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Determination of Surface Runoff Using Rational Method at Al-Sultan Abdullah Hospital, Universiti Teknologi MARA, Puncak Alam

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ABSTRACT

The Al-Sultan Abdullah Hospital development area dominates the ground surface with an impervious surface and few remaining green spaces. This could increase the surface runoff in the area. This study adopted a rational method to determine the amount of surface runoff discharge accumulating on the impervious surface in Al-Sultan Abdullah Hospital. This method considers the catchment area, rainfall intensity, and runoff coefficients. The parameter of rainfall intensity (I) uses the Mononobe formula. In contrast, the weightage average for the total rainfall coefficient (C) and the size of the catchment area (A) is derived from mapping land cover. The results reveal that the total runoff coefficient value is 0.74, meaning that seventy-four percent (74%) of the rainfall becomes surface runoff. The highest surface runoff discharge was on the third of December 2022, with 0.684 m^3/s with a rainfall intensity of 17.73 mm/hr. In contrast, the lowest was on the ninth of November 2022 at 0.331 m^3/s, with a rainfall intensity of 8.59 mm/hr. The results found that the type and size of land cover influence the runoff coefficient in the study area. The results of this study demonstrate that surface runoff discharge from the site study increased as the impervious surface area increased.

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INTRODUCTION

Urban green spaces sustain valuable functions and provide various ecosystem services, addressing the damaging environment and enhancing urbanisation's health while promoting human well-being (Carrus et al., 2015). In the stormwater context, urban green spaces play an important role in absorbing, filtering, and storing stormwater in a natural system. However, the impact of human population growth, coupled with uncontrolled rapid urban expansion, has created enormous pressure on urban green spaces and caused these areas to decline considerably (Jia et al., 2016; Muhamad et al., 2021). In Kuala Lumpur, Malaysia, the area of green space per capita dropped from 13 m^2/inhabitant in 2010 to 8.5 m^2/inhabitant in 2014 (Yusof et al., 2019). Green spaces are typically converted to impervious surfaces by building rooftops, asphalt roads, parking lots, sidewalks, and other paved surfaces.

Problems start to arise during rainy days. These impervious surfaces do not allow water to penetrate through the ground and eventually become runoff, namely what is often called surface runoff (Abdul Khadir et al., 2023; Faraj & Hamaamin, 2023; Ibrahim & Ahmad, 2022; Ozdemir, 2017). An increase in impervious surfaces results in increased surface runoff volume and velocity. It can negatively impact the urban water cycle system and reduce water infiltration into the soil. Traditional solutions to this problem often involve pipe network systems that capture and channel untreated surface runoff to nearby receiving water (Özdemir, 2017). Unfortunately, it contributes to a decline in receiving water quality. According to the Department of Environment (DoE) (2023), out of 672 rivers monitored in Malaysia, 148 (22%) were slightly polluted, while 29 (4%) were polluted. Sustainable stormwater practices must be adapted to address these challenges and minimise adverse environmental and property impacts. Some examples of these practices include permeable pavements, green roofs, rain gardens, bioretention areas, vegetated swales and buffers, and rainwater harvesting (Abdul Khadir et al., 2023). Integrating sustainable stormwater practices into urban planning and design can help address the challenges associated with increased impervious surfaces and surface runoff, ultimately leading to healthier urban environments and enhanced water quality (Chin, 2019). Therefore, monitoring and determining the amount of runoff is crucial for effectively informing decision-making and implementing stormwater management strategies.

For this reason, a study needs to be carried out to determine the amount of surface runoff that accumulates on the surface runoff using a rational method. The rational method can be used to estimate surface runoff discharge within a catchment area of less than 80 hectares. The case study was conducted at Al-Sultan Abdullah Hospital, Universiti Teknologi MARA (UiTM), Puncak Alam. The hospital area was chosen because its surface is largely covered with impervious surfaces, which causes reduced water infiltration and increased surface runoff, contributing to heat-island creation, environmental discomfort, and the possibility of substantial property damage in the future. The planning and design of a hospital's outdoor space should ideally promote a 'healing' and calming green landscape that can have positive health outcomes.

LITERATURE REVIEW

The water cycle describes the endless circulation between the biosphere, atmosphere, lithosphere, and hydrosphere. Water moves from one catchment to another via physical processes such as precipitation, interception, evaporation, transpiration, evapotranspiration, surface runoff, condensation, infiltration, and groundwater base flow. The hydrological cycle begins when water evaporates into the atmosphere from the oceans and the land surface, forming water vapor into clouds. Water vapor will then fall as precipitation on land when it condenses within clouds. It will be distributed in four main ways: fall on open bodies of water, be intercepted by vegetation, infiltrate the soil, or become surface runoff (Pagano & Sorooshian, 2002). Surface runoff can pick up and deposit particle matter and silt into rivers when it travels on impervious surfaces. The impervious surfaces are anthropogenic surfaces such as buildings, concrete or asphalt paving,

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roads, walkways, and parking lots. The surfaces cause increased surface runoff and reduced water infiltration into the ground (Eshtawi et al., 2016). For example, a 0.4-hectare parking lot can produce 16 times more surface runoff yearly than a 0.4-hectare meadow (Ibrahim, 2019). Surface runoff occurs when the intensity of rain that falls in an area exceeds the soil's infiltration capacity. Factors affecting surface runoff are divided into two groups, namely meteorological elements, and the physical properties elements of the drainage area (Muhammad et al., 2022). Meteorological elements include types of precipitation, rainfall intensity, rainfall duration, and distribution in the drainage area. In contrast, the physical properties elements include land use, soil type, and topographical conditions.

In Malaysia, proactive measures were taken to ensure that surface runoff is managed in an eco-friendlier concept for environmental sustainability, resulting in the introduction of The Urban Stormwater Management Manual for Malaysia (MASMA) in 2001. MASMA provides clear and detailed guidelines on various aspects of stormwater management, from design criteria to best management practices (BMPs) and maintenance requirements. It is crucial to ensure developers, engineers, and local authorities can easily understand and implement the recommended measures (Ismail, 2022; DID, 2012). In addition, MASMA considers specific geographical, climatic, and hydrological characteristics. This adaptability ensures that the stormwater management strategies are well-suited to local conditions, enhancing their effectiveness. In the face of urbanisation and climate change challenges, MASMA is no exception in prioritising the issue. It provides strategies to mitigate their impacts through proper stormwater system planning, design, and management (DID, 2012; Zakaria et al., 2004). In addressing surface runoff problems, MASMA emphasises strategies using permeable surfaces, retention and detention, green infrastructure, and integrated stormwater management. These strategies consider the entire water cycle and mimic natural drainage patterns. In conclusion, MASMA is an effective tool for managing stormwater in urban areas. Continuous monitoring and quantifying of surface runoff are essential to ensure the long-term effectiveness of MASMA in mitigating the impacts of surface runoff and improving urban water management.

However, currently, Malaysia's construction management cycle often integrates surface runoff into soil erosion control practices, utilising traditional soft landscaping methods. The methods include grassed waterways, terracing, sediment basins, silt fences, straw mulching, hydroseeding, soil binders, and geotextiles in stabilising and reinforcing soil (DID, 2010). Over time, the application of these methods has evolved from traditional methods to advanced engineering approaches such as rational methods. The rational method provides a more scientific and systematic approach to post-construction stormwater management (Samani, 2021; Özdemir, 2017). The method emphasises the importance of understanding and quantifying the hydrological processes to design effective erosion control measures and ensure the long-term sustainability of construction projects (Samani, 2021). Several other methods can be incorporated with the rational method, such as the Time-Area Method (Green, 2014), SCS-CN Method (Reshma et al., 2010; Cronshey, 1986), Unit Hydrograph Method (Guo, 2022; Cronshey, 1986), Green-Ampt Method (Mein & Larson, 1973), Muskingum-Cunge Method (Reshma et al., 2010; Tewolde & Smithers, 2006). Incorporating these methods into the discussion on the rational method can enrich the technical aspect of surface runoff analysis and provide researchers and practitioners with more options and tools for estimating peak runoff rates and managing stormwater in urban and suburban areas.

METHODOLOGY

Site Study

Al-Sultan Abdullah Hospital is located at a latitude of about 3°12'28" to 3°12'42"N and a longitude of 101°26'58" to 101°27'11" E, with an elevation of thirty-three meters (33m) above the mean sea level. The area’s hot and humid tropical climate has an average annual rainfall of 2400 mm. Al-Sultan Abdullah Hospital, which covers 18.62 hectares, was completed in 2020 and commenced operations on April 5, 2021. The hospital is in the Kuala Selangor district, as shown in Figure 1. It is now a new landmark of UiTM,

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offering treatment and health services to nearly 1.5 million people in Selangor and South Perak. In managing surface runoff, this hospital area uses a traditional civil engineering approach which conveys runoff from paved surfaces directly into storm drains, carrying it offsite as quickly as possible.

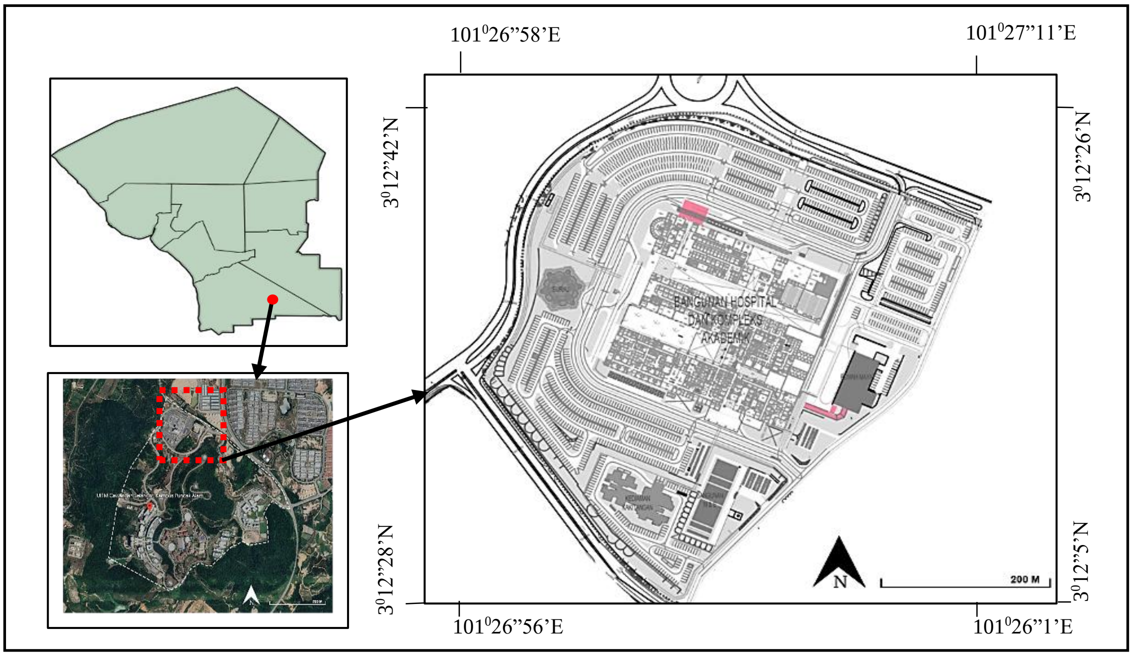

Fig. 1. Location of study area

Source: Authors, 2023

Data Collection

Data collection consisted of primary and secondary data. Primary data was obtained from a fieldwork survey using visual observation, activity mapping, photographic records, and notes. Data collection was conducted for one week within the mid-month of June 2023 to obtain the existing land use type of the study site. The collection of land use data was based on its land cover, namely buildings, roads, pavement, parking lots, paved surfaces, and open and green spaces. This was composited into an AutoCAD drawing of the site study (Figure 2). The types of secondary data needed were as follows:

(i) Information on theoretical surface runoff issues and background information on site study was obtained from scholarly journals, books, reports, and internet sources.

(ii) Daily rainfall data was obtained from the Malaysia Meteorological Department at Selangor River Estate measuring stations for the past three months (October to December 2022). The three months were chosen because the largest rainfall events could lead to significant amounts of surface runoff. This data was used to obtain the rainfall intensity value in mm/hr using the Mononobe method.

(iii) A site map was obtained from Google Maps on a scale of 1:200. This map was used to identify the existing land cover type and processed using AutoCAD tools to produce a land cover map

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(iv) The runoff coefficient value data for each land use type was used to calculate the total runoff coefficient using the weighted average method. The data from this method was then used to calculate the surface runoff discharge of the Al-Sultan Abdullah Hospital areas.

Data Processing

Data analysis has been performed with mathematical calculation methods and descriptive methods as described in the following section.

Rainfall Intensity

Rainfall intensity is the amount of rain that falls expressed in mm/hour. Calculating the intensity of rain is based on daily rainfall data using the Mononobe formula (Sujono, 1997).

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{0.75} \qquad (1)$$

Where I = rainfall intensity (mm/hr)
R_{24} = maximum rainfall in 24 hr (mm)
t = rain duration (hr)

Weightage Average Runoff Coefficient

The calculation of the runoff coefficient in this study uses the land cover approach. Each land cover type has a different runoff coefficient value, as Manual Saliran Mesra Alam (MSMA) (2012) states. Table 1 presents the runoff coefficient values. After determining the runoff coefficient for each land cover, the total runoff coefficient was calculated using the weightage average runoff coefficient as follows:

$$Cw = \frac{\Sigma C_1A_1 + C_2A_2 + C_3A_3 + C_nA_n}{A_1 + A_2 + A_3 + \cdots A_n} \qquad (2)$$

Where $C_{1,2,3\ldots n}$ = runoff coefficient values of each type of land cover area
$A_{1,2,3\ldots n}$ = area of each land cover
C_W = weightage average runoff coefficient

Table 1. Recommended runoff coefficient (c) for various land uses

Land Use	Runoff Coefficient	
	For Minor System (≤ 10-year ARI)	For Major System (≥ 10-year ARI)
Residential		
Bungalow	0.65	0.70
Semi-detached Bungalow	0.70	0.75
Link and Terrace House	0.80	0.90
Flat and Apartment	0.80	0.85
Condominium	0.75	0.80
Commercial and Business Centers	0.90	0.95
Industrial	0.90	0.95
Spot Fields, Park and Agriculture	0.30	0.40
Open Spaces		
Bare Soil (No Cover)	0.50	0.60
Grass Cover	0.40	0.50
Bush Cover	0.35	0.45
Forest Cover	0.30	0.40
Road and Highways	0.95	0.95
Water Body (Pond)		
Detention Pond (with outlet)	0.95	0.95
Retention Pond (no outlet)	0.00	0.00

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Source: Manual Saliran Mesra Alam, 2012

Surface Runoff Discharge

The rational method was used to estimate the amount of surface runoff discharge (Q_P). This relative method, developed by Emil Kuichling in 1889, is most effective in small areas with drainage areas of less than 80 hectares (Cleveland, et al., 2011). The rational method to estimate the amount of surface runoff is as follows:

$$Q_P = 0.0028\,CiA \qquad (3)$$

Where Qp = peak discharge runoff (m^3/s)
C = runoff coefficient
i = average rainfall intensity (mm/hr)
A = area (ha)

Data Analysis

The study analysis involves an analytical approach to estimating surface runoff discharge within the study area by integrating land cover mapping, rainfall intensity, runoff coefficients, and rational methods for runoff estimation. The following is a detailed elucidation of each step involved in the study analysis:

(i) The development of land use mapping aims to categorise various land cover types (parking areas, roads, pavements, paved surfaces, buildings, and green areas) within the study site, as illustrated in Figure 1. This map serves as a tool for determining the percentage of each land cover type, which is presented in a tabular format as Table Analysis 2.

(ii) Subsequently, the rainfall intensity was analysed using the Mononobe formula (1) by selecting the daily rainfall event data exceeding the thirty (30) mm/hr category from October to December 2022. The results of this analysis are generated into Intensity-Duration-Frequency (IDF) curves shown in Figure 3. These curves accurately depict the maximum event anticipated in an area, reflecting the average rainfall intensity for various events at each return frequency. However, the study solely focuses on rainfall intensity data for a 2-hour duration, as presented in Table Analysis 4.

(iii) Next, based on the MSMA table (Table 1) for standard rainfall coefficients and employing the weightage average formula (2), the rainfall coefficient of each land cover type is estimated to obtain the total rainfall coefficient of the study area, as tabulated in Table 5.

(iv) Upon the rainfall intensity data and total runoff coefficients are obtained, empirical equations known as rational methods (3) have been applied to determine surface runoff discharge according to the analysis of rainfall events and each land cover type. Both analyses are illustrated in Tables 6 and 7, along with graphical representations in Figures 4 and 5.

RESULTS AND DISCUSSION

Land Cover

Land cover refers to the surface cover on the ground consisting of vegetation, water, soil, and other physical features. In contrast, land use is related to human activity on land, such as agriculture, settlements, recreation, or industry (Kaul & Sopan, 2012). The Al-Sultan Abdullah Hospital area has various types of land cover consisting of buildings, open land and green areas, paved surfaces, roads, and pavement, as shown in Figure 2.

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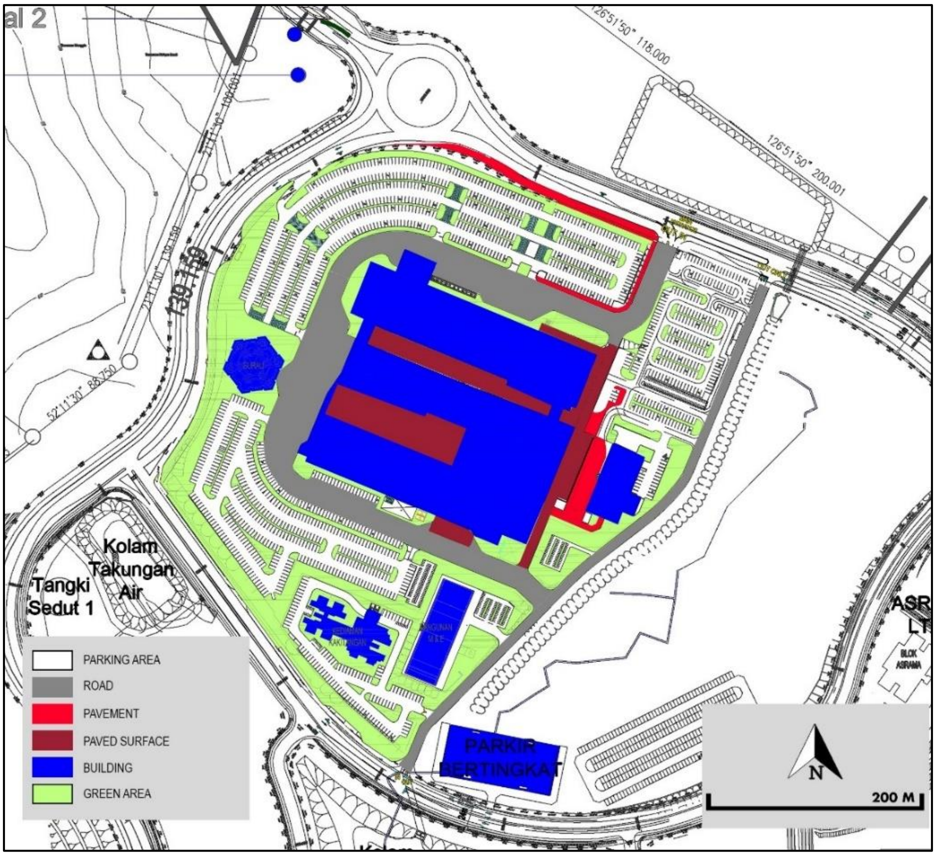

Fig. 2. Land cover map within Al-Sultan Abdullah Hospital

Source: Authors, 2023

Due to built-up land having replaced the natural soil cover with an impervious surface when it rains, water will stagnate and puddle in several locations, especially those at lower elevations, because the water cannot seep appropriately into the ground. To reduce surface runoff in this area, a drainage system was constructed. However, this is not the best solution, considering the importance of the ground, which ideally acts as a 'sponge' area to ensure that groundwater is accumulated. In addition, the effect of runoff channeled through the drainage system will increase the rate of surface runoff and subsequently cause the possibility of property damage in the future.

Table 2 shows the area and percentage of each land cover, respectively. Buildings occupy 21.95% of the study area, while green space occupies only 17.29%. The impervious surface (paved surfaces, parking lots, pavement, and roads) occupies 60.76% of the area. Based on this distribution, buildings, and impervious surfaces dominate the entire study area. The issue of stagnant and puddled water in some locations necessitates development planning that prioritises green spaces. Green spaces play an important function in absorbing or collecting rainfall into the ground while minimising runoff.

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Table 2. Land cover area

Land Cover	Area (m^2)	Percentage (%)
Buildings	40,864	21.95
Roads	33,945	18.23
Parking lots	56,501	30.34
Pavement	10,231	5.49
Paved surfaces (courtyard)	12,459	6.70
Green space	32,200	17.29
Total	186,200	100.00

Source: Authors, 2023

The impact of land cover changes on hydrological response can be seen from the total surface runoff discharge, increase or decrease of runoff, and groundwater and water availability. The greater the green land cover percentage, the lower the baseflow, runoff coefficient, and surface runoff discharge. Due to thick green layers, rain can deeply infiltrate the soil (Sunandar, 2016).

Rainfall Intensity

Rainfall intensity is the amount of rainfall event during a given period and the measurement is expressed in mm/hr. High-intensity rainfall generally occurs for a short duration and covers a small area. Rainfall covers a wide area, rarely with high intensity unless it occurs for a long period. Rainfall intensity is determined using the Mononobe formula (1) sourced from daily rainfall data, assuming that rainfall is distributed over 24 hours. The daily rainfall analysed spanned from October to December 2022, with an intensity of more than 30 mm/day (heavy to very heavy category). The category of rainfall is considered to have the potential to cause water stagnation or puddles on impermeable surfaces. The categorisation of daily rainfall is presented in Table 3.

The determinations of the distribution, duration, and intensity of rainfall are based on the IDF curve (Figure 3). From the figure, for increasing rainfall duration, the rainfall intensity decreases. This shows that heavier rainfall leads to greater intensity, even though the duration is the same. This will cause an increase in the amount of surface runoff as calculated using the rational method (3).

Table 3. Categorisation of rainfall intensity

Rain Categorise	Rain Intensity
Light	1-10 (mm)
Moderate	11-30 (mm)
Heavy	31-60 (mm)
Very Heavy	>60 (mm)

Source: Department of Irrigation and Drainage Malaysia, 2019

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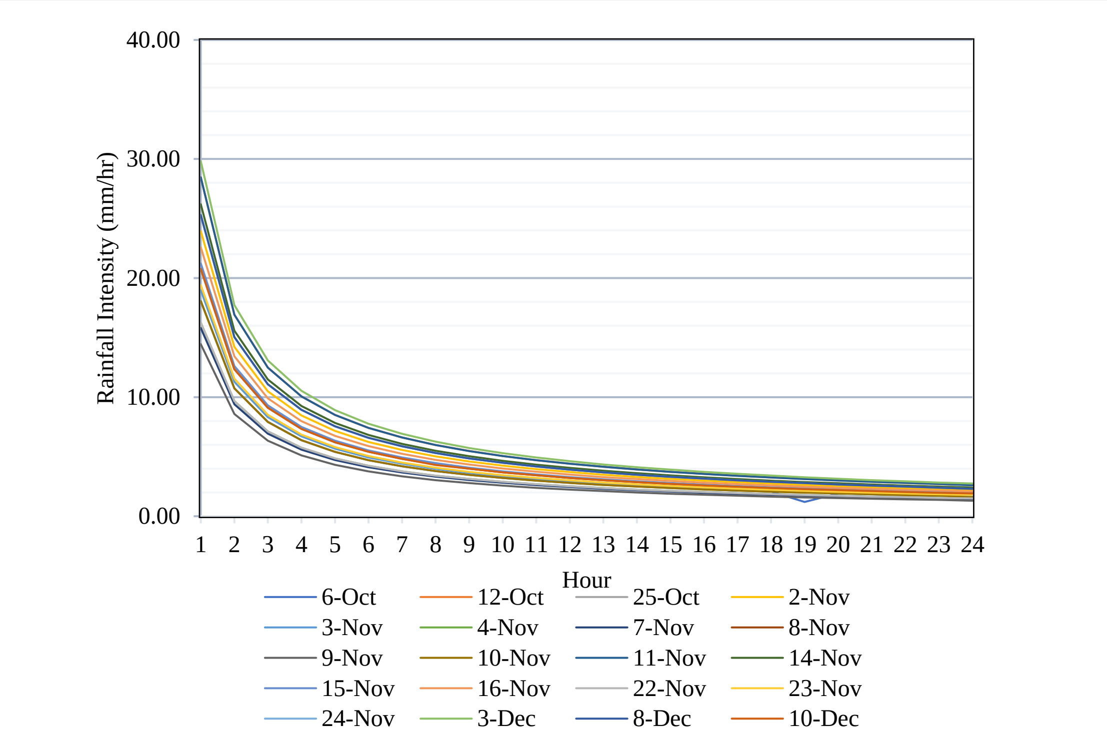

Fig. 3. Intensity Duration Frequency (IDF) curve

Source: Authors, 2023

The Mononobe formula (1) calculates the rainfall intensity assuming that the rainfall in an area is constant over 24 hours. The average rainfall in the hospital area is assumed to last two hours. Table 4 shows the rainfall intensity data over two hours used to analyse surface runoff release. The calculation of rainfall intensity uses the following equation.

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{0.75}$$

$$I = \frac{40}{24}\left(\frac{24}{2}\right)^{0.75}$$

$$I = 10.75\, mm/hr$$

Compared to low-intensity rainfall, high-intensity rainfall has a greater capability for infiltration. Even if the rainfall is the same in both cases, the surface runoff produced by high-intensity rainfall will be greater.

Table 4. Rainfall intensity

Date	Heavy rainfall (mm)	Rainfall Intensity (mm/hr)
October 06, 2022	40.0	10.75
October 12, 2022	63.0	16.92
October 25, 2022	56.0	15.04
November 2, 2022	53.0	14.23
November 3, 2022	42.0	11.28
November 4, 2022	36.0	9.67
November 7, 2022	35.0	9.40

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November 8 2022	46.0	12.35
November 9, 2022	32.0	8.59
November 10, 2022	40.0	10.74
November 11, 2022	63.0	16.92
November 14, 2022	58.0	15.58
November 15, 2022	47.0	12.62
November 16, 2022	50.0	13.43
November 22, 2022	36.0	9.67
November 23, 2022	43.0	11.55
November 24, 2022	56.0	15.04
December 3, 2022	66.0	17.73
December 8, 2022	56.0	15.04
December 10, 2022	46.0	12.35

Source: Authors, 2023

Based on these calculations, the highest rainfall intensity on 3 December 2022 was 17.73 mm/hr. The heavy rainfall occurred in the very heavy category, which is 66.0 mm. As shown in Table 4, there were three rainfall events in the 'very heavy' category with the thickness of the rainfall above 60.0 mm. Rainfall in the 'heavy to very heavy' category can produce high surface runoff by producing a large volume of runoff. As a result, water will stagnate or puddle, particularly in impervious areas, potentially triggering property damage in the future.

Runoff Coefficient

The runoff coefficient (C) is a dimensionless coefficient related to the amount of rainfall generated to become runoff. The value of C ranges from 0 to 1, where the value C = 0 indicates that all rainfall is infiltrated into the ground, whereas the value C = 1 indicates rainfall becomes surface runoff. Thus, as the value approaches 1, the watershed's condition is increasingly damaged. Referring to the value of the runoff coefficient from MSMA (Table 1), a field study within the Al-Sultan Abdullah Hospital was conducted to calculate the runoff coefficient of each existing land cover, as shown in Table 5. The highest runoff coefficient is 0.95 in the roads and parking lots and the smallest is 0.35 in the green space. Due to the high runoff coefficient on roads and parking lots, 95% of the rain becomes surface runoff and shows very low water infiltration capacity into the soil. As a result, the soil's total water is decreased and may become non-existent. Meanwhile, calculating the total runoff coefficient in the study area can be done by using the weightage average equation (2):

$$Cw = \frac{\Sigma C_1 A_1 + C_2 A_2 + C_3 A_3 + C_n A_n}{A_1 + A_2 + A_3 + \cdots A_n}$$

$$Cw = \frac{139186.70}{186200}$$

$$Cw = 0.74$$

From the equation, the total runoff coefficient in the study area is 0.74, showing that 74% of the rainfall becomes surface runoff.

Table 5. Rainfall coefficient within Al-Sultan Abdullah Hospital

An example of a column heading	Area (A) m^2	Runoff Coefficient (C)	C x A
Buildings	40,864	0.75	30,648.0
Roads	33,945	0.95	32,247.75
Parking lots	56,501	0.95	53,675.95
Pavement	10,231	0.50	5,115.5.45
Paved surfaces (courtyard)	12,459	0.50	6,229.50
Green space	32,200	0.35	11,270.00

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Total	186,200	139186.70

Source: Authors, 2023

Land cover of the green space type has a low runoff coefficient, due to the abundance of vegetation that intercepts precipitation so that it does not all fall to the ground surface. Green areas may also produce debris, which is a good medium because it absorbs water up to 70%, reducing total surface runoff. In contrast, impervious and open land have higher runoff coefficient values and the surface runoff is 5.5 times higher, caused by reduced evapotranspiration and infiltration (Paul et al., 2001). As a result, there is a correlation between the runoff coefficient and the land cover in green space.

The Surface Runoff Discharge

The surface runoff discharge rate is the peak rate of runoff from a drainage area caused by intense rainfall where rain intensity exceeds the soil's infiltration capacity. Based on the rainfall intensity and total runoff coefficient data, the surface runoff discharge for each rainfall event can be estimated using the rational method (3):

$$Q_P = 0.0028\ CiA$$
$$Q_P = 0.0028\ \times 0.74 \times 10.75 \times 18.62$$
$$Qp = 0.414\, m^3/s$$

Calculations of surface runoff for each rainfall event are provided in Table 6. According to the calculation results, the highest surface runoff discharge that occurred during the rainfall event on December 3, 2022, was 0.684 m3/s and the lowest surface runoff discharge that occurred on November 9, 2022, was 0.331 m3/s (Figure 4). The estimation of the total surface runoff discharge in one rainfall event with relatively high rainfall intensity, namely December 3, 2022, indicates the influence of land cover factors on surface runoff discharge.

Table 6. Surface runoff discharge based on rainfall events from rational method

Rainfall Events	C_w	I (mm/hr)	A (ha)	Q (m^3/s)
October 6, 2022	0.74	10.75	18.62	0.414
October 12, 2022	0.74	16.92	18.62	0.652
October 25, 2022	0.74	15.04	18.62	0.580
November 2, 2022	0.74	14.23	18.62	0.550
November 3, 2022	0.74	11.28	18.62	0.435
November 4, 2022	0.74	9.67	18.62	0.373
November 7, 2022	0.74	9.40	18.62	0.362
November 8 2022	0.74	12.35	18.62	0.476
November 9, 2022	0.74	8.59	18.62	0.331
November 10, 2022	0.74	10.74	18.62	0.414
November 11, 2022	0.74	16.92	18.62	0.652
November 14, 2022	0.74	15.58	18.62	0.601
November 15, 2022	0.74	12.62	18.62	0.486
November 16, 2022	0.74	13.43	18.62	0.518
November 22, 2022	0.74	9.67	18.62	0.373
November 23, 2022	0.74	11.55	18.62	0.445
November 24, 2022	0.74	15.04	18.62	0.580
December 3, 2022	0.74	17.73	18.62	0.684
December 8, 2022	0.74	15.04	18.62	0.580
December 10, 2022	0.74	12.35	18.62	0.450

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Source: Authors, 2023

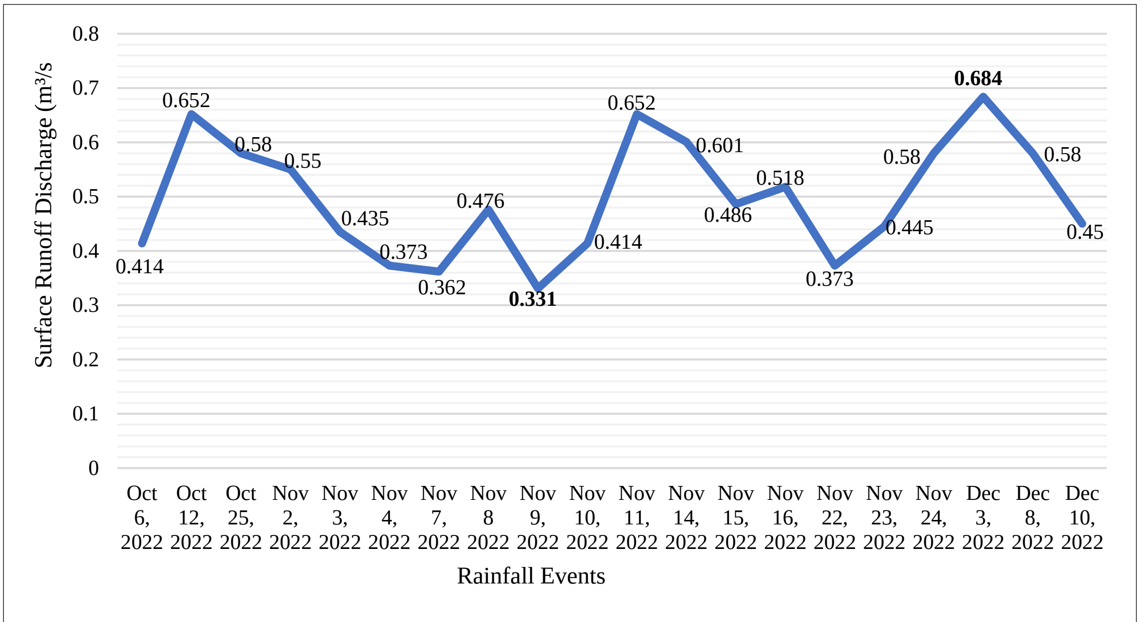

Fig. 4. The highest surface runoff discharge was 0.684 m^3/s on December 3, 2022, and on November 9, 2022, it was the lowest surface runoff discharge, 0.331 m^3/s

Source: Authors, 2023

As for the calculation of surface runoff discharge for each land cover, it can be determined by using the following formula (3):

$$Q_P = 0.0028\ CiA$$
$$Q_P = 0.0028\ \times 0.75 \times 17.73 \times 4.0864$$
$$Qp = 0.152\ m^3/s$$

Calculations for surface runoff for each type of land cover are shown in Table 7. According to the calculation results, the highest surface runoff discharge for land cover is parking lots (0.266 m^3/s) because it dominates the area and has a runoff coefficient of 95% compared to other land cover in the study area. Similarly, buildings have a relatively high discharge runoff of 75%. Table 7 and Figure 5 show the surface runoff discharge estimation results for each land cover.

Table 7. Surface runoff discharge calculation of each land cover from rational method (rainfall events on December 3, 2022)

Land Covers	C	I (mm/hr)	A (hec)	Q (m^3/s)
Buildings	0.75	17.73	4.0864	0.152
Roads	0.95	17.73	3.3945	0.160
Parking lots	0.95	17.73	5.6501	0.266
Pavements	0.50	17.73	1.0231	0.025
Paved Surfaces	0.50	17.73	1.2459	0.030
Open and Green Spaces	0.35	17.73	3.2200	0.057

Source: Authors, 2023

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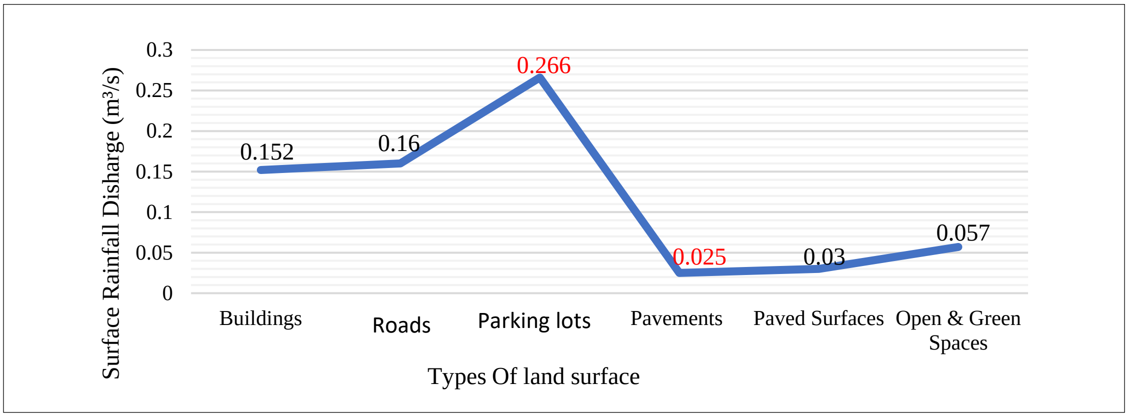

Fig. 5. The highest surface runoff discharge is parking lots, which is 0.266 m^3/s, and the lowest surface runoff discharge, 0.025 m^3/s is pavements.

Source: Authors, 2023

Generally, the development of built-up areas neglects to consider the other land cover coefficient, which suggests that sixty percent (60%) of total land cover should be for green areas and forty percent (40%) for built-up areas. However, about eighty-two percent (82%) of the study area has been used to develop buildings and impervious surfaces. As a result, there is a very low runoff infiltration rate, whereas surface runoff discharge is very high. Apart from the impervious surface factor, the soil type also considerably impacts the infiltration rate. A sandy soil texture tends to infiltrate more water at less than thirty (30) mm/hr, as compared to clay soil texture, which will take one (1) to five (5) mm/hr (Brouwer et al., 1988). Other factors influencing the infiltration rate include soil depth, layer depth, and soil moisture. If the soil is moist and has a thick layer, it requires less rainfall to reach the layer where the soil gets saturated leading to surface runoff (Ibrahim & Ahmad, 2022).

CONCLUSIONS

The total runoff coefficient within the study site is high at 0.74, meaning that 74% of the rainfall will become surface runoff. The type and size of land cover in the study area are two factors that affect the runoff coefficient. Based on rainfall events, the highest surface runoff discharge value was 0.684 m^3/s on third (3^{rd}) of December 2022 with a rainfall intensity of 17.73 mm/hr. The lowest was 0.331 m^3/s on ninth (9^{th}) of November 2022, with a rainfall intensity of 8.59 mm/hr. The results of this study proved that surface runoff discharge increased as the impervious surface increased. This study will increase insight into and knowledge of methods for determining the amount of surface runoff that occurs spatially. This study recommends that the estimated quantity of surface runoff in a catchment area should serve as a benchmark for the determination towards planning and redesign of sustainable stormwater management.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest in the research and agree that this research was conducted in the absence of self-benefits or financial conflicts.

AUTHORS' CONTRIBUTIONS

Faridatul Akma Abdul Latif and Danial Iqmal Khairil conceptualised the research idea, wrote, and analysed study data, designed the methodology, and investigated and collected the data. Faridatul Akma Abdul Latif supervised the research progress and revisions and approved the article submission. Mohd Ruzaini Che Zahari, Salina Mohamed Ali, and Masbiha Mat Isa were involved in carrying out the research's critical review, commentary, and revisions.

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