiveness of Vegetated Drains in UTHM, Parit Raja

Muhammad Aqil Hakimi Ismail[1], Noor Aliza Ahmad[1]*

[1] *Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, MALAYSIA*

*Corresponding Author: aliza@uthm.edu.my
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Abstract

Vegetated drains are a type of green infrastructure that uses vegetation to capture, infiltrate, and filter stormwater runoff. The study aims to evaluate the performance of vegetated drains in reducing flood risk and improving water quantity in UTHM. Site investigation was at vegetated drains located near the Tunku Tun Aminah Library in UTHM. With hydraulic and statistical analyses, the research evaluates the performance of vegetated drains in reducing peak flow rates, improving infiltration, and enhancing water quantity. Results indicate that vegetated drains effectively reduce peak discharge rates and enhance water infiltration, contributing to flood risk reduction. The analysis highlights that vegetated drains in downstream sections accumulate higher discharges due to upstream contributions and wider channel design. From sample calculation, value of Q_{drain} for section A and B are both 0.3260 m^3/s and 0.3638 m^3/s while the value of Q_{peak} is 0.17 m^3/s. Based on result obtained, Q_{drain} for both section is higher than Q_{peak} that indicate drainage system is capable of handling the peak flow without overflowing. Factors such as vegetation density, drain geometry, and rainfall intensity significantly influence hydraulic performance. Vegetated drains are a viable, sustainable solution for stormwater management, offering cost-effective maintenance, enhanced water quality, and improved biodiversity while mitigating urban flooding risks.

1. Introduction

Urbanization has significantly impacted stormwater management by increasing surface runoff during heavy rainfall. Urbanization has become one of the main factors that cause flooding worldwide in modernized area [1]. In Malaysia urbanization rate of Malaysia is increased rapidly in past 30 years [2]. In Malaysia, the rapid expansion of urbanized regions has replaced natural permeable surfaces with impermeable materials such as concrete and asphalt. Sustainable solutions are important to overcome this rapid growing challenge. Sustainable storm water management refers to applying eco-friendly techniques in dealing with rainwater drainage to avoid having adverse impacts on the environment. Sustainable storm water management concerned the water quality that makes the agriculture has led to discovering new best management practices (BMPs) to minimize effect of storm water. Implementation of natural features such as plants, and permeable surfaces can slow down and capture the stormwater runoff. The vegetated drain is one of the most effective ways in managing the storm water runoff in Malaysia as new best management practices (BMPs).

Vegetated drains represent an effective and eco-friendly method for addressing these challenges. Vegetated drain is an open channel design that treats and manages storm water runoff for a designate water quality and quantity volume used in an agricultural for controlling the erosion [3]. Based on Best Management Practices (BMPs), vegetated drains are pipes or channels that carry stormwater runoff to drainage system. Designed as gently sloped channels with vegetation such as grasses, shrubs, or trees, vegetated drains capture, infiltrate, and filter stormwater runoff from various surfaces like roads and rooftops. Vegetation can reduce water flow that can minimize the effect of stormwater runoff consist of nutrients, bacteria, sediment and pesticides [4]. Vegetated drains perform their role by conveying urban runoff, runoff volume, discharge and improving runoff quality by filtration and settling.

Vegetated drains have been used worldwide as sustainable drainage system applied in many settings such in urban areas [5]. In water management and urban planning, vegetated drains are increasingly recognized due to effectiveness in reducing flood risk. The low cost needed made vegetated drain as a preferred solution for addressing flooding issues in specific areas. According to [3] vegetated drains can be implemented as Best Management Practices (BMPs) without incurring significant construction expenses. The vegetation used on the vegetated drain should be maintained frequently. The maintenance cost of vegetated drain is negligible for vegetated filter strip [6]. Compared to traditional flood control structures like levees or concrete channels, vegetated drains require lower material and labor costs.

This research focuses on the effectiveness of vegetated drains installed at Universiti Tun Hussein Onn Malaysia (UTHM) in Parit Raja. The research provided analysis of the performance of vegetated drains in capturing and retaining stormwater runoff and impact of vegetated drains on reducing peaks flows and volume of runoff. The study uses hydraulic principles and statistical analysis on determining important parameters such as flow depth, water velocity, and discharge rates. These parameters are essential for understanding how vegetated drains perform under varying stormwater conditions, including the ability to manage peak flows and enhance infiltration. By understanding the performance of vegetated drains in specific areas of UTHM, this research aims to provide insights into their potential as cost-effective and eco-friendly solutions for urban stormwater management.

2. Material and Methods

2.1 Study Area

The site for this study was selected by conducting a site survey in the UTHM area. The survey aimed to find a suitable location with vegetated drains. After observation, the chosen location was near Tunku Tun Aminah Library. Fig. 1 illustrates the selected site, located near Tunku Tun Aminah Library at UTHM. The vegetated drains along the library were inspected to understand how they manage stormwater within the area. The selected vegetated drains were used to measure and record parameters such as top width, bottom width, slope, and height.

(a) (b)

Fig. 1 *(a) Map location of the vegetated drains near Tunku Tun Aminah Library; (b) Vegetated drain near Tunku Tun Aminah Library*

2.2 Field Exploration

2.2.1 Measurement Tape

A measuring tape is a tool used to measure the distance or length. This measuring tape is used to collect data from the vegetated drains at site study such as length, width and flow depth. Fig. 2 shows measurement tape.

J. Adv. Environ. Solut. Resour. Recover. Vol. 3 No. 1 (2026) p. 1-9

Fig. 2 *Measurement tape*

2.2.2 Levelling

Levelling equipment is the tools used for set up a level or sloped surfaces. This equipment is commonly used in construction, landscaping and surveying. Levelling is the method used to determine the relative height or elevation of land surface. This equipment contains three main tools which are levelling staff, tripod and total stations. The function of the auto level is to measure the distances, angles and elevations accurately. For this study, levelling work is used to obtain the value of slope. Fig. 3 shows the levelling equipment.

Fig. 3 *Levelling equipment*

2.2.3 Current Meter

Velocity of flow is an important parameter in hydrology, hydraulic and fluid mechanics. The velocity of water can influence a lot of criteria in water movement and transport such as sediment transport, erosion and pollutant. This become an important parameter to be measured in vegetated drains. To measure the velocity of water flow in vegetated drains, the current meter flow is a device are used. The application of this device is the propeller track the speed of water flow and the propeller react with the water flow. Then, the velocity of the water in vegetated drains can be determined based on the speed of rotational propeller. The current meter flow was placed on a point in a stream of the vegetated drain to collect the data. Fig. 4 shows current meter flow used for collecting data.

Fig. 4 *Current meter*

2.3 Data Collection and Analysis

The data collection was carried out in a vegetated drain located near Tunku Tun Aminah Library in UTHM. The data was collected on four different dates. The study was carried out to obtain all important parameters for determining the hydraulic characteristic of vegetated drains. The parameters are such as length of drain, cross sectional area, width, flow depth, velocity and discharge. For collecting data, the vegetated drain was divided into two sections which is section A and section B. The data collected from the vegetated drain includes measurements of flow depth (Y), velocity (V), and the top width of the vegetated channel (T).

The data is crucial for evaluating the channel's performance in terms of its hydraulic characteristics, particularly the cross-sectional area (A) and the flow discharge (Q) of the drain [7]. Determining the hydraulic characteristic of vegetated drains involves some steps of collecting the data and statistical analysis. By collecting the data, the analysis is continued by using statistical method of Manning's equations to determine roughness coefficient, velocity and discharges. Subsequently, hydraulic parameters such as discharge (Q), hydraulic radius (R), and wetted perimeter (P) are calculated. The Manning's value is obtained by empirical testing and references to roughness coefficients for vegetated channels.

To ensure accuracy in the hydraulic assessment, peak flow conditions are also analyzed. The study employs two methods for peak flow determination which are the Mean Section Method and the Rational Method. The Mean Section Method involves dividing the vegetated drain into segments, calculating the area and wetted perimeter for each, and deriving the hydraulic radius and flow rate using Manning's equation. Meanwhile, the Rational Method estimates peak discharge by relating drainage area characteristics, rainfall intensity, and runoff coefficients, ensuring the vegetated drain can handle peak flow events effectively.

3. Result and Discussion

The length of vegetated drain from Section A to Section B was 50m with width of 3.0m and 2.8m. Table 1 shows the hydraulic characteristics while Fig. 5 and Fig. 6 show drain profile for section A and section B.

Table 1 *Hydraulic characteristics for drain*

Hydraulic characteristic	Section of drain	
	Section A	Section B
Width surface	3.0 m	2.8 m
Width basis	0.2 m	0.2 m
Slope, So	0.001	0.001

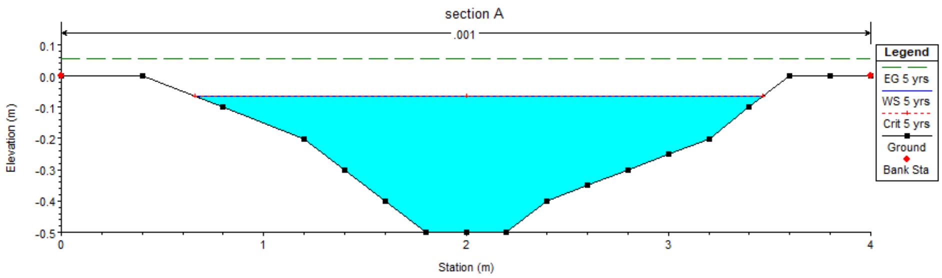

Fig. 5 *Drain profile for section A*

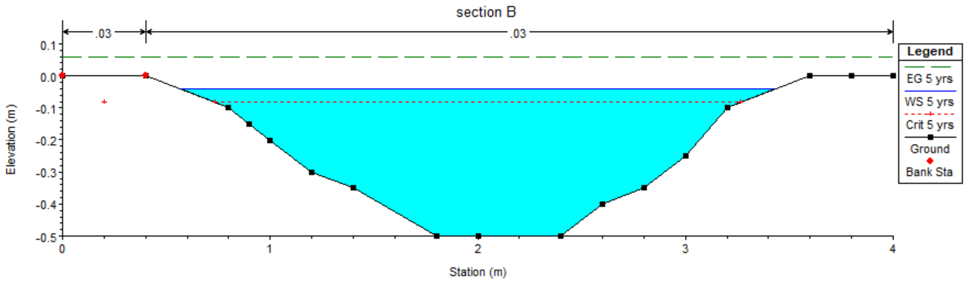

Fig. 6 *Drain profile for section B*

J. Adv. Environ. Solut. Resour. Recover. Vol. 3 No. 1 (2026) p. 1-9

3.1 Flow depth Against Discharge

The data of flow depth and discharge for section A and section B on 28/10/2024, 1/11/2024, 8/11/2024 and 9/11/2024 are analyzed and presented as graph in Fig. 7 and Fig. 8. The graphs display the relationship between flow depth and discharge across section A and section B.

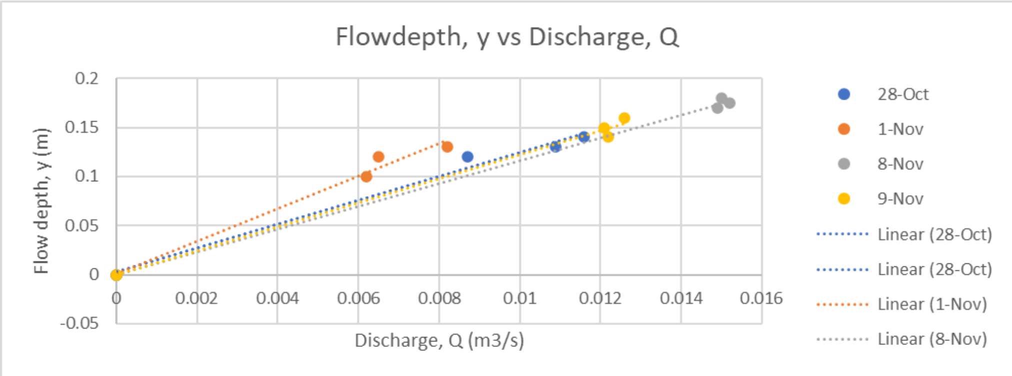

Fig. 7 *Graph flow depth against discharge for section A*

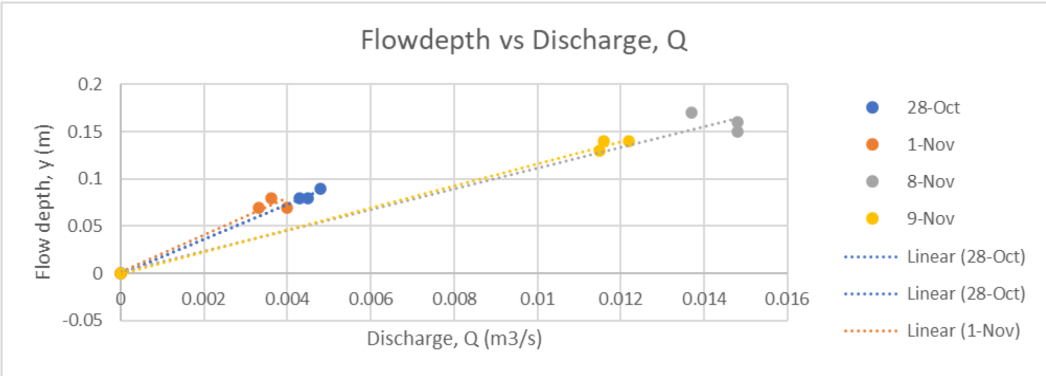

Fig. 8 *Graph flow depth against discharge for section B*

Fig. 7 and Fig. 8 present the relationship between flow depth and discharge at Sections A and B during rainfall events on 28/11/2024, 1/11/2024, 8/11/2024, and 9/11/2024. The data indicate a positive correlation, with higher flow depths resulting in increased discharge for both sections on all four dates. Section A consistently recorded higher discharge values than Section B, as Section A serves as the downstream section, accumulating flow from upstream (Section B). The highest discharge at Section A was 0.0152 m^3/s at a flow depth of 0.175 m on 8/11/2024, reflecting significant runoff accumulation. Section B, being upstream, exhibited its peak discharge of 0.0148 m^3/s at a depth of 0.16 m on the same date, highlighting a quick hydrological response to rainfall. However, discharges at Section B were consistently lower due to the progressive accumulation of water downstream. On 28/11/2024, Section A recorded its lowest maximum discharge of 0.0116 m^3/s at a depth of 0.14 m, corresponding to less intense rainfall. Similarly, Section B's minimum discharge was 0.0048 m^3/s at a depth of 0.09 m on the same date.

3.2 Velocity Against Discharge

Fig. 9 and Fig. 10 depict the relationship between velocity and discharge at Sections A and B during rainfall events on 28/11/2024, 1/11/2024, 8/11/2024, and 9/11/2024. Discharge values in Section A are consistently higher than in Section B, consistent with downstream flow accumulation due to contributions from runoff, tributaries, and rainfall [8]. On 8/11/2024, Section B recorded a velocity of 0.13 m/s and a discharge of 0.0148 m^3/s, while Section A recorded a slightly lower velocity but a higher discharge of 0.0152 m^3/s. This difference is attributed to downstream water accumulation and the wider, flatter channel at Section A, which accommodates larger volumes despite reduced velocity [9]. In contrast, the steeper and narrower upstream channel at Section B results in higher velocities during rainfall events.

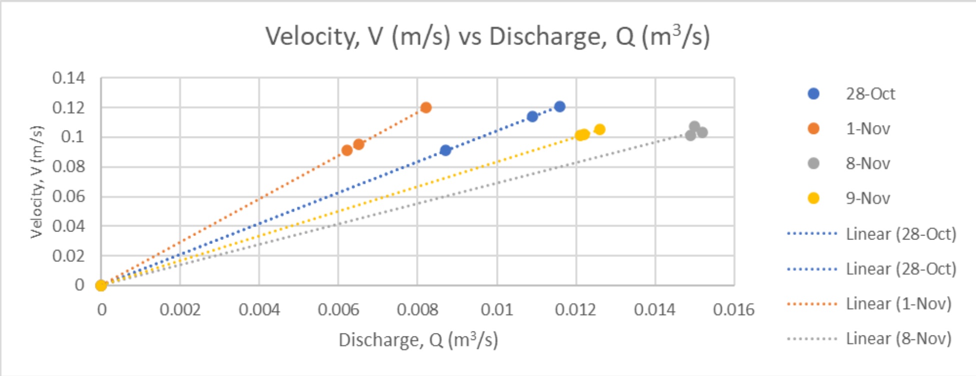

Fig. 9 *Graph velocity against discharge for section A*

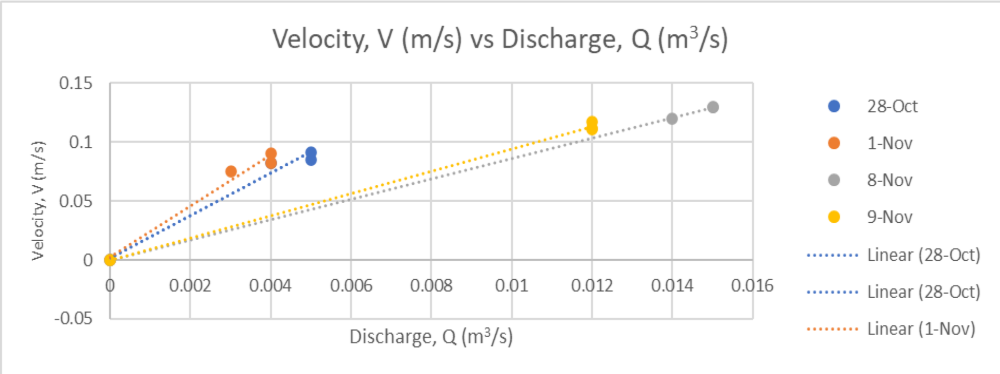

Fig. 10 *Graph velocity against discharge for section B*

Velocity and discharge are strongly influenced by rainfall intensity. On 8/11/2024, both sections recorded peak flow due to intense rainfall. While on 28/11/2024 minimal flow was observed for both sections, reflecting lower rainfall intensity. Other factors may also contribute to the differences observed between the two sections. Vegetation along the channel increases surface roughness, reducing velocity while allowing for greater discharge downstream. Channel roughness, influenced by vegetation and boundary characteristics, significantly impacts flow resistance relative to depth.

3.3 Manning Against Discharge

The data of Manning, n and discharge for section A and section B on 28/10/2024, 1/11/2024, 8/11/2024 and 9/11/2024 are analyzed and presented as graph in Fig. 11 and Fig. 12. Fig. 11 and Fig. 12 depict the relationship between Manning, n and discharge at Sections A and B during rainfall events. Both graphs illustrate a positive correlation between Manning's coefficient, n and discharge. As channel roughness increases, both the Manning value and discharge tend to increase. This relationship is influenced by channel surface characteristics, particularly vegetation. In Section A, the highest discharge of 0.0152 m^3/s was recorded on 8/11/2024, with a corresponding Manning's n of 0.0641. This reflects the impact of dense vegetation in the downstream section, which increases flow resistance but accommodates greater volumes due to accumulated runoff. Similarly, in Section B, the peak discharge of 0.0148 m^3/s on the same day corresponded to a Manning's n of 0.0506, indicative of its narrower, steeper upstream characteristics with less vegetation and lower discharges.

J. Adv. Environ. Solut. Resour. Recover. Vol. 3 No. 1 (2026) p. 1-9

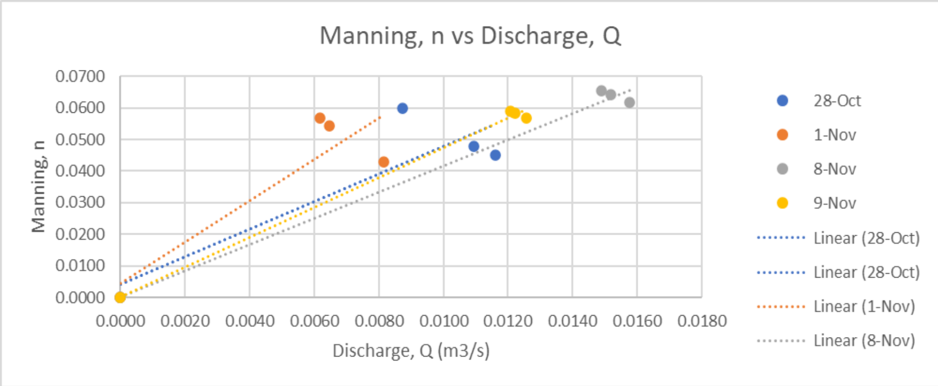

Fig. 11 *Graph Manning against discharge for section A*

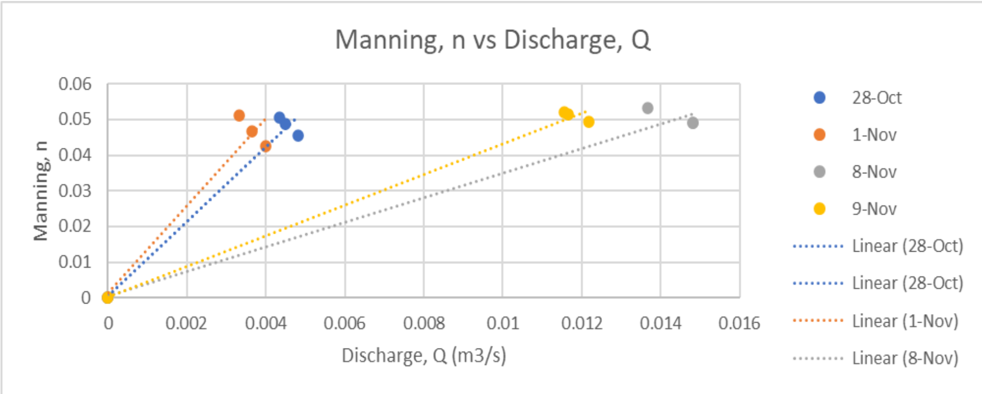

Fig. 12 *Graph Manning against discharge for section B*

Vegetation along both sections contributes to increased surface roughness, which raises Manning's coefficient n. Dense vegetation enhances surface runoff by increasing resistance to flow within the channel. Thus, higher vegetation density correlates with an increase in both Manning's coefficient and overall discharge capacity during rainfall events [10].

3.4 Determination of Q_{drain} and Q_{peak}

The calculation of flow discharge on drain (Q_{drain}) and flow discharge on drainage area (Q_{peak}) is shown in Table 2 and Table 3 respectively. The channel area in Table 2 was determined by assuming the maximum flow depth for each drain. In determining the Q_{drain} the value of Manning, n is using average manning for data collected on 28/10/2024 as reference for the calculations.

Table 2 *Calculation of Q_{drai}n*

Site Study	Channel Area	Wetted Perimeter	Hydraulic Radius	Manning, n	Q_{drain}(m^3 /s)
Section A	0.750	3.00	0.2500	0.050	0.3260
Section B	0.800	3.18	0.2516	0.048	0.3638

Table 3 *Calculation of Q_{peak}*

Runoff coefficient, C Minor system (<10 years ARI)	Average rainfall intensity, i (mm/hr)	Area, A (ha)	Q_{peak}(m^3 /s)
0.83	253.91	0.291	0.17

Based on Table 2 and Table 3, the comparison between Q_{drain} and Q_{peak} can be made. The result shown that the value of Q_{drain} for section A and section B are greater than Q_{peak}. According to [11], the drain is efficient as stormwater quantity control in prevent flash flood is when Q_{drain} greater than Q_{peak}. The results indicate that the drains in Section A and Section B meet this criterion, demonstrating their capability to efficiently manage stormwater runoff and mitigate flash flood risks. Additionally, these findings validate the design and implementation of the drainage system, confirming its compliance with Malaysia's urban stormwater management standards and its role as a reliable stormwater management solution.

4. Conclusion

The study near the Tunku Tun Aminah Library at UTHM aimed to assess the flow characteristics of vegetated drains, focusing on flow depth, discharge, velocity, and Manning's coefficient (n), to evaluate the effectiveness of vegetated drain in stormwater management. Data from multiple rainfall events revealed that the vegetated drains effectively capture and retain stormwater runoff, reducing discharge rates upstream (Section B) compared to downstream (Section A). The analysis confirmed a positive correlation between flow depth and discharge, moderated by vegetation, which absorbed runoff and reduced peak flows. The increased surface roughness due to vegetation slowed water flow and enhanced infiltration. Higher vegetation density was associated with increased Manning's n values, demonstrating higher flow resistance and water retention capacity. The vegetated drains showed significant reductions in peak flows and runoff volumes, aligning with Malaysia's urban Stormwater management standard for effective stormwater systems. Manning's n values ranged from 0.042–0.064 in Section A and 0.047–0.051 in Section B, slightly exceeding Malaysia's urban stormwater management recommendations due to factors like heavy rainfall and vegetation overgrowth. Overall, the study validates vegetated drains as a sustainable urban drainage solution, mitigating flood risks and improving stormwater management.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

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J. Adv. Environ. Solut. Resour. Recover. Vol. 3 No. 1 (2026) p. 1-9

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