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Article

Evaluation of the Drainage System at Universitas Pahlawan Tuanku Tambusai Based on an Analysis of the Rainfall Catchment Area

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A B S T R A C T

Drainage systems play a crucial role in managing stormwater runoff and preventing water pooling within the campus area. Infrastructure development at the Universitas Pahlawan campus has led to land-use changes that potentially increase surface runoff and affect the performance of the drainage network. This study aims to analyze catchment area characteristics, calculate design runoff discharge, and evaluate the capacity of the existing drainage network by comparing design runoff discharge with channel capacity. A quantitative descriptive method was employed, utilizing hydrological and hydraulic analysis approaches. Data sources included 10 years of rainfall data from the Silam Station, topographic data and field observations, Rainfall analysis was conducted using probability distributions; runoff discharge was calculated using the Rational Method, and channel capacity was analyzed using Manning's Equation. The results indicate that the Universitas Pahlawan campus area is divided into four catchment zones (A1, A2, A3, and A4) with a total area of 4.27 hectares. Frequency analysis identified the Log Pearson III distribution as the best fit, yielding a design rainfall of 150.256 mm for a 10 year return period. Of the 12 channels evaluated, all channels were individually capable of accommodating the design runoff discharge; however, overtopping was identified in Channel 10, as this channel is located at the confluence of four flows from Zones A1 to A4 that converge at the same outlet point, causing the discharge from the four upstream channels to concentrate simultaneously and exceed the channel's holding capacity. This study provides information on the performance of the campus drainage system and serves as a basis for considering capacity improvements and regular channel maintenance.

1. Introduction

Climate change, the growth of built-up areas, and increasing pressure on water management systems have made surface runoff management an important issue in the development of urban areas and educational institutions. An increase in rainfall intensity over a relatively short time can generate large amounts of surface runoff, especially in areas where impervious land cover is increasing. This condition can cause the capacity of the drainage network to be exceeded, resulting in waterlogging and flooding. Studies on drainage network adaptation show that changes in precipitation patterns and land-use changes are important factors that can increase pressure on urban drainage systems. Therefore, evaluating drainage capacity is no longer sufficient if it only considers the physical condition of the channels; it must also consider the characteristics of the rainfall catchment area and changes in the runoff load received by the drainage network (Panos et al., 2021)

This issue is increasingly relevant in the Indonesian context, which is characterized by high rainfall and extreme rainfall events that can occur in various regions. Data from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) show that in February 2024, 92 of 7,600 observation points experienced rainfall in the extreme category, namely more than 150 mm per day. Extreme rainfall events were also recorded in Riau Province, in addition to a number of other regions in Indonesia. BMKG also recorded very heavy to extreme rainfall in various regions of Indonesia during 2026, which in some cases triggered hydrometeorological disasters. These conditions show that the capacity of drainage systems must be planned and evaluated based on realistic rainfall characteristics and runoff potential, because extreme rainfall events can impose a hydrological load far greater than that of normal rainfall conditions(BMKG, 2026).

Besides rainfall, the development of built-up areas is an important factor influencing the magnitude of surface runoff. Surfaces covered by buildings, roads, parking areas, and other pavements reduce the soil's ability to infiltrate, so the proportion of rainwater that becomes runoff increases. The study by Panos et al. (2021) showed that land-use change through area redevelopment can affect stormwater runoff to a degree comparable to the effects of climate change. Studies at the catchment scale also show that increasingly intensive urbanization can significantly increase peak drainage discharge, so that drainage systems face a risk of overload. Therefore, the characteristics of the rainfall catchment area are an important aspect in determining the magnitude of the runoff contribution that must be conveyed through the drainage network**.**

A drainage system is an important part of water management in an area because it functions to convey and control excess water, especially rainwater, so that it does not disrupt the activities and functions of the area. The presence of a drainage system becomes increasingly important as area development changes the characteristics of the land surface. An increase in the surface area covered by buildings and pavements can reduce the soil's infiltration capacity and increase the volume of water that becomes surface runoff. In the context of hydrology, rainwater management needs to consider the characteristics of the catchment area, land surface conditions, rainfall intensity, and the ability of channels to convey water. Salsabila and Nugraheni (2020) explained that hydrology plays an important role in understanding the processes of rainwater, runoff, and water movement as a basis for water resources management.

Drainage system problems are related not only to the amount of rainfall that occurs, but also to the ability of an area to control the runoff it generates. When high-intensity rainfall occurs in an area with extensive impervious surfaces, most of the rainwater becomes surface runoff and enters the drainage network. If the runoff discharge is greater than the channel capacity, the water can overflow and cause waterlogging. Pangaribuan (2022) explained that drainage functions to control excess water in an area, including reducing waterlogging and controlling excessive stormwater runoff. Therefore, evaluating the capability of the drainage system is an important part of ensuring the sustainability of the area's functions.

This condition is also relevant to the development of educational areas that are experiencing increased physical construction. A campus, as an area with daily activities, requires a drainage system capable of conveying stormwater runoff effectively. The

addition of buildings, parking areas, roads, and supporting facilities can change land use and increase the area of impervious surfaces. Such changes have the potential to increase the load on the existing drainage network. Research on drainage systems in campus areas shows that area characteristics and the magnitude of runoff discharge need to be taken into account when evaluating the capability of the available channels.

Universitas Pahlawan Tuanku Tambusai (UPTT) is an educational area that has experienced infrastructure development in recent years. The construction of new buildings, additional parking areas, and improved supporting facilities have enlarged the paved surface area. This condition reduces the area of land that can naturally absorb rainwater, so that rainwater falling on the campus tends to flow more heavily toward the drainage channels. Field observations in this study also found soil deposits and other materials in several sections of the channels. The presence of these deposits can reduce the effective flow space and potentially reduce the channels' ability to convey water.

This problem shows the importance of understanding the characteristics of the rainfall catchment area at the UPTT Campus. A rainfall catchment area is an area that collects rainwater and directs runoff toward certain channels based on topographic conditions and the direction of surface flow. The size of the catchment area, land-use characteristics, surface slope, and hydrological conditions of the area determine the amount of runoff discharge entering the drainage system. By identifying the catchment areas in more detail, the runoff discharge received by each section of channel can be calculated so that drainage capacity evaluation can be carried out in a more measurable way. This approach is in line with hydrological studies that position catchment area characteristics as one of the important components of runoff analysis.

Design rainfall analysis is also an important part of determining the magnitude of runoff discharge. Adequate rainfall data availability is required so that the hydrological analysis results can represent the rainfall characteristics of the study area. In this study, 10 years of rainfall data from the Silam Station were used and a probability distribution analysis was carried out to obtain the design rainfall. Based on the results, the Log Pearson III distribution was the most suitable for the characteristics of the data used, with a 10-year return period design rainfall of 150.31 mm. The distribution selection process was based on the statistical characteristics of the rainfall data, including the skewness coefficient, so that the selected distribution could be used as the basis for calculating rainfall intensity and design discharge. Dwijayanthi and Ningrum (2024) also demonstrated the importance of frequency analysis in determining the probability distribution appropriate for hydrological data.

Runoff discharge in a catchment area can be determined using the Rational Method. This method considers several main parameters, namely the runoff coefficient, rainfall intensity, and catchment area. In this study, the design discharge was calculated using the Rational Method, while channel capacity was analyzed using Manning's Equation. The use of these methods allows a quantitative comparison between the estimated amount of runoff and the capacity of the channels to convey it. Ramdhani and Yustiana (2023) also used the Modified Rational Method to analyze runoff discharge in the micro drainage of a campus area. Their results showed a design discharge of 0.5313 m^3/s, while the channel capacity reached 1.4747 m^3/s, so the channel was still able to accommodate the design discharge.

Previous studies show that the drainage systems in various areas do not always have the same ability to accommodate runoff discharge. (Affandy et al., 2021), for example, evaluated urban drainage capacity using hydrological and hydraulic approaches. That study used the Rational Method to calculate the design flood discharge and Manning's Equation to analyze channel capacity. The results showed that several channel segments were unable to accommodate the design flood discharge, so capacity improvements and drainage system repairs were required. These findings show that channel capacity evaluation must be carried out based on the specific conditions of the study area, because channel capacity and runoff discharge can differ in each segment.

Similar findings are also seen in studies of residential areas and other regions. Aqsha and Harahap (2022) evaluated the drainage system in a residential area on Jalan Air Bersih, Sudirejo I Subdistrict, Medan Kota District. Meanwhile, Prawati et al. (2022) analyzed the

drainage system for flood and waterlogging mitigation in East Metro District, Metro City. Both studies show that drainage system evaluation is needed to determine the network's ability to control runoff and waterlogging. The study by (Sianipar, 2022) more specifically examined the evaluation of the drainage system at Universitas Medan Area Campus 1, showing that university campuses are relevant locations to study from the perspective of drainage system capability in dealing with stormwater runoff. These references are listed in the References section of this study.

Other studies show variation in the approaches used to evaluate drainage systems. Agustinus (2020) used a hydrological and hydraulic analysis approach in planning the drainage system of the Kampa Sultanate Restoration area. Agustinus's results showed that the planned channel dimensions were able to accommodate the runoff discharge of the study area. These studies strengthen the argument that comparing runoff discharge with channel capacity is an approach that can be used to determine the performance condition of a drainage system.

Although research on drainage systems has been conducted in urban areas, residential areas, and universities, there is still room to deepen drainage evaluation in the Universitas Pahlawan Tuanku Tambusai Campus area by using the rainfall catchment area as the basis of analysis. Previous studies in the document placed more emphasis on calculating runoff discharge, channel capacity, or the use of specific modeling tools. Meanwhile, this study integrates catchment area identification, design rainfall analysis, runoff discharge calculation, and evaluation of existing channel capacity in a single analytical sequence. The research document also notes that previous studies used various approaches, such as SWMM and HEC-RAS, whereas this study uses hydrological and hydraulic analysis with the Rational Method and Manning's Equation.

This gap becomes more important because the capability of a channel is determined not only by its physical dimensions, but also by the amount of discharge entering from the catchment area and the actual condition of the channel. In this study, the UPTT Campus area was divided into four rainfall catchment zones, namely A1, A2, A3, and A4, with a total area of 4.27 hectares. The analysis was carried out on 12 existing channels to determine the ability of each channel to accommodate the design runoff discharge. The results show that, individually, all channels have the capacity to accommodate the design discharge, but there is an overtopping problem in Channel 10 because it is located at the confluence of flows from four catchment zones. This condition shows that drainage system evaluation cannot be carried out only partially based on the capacity of each channel, but must consider the flow accumulation pattern across the entire network.

Based on the above description, research on the "Evaluation of the Drainage System of Universitas Pahlawan Tuanku Tambusai Campus Based on Rainfall Catchment Area Analysis" is important to conduct in order to obtain a quantitative picture of the catchment area characteristics, the magnitude of the design runoff discharge, and the capability of the existing drainage network. This study aims to identify the characteristics of the rainfall catchment areas at the UPTT Campus, calculate the design runoff discharge generated by each catchment area, and evaluate the capacity of the existing drainage channels by comparing the design runoff discharge with the channel capacity. The research questions are: (1) what are the characteristics of the rainfall catchment areas at the UPTT Campus; (2) how large is the design runoff discharge generated in each catchment area; and (3) is the capacity of the existing drainage channels able to accommodate the design runoff discharge occurring in the campus area? Because this study is a technical evaluation using a quantitative descriptive approach, its focus is not on testing hypotheses of causal relationships between variables, but on producing numerical measures that can be used to determine the capability of the drainage system. Thus, this study is expected to make an empirical and technical contribution to the evaluation and maintenance of the drainage network at Universitas Pahlawan Tuanku Tambusai Campus.

2. Literature Review

A drainage system is an important part of water management in an area because it functions to convey, control, and dispose of excess water so that it does not disrupt the area's functions. In civil engineering, drainage relates to efforts to control surface water as

well as water originating from other hydrological processes so that waterlogging can be minimized. In areas undergoing physical development, drainage becomes increasingly important because land-use change can affect rainwater flow patterns. The study by Agustinus (2020) showed that drainage system planning needs to consider the hydrological and hydraulic characteristics of the area so that the planned channel dimensions are able to convey the runoff discharge. Thus, the drainage system in this study is understood as a network of channels that functions to receive and convey stormwater runoff from the Universitas Pahlawan Tuanku Tambusai Campus area.

The concept of a drainage system cannot be separated from hydrology as the basis for understanding how runoff is formed. Hydrology is the science that studies water on Earth, including the processes of rainfall, infiltration, surface flow, evaporation, and other hydrological processes.

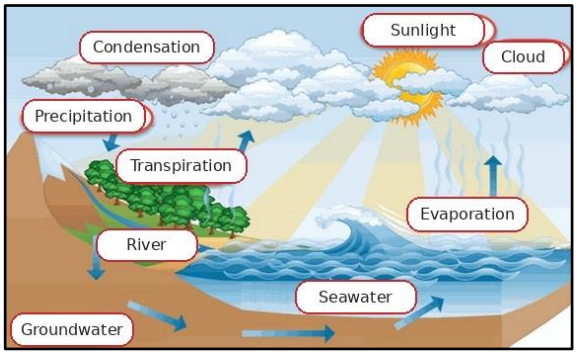


Figure 1. Hydrological Cycle (Immanuel, S. J. 2022)

Figure 1 explains that in the hydrological cycle, rainwater reaching the ground surface undergoes several processes: some infiltrates into the soil and some flows as surface runoff. The amount of runoff is influenced by ground surface conditions, catchment area characteristics, land slope, and rainfall intensity. (Salsabila & Nugraheni, 2020) places an understanding of hydrological processes as the basis for rainwater analysis and management. In this study, the concept of hydrology is used to explain the process of converting rainfall into runoff, which then enters the drainage network. The rainfall catchment area is the main concept in evaluating the contribution of rainwater to a drainage network. A catchment area is an area that receives rainfall and directs runoff toward a certain outlet point or channel. The size of the catchment area is an important parameter because the larger the area contributing flow, the greater the potential volume of water entering the drainage system. In addition to size, catchment area characteristics are also related to land slope, surface flow direction, and land-use conditions. In this study, catchment delineation was carried out based on topographic conditions and flow direction toward the drainage network. The analysis results show that the Universitas Pahlawan Campus area is divided into four zones, namely A1, A2, A3, and A4, with areas of 0.91 ha, 1.46 ha, 0.76 ha, and 1.14 ha respectively, so the total catchment area is 4.27 ha.

The amount of runoff from a catchment area is further influenced by the runoff coefficient. The runoff coefficient indicates the ratio between the portion of rainwater that becomes surface runoff and the total rainfall falling on the drainage area. Its value is influenced by ground surface conditions, type of land use, slope, and soil characteristics. Impervious surfaces such as concrete and asphalt tend to have higher runoff coefficients than parks or land with greater infiltration capacity. In this study, the runoff coefficient is used as one of the parameters in the Rational Method. Based on the largest land-use condition at the study site, the coefficient value used is 0.20, referring to the characteristics of parks and gardens.

The next parameters are rainfall and rainfall intensity. Design rainfall is the amount of rain expected to occur at a certain return period and is used as a basis for hydrological planning. To obtain the design rainfall, frequency analysis of historical rainfall data is required. Dwijayanthi and Ningrum (2024) explained that the selection of a probability distribution in hydrological analysis can be made by considering the statistical characteristics of the data, such as the mean, standard deviation, coefficient of variation, skewness coefficient, and kurtosis coefficient. Distributions commonly used in rainfall analysis include Normal, Gumbel, and Log Pearson III. In this study, the rainfall data used are from the Silam Station for the period 2015–2024, and the analysis results show that the Log Pearson III Distribution is the distribution used to obtain the design rainfall.

Rainfall intensity is the amount of rainfall occurring in a certain unit of time and is generally expressed in mm/hour. This parameter plays an important role in determining runoff discharge because high-intensity rainfall over a relatively short time can produce greater runoff. In drainage analysis, rainfall intensity needs to be adjusted to the time of concentration of the catchment area so that the rainfall conditions used in the calculation can represent the rainfall duration that affects flow at the observation point. The time of concentration is the time required for water to travel from the farthest point of the catchment area to the downstream control point. In this study, the time of concentration is used to determine the rainfall intensity, which then becomes an input in the runoff discharge calculation. This concept is reflected in the stages of the research analysis, which include determining the time of concentration, rainfall intensity, runoff discharge, and evaluating channel capacity.

Runoff discharge is the amount of surface flow generated by rainfall in a catchment area over a certain period. In this study, runoff discharge is calculated using the Rational Method by considering three main parameters, namely the runoff coefficient (C), rainfall intensity (I), and catchment area (A). Conceptually, the larger the catchment area, the higher the rainfall intensity, and the greater the proportion of the surface that generates runoff, the more the runoff discharge that must be conveyed by the channels also tends to increase. The use of the Rational Method is relevant to the study by (Ramdhani & Yustiana, 2023) that used it to evaluate runoff discharge in the micro drainage of the ITENAS Campus area. That study obtained a design discharge of 0.5313 m^3/s, which was then compared with a channel capacity of 1.4747 m^3/s.

Channel capacity is the hydraulic ability of a channel to convey water discharge based on its geometric characteristics and physical condition. The parameters considered include wetted cross-sectional area, wetted perimeter, hydraulic radius, channel slope, surface roughness, and flow velocity. Manning's Equation is used in this study to calculate the velocity and capacity of flow in open channels. The Manning roughness coefficient describes the degree of resistance that the channel surface imposes on the flow; the rougher the channel surface, the greater the flow resistance. Thus, the physical condition of a channel has a direct relationship with its hydraulic capability. Channel capacity evaluation is then carried out by comparing the actual capability of the channel with the runoff discharge that must be conveyed.

Previous studies have produced varied results regarding the relationship between runoff discharge and channel capacity. Ramdhani and Yustiana (2023) found that the drainage capacity of the ITENAS Campus was still greater than the design discharge, so the channels were considered able to accommodate runoff. In contrast, Sianipar (2022) found that some channels were not yet able to convey rainwater discharge properly and experienced sedimentation, so repairs or re-planning were needed. Meanwhile, (Affandy et al., 2021) used hydrological and hydraulic analysis with the Rational Method and Manning's Equation and found that several channel segments were unable to accommodate the design flood discharge at certain return periods. These differing results show that drainage system performance depends heavily on catchment area characteristics, the magnitude of runoff discharge, and the physical capacity of the channels at the study location.

Based on these previous studies, there is a research gap in terms of location context and integration of analysis. The study by Ramdhani and Yustiana (2023) focused on the micro drainage of the ITENAS Campus. The studies by Azizah et al. (2021) and Sianipar (2022) also show the importance of comparing runoff discharge and channel capacity, but catchment area characteristics and flow accumulation patterns in each area can produce different conditions. Therefore, this study at Universitas Pahlawan Tuanku Tambusai Campus is positioned to complement the literature through the integration of *catchment area* delineation, rainfall analysis, determination of rainfall intensity, and calculation of runoff discharge using

The conceptual framework of this study places the rainfall catchment area as the hydrological basis, which then yields the parameters of catchment area size and surface characteristics. These parameters are combined with design rainfall, rainfall intensity, time of concentration, and the runoff coefficient to obtain the design runoff discharge through the

Rational Method. This runoff discharge is then compared with the capacity of the existing drainage channels, calculated based on the channel geometric characteristics and Manning's Equation. The analysis stages in the research file show a systematic sequence, namely delineation of area boundaries, area measurement, identification of land characteristics, determination of the runoff coefficient, design rainfall analysis, calculation of time of concentration, rainfall intensity, runoff discharge, and evaluation of channel capacity. With this framework, the condition of the drainage system is assessed based on a comparison between the design runoff discharge (Q design) and channel capacity (Q capacity)**.** If the channel capacity is greater than or equal to the design discharge, the channel is considered able to convey the runoff; conversely, if the design discharge exceeds the channel capacity, further evaluation is needed regarding the potential for overflow and the need for drainage system treatment.

3. Research Methodology

This study uses a quantitative descriptive design with an applied hydrological and hydraulic analysis approach to evaluate the performance of the area's drainage system. The quantitative descriptive approach was chosen because this study focuses on the systematic and objective collection of numerical data to describe and analyze the physical phenomena of the drainage network system and the rainfall catchment area within the Universitas Pahlawan Tuanku Tambusai Campus environment. This approach allows an explicit quantitative comparison between the design stormwater runoff discharge generated by land cover and the actual holding capacity of the existing drainage channels. Methodologically, quantitative descriptive research based on empirical mathematical modeling is highly effective for identifying potential failures of an area's drainage structures and for determining waterlogging-prone points in a measurable and precise manner (Tallar, 2023)

The population in this study includes all elements of the artificial drainage network and the stormwater catchment areas within the Universitas Pahlawan Tuanku Tambusai Campus, with a total area of 4.27 hectares. The sampling technique was carried out using *non-probability* sampling with the *purposive sampling* method. According to Sugiyono (2023) The selection of channel and catchment samples was based on specific criteria, namely open rectangular-section drainage channels that serve the vital function of conveying the main runoff from campus buildings and parking areas and are directly connected to the final outlet (Ramdhani & Yustiana, 2023). Based on these purposive sampling criteria, the research samples were determined to be 12 existing drainage channel segments (Channel 1 to Channel 12) and 4 main rainfall catchment zones (Zones A1, A2, A3, and A4), whose hydrological and hydraulic characteristics were analyzed intensively.

3.1 Instruments and Materials

The research instruments used include physical and non-physical instruments. Physical instruments include measuring tapes (cloth and steel) to measure channel geometric dimensions, a digital camera/smartphone for visual documentation, and Google Earth Pro software for spatial measurement and delineation of the catchment area. The non-physical instrument is a structured interview guide containing 10 questions related to waterlogging locations, water recession duration, and maintenance obstacles. Validation of the physical instruments was carried out through calibration of measuring tools against technical standards and *cross-validation* of the area between satellite imagery and the coordinate stake boundaries in the field.

Validation of the interview instrument was carried out through data source triangulation, namely matching respondents' verbal information with physical evidence of sedimentation in the field and historical rainfall records (Affandy et al., 2021). The observation sheet was used to record the physical condition of each channel systematically, while the measuring tools were used to obtain the geometric dimensions of the channels directly. The interview guide was used to obtain supporting information on Interviews were conducted with relevant parties or users of the campus environment to obtain information on drainage conditions, locations that frequently experience waterlogging, and the factors influencing the occurrence of rainwater inundation in the study area

Table 1. Research Instruments

List of Questions
What is the current condition of the drainage system on the Universitas Pahlawan?
Is the current capacity of the drainage channels able to accommodate the rainwater discharge?
In which locations does waterlogging usually occur?
In your opinion, what are the main causes of the waterlogging?
How long does the standing water usually take to recede?
What is the condition of the drainage channels that you see (clean, clogged, damaged, etc.)?
Is there any garbage or sediment clogging the channels?
Is there any routine maintenance or cleaning of the drainage channels?
Has any repair or cleaning of the drainage been carried out previously?
What are your hopes or suggestions regarding the improvement of the drainage system at Universitas Pahlawan?

Data reliability was maintained through direct measurement, documentation of field conditions, and matching primary data with secondary data and the results of hydrological-hydraulic calculations.

3.2 Data Collection and Analysis

The analysis stages began with the delineation of the rainfall catchment area using Google Earth Pro software, confirmed with the field topographic contour conditions. Delineation was carried out by drawing the maximum elevation ridge line that bounds the direction of surface water flow toward each drainage segment. From the spatial delineation results, the study area was divided into 4 main zones: Zone A1 (0.91 ha), Zone A2 (1.46 ha), Zone A3 (0.76 ha), and Zone A4 (1.14 ha), with a total area of 4.27 ha. Based on the dominant land cover (parks, asphalt/concrete roads, and building roofs), where the value for the area was set at 0.20 to 0.91 in line with the Bina Marga Standard criteria and the actual pavement conditions in the area (Kustamar, 2019) Data reliability was ensured through the technique of *repeated measurement* on the same channel segments by two different surveyors until a measurement error rate below 1% was achieved.

Hydrological analysis was carried out to determine the design rainfall for a 10-year return period. Based on annual maximum daily rainfall data for 2015–2024 (10 years) from the Silam Station. The frequency analysis procedure involved testing basic statistical parameters, namely the arithmetic mean (X), standard deviation (S), coefficient of variation (C_v), skewness coefficient (C_s), and kurtosis coefficient (C_k) (Suripin, 2010)

4. Results and Discussion

4.1 Characteristics of the rainfall catchment area at the Universitas Pahlawan Campus

Identification of the rainfall catchment area was carried out to determine the area size and the contribution of surface runoff volume entering the drainage network of Universitas Pahlawan Tuanku Tambusai Campus. Based on the delineation results, the Universitas Pahlawan Campus area is divided into four rainfall catchment zones, namely A1, A2, A3, and A4. Each zone has a different size and characteristics, resulting in a different runoff discharge contribution to the drainage channels.

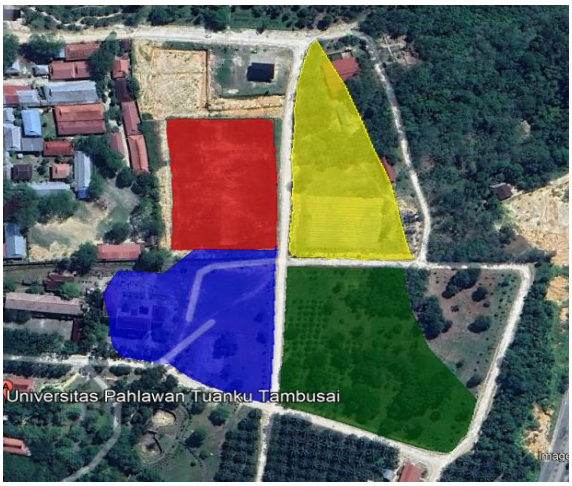


Figure 2. Catchment Area of the Study

The catchment area size taken in the case study was obtained using the Google Earth application. The division of zones was chosen based on the drainage areas that flow toward the case study drainage. The area data by zone division are given in Table 2 beside this text:

Table 2. Rainfall Catchment Area

No	Zone	Area (Ha)
1	A1	0.91
2	A2	1.46
3	A3	0.76
4	A4	1.14
	Total	4.27

Source: Analysis results, 2026

Based on Table 2, Zone A2 has the largest area at 1.46 ha, followed by Zone A4 at 1.14 ha, Zone A1 at 0.91 ha, and Zone A3 at 0.76 ha. The dominance of impervious surfaces in Zones A1 and A2 causes the runoff coefficient 1.46 to be high, which directly increases the volume of rainwater converted into surface runoff toward the drainage network.

4.2 Frequency Analysis

Hydrological analysis used annual maximum daily rainfall data for 10 years (2015–2024) from the Silam Rain Station. Basic statistical processing yielded a mean rainfall {X} of 116.45 mm, a standard deviation (S) of 24.939 mm, a coefficient of variation Cv of 0.214, a skewness coefficient Cs of 0.533, and a kurtosis coefficient Ck of 3.067. To determine the most precise frequency distribution method, an evaluation of the statistical requirements was carried out for three methods (Normal, Gumbel, and Log Pearson III), as presented in Table 3

Table 3. Frequency analysis using the Normal, Gumbel, and Log Pearson III methods

No	Distribution Type	Theoretical Requirement	Sample Result
1	Normal	Cs = 0 and Ck = 3.0	Cs = 0.533; Ck = 3.067
2	Gumbel	Cs ≈ 1.14 and Ck ≈ 5.4	Cs = 0.533; Ck = 3.067
3	Log Pearson III	**Cs ≠ 0**	Cs = 0.301 (on log scale)

Source: Processed research data, 2026

Based on the statistical requirements in Table 3, the Log Pearson III Distribution was selected as the most representative distribution. A recapitulation of the design rainfall calculations for various return periods is presented in the following table:

Table 4. Rainfall Frequency

Return Period (T)	Normal	Gumbel	Log Pearson III
2 years	116.450 mm	113.078 mm	112.979 mm
5 Years	137.398 mm	142.850 mm	135.831 mm
10 Years	148.317 mm	162.562 mm	150.256 mm

Source: Processed research data, 2026

Based on the statistical analysis results in Table 4 above, the mean rainfall ($\bar{X}$) was 116.45 mm, the standard deviation (S) was 24.939 mm, the coefficient of variation (Cv) was 0.214, the skewness coefficient (Cs) was 0.533, and the kurtosis coefficient (Ck) was 3.067. The standard deviation shows that the variation of the rainfall data around its mean is relatively moderate, while the positive skewness coefficient shows that the data distribution tends to be skewed to the right (positively skewed), indicating several rainfall events with high intensity.

Frequency analysis was then carried out using three probability distribution methods, namely the Normal Distribution, the Gumbel Distribution, and the Log Pearson III Distribution. The use of several distribution methods aims to obtain the distribution model that best fits the characteristics of the rainfall data so that the design rainfall calculation results can describe more representative conditions.

The calculation results using the Normal Distribution show that the design rainfall for return periods of 2, 5, and 10 years is 116.450 mm, 137.398 mm, and 148.317 mm, respectively. These values were obtained from the mean rainfall and a frequency factor assumed to follow a normal distribution. However, based on the statistical parameters, Cs = 0.533 and Ck = 0.3067, so the data do not meet the characteristics of a normal distribution, which requires Cs close to 0 and Ck close to 3. Therefore, the normal distribution is considered less suitable for describing the characteristics of the study's rainfall data.

For the Gumbel Distribution, the design rainfall obtained was 113.078 mm for a 2-year return period, 142.850 mm for a 5-year return

period, and 162.562 mm for a 10-year return period. The resulting rainfall values are larger than those of the Normal Distribution, especially for longer return periods. This shows that the Gumbel Distribution is more sensitive to extreme data because it was developed to analyze maximum hydrological events. Nevertheless, based on the statistical parameters, Cs = 0.533 and Ck = 3.067 still do not fully meet the characteristics of the Gumbel Distribution, so this method is also considered less suitable for the study data.

Analysis was then carried out using the Log Pearson III Distribution by first transforming the rainfall data into logarithmic form. The analysis results show that the design rainfall for return periods of 2, 5, and 10 years is 112.979 mm, 135.831 mm, and 150.256 mm, respectively. Based on the calculation results, a skewness coefficient (Cs) of 0.301 was obtained, which meets the requirements for using the Log Pearson III Distribution. This distribution is able to accommodate data with positive skewness, so it is more suitable for hydrological data, which are generally not normally distributed.

Based on the recapitulation of analysis results in Table 4, it can be seen that each method produces different design rainfall values. For a 2-year return period, the design rainfall ranges from 112.979 to 116.450 mm, while for a 10-year return period it ranges from 148.317 to 162.562 mm. These differences are caused by the characteristics of each distribution method in modeling the probability of extreme rainfall. The longer the return period used, the greater the design rainfall obtained, because the probability of high-intensity rainfall occurring becomes smaller.

Based on the statistical evaluation parameters and the uniformity of the distribution, the Log Pearson III Distribution was selected as the method used in this study. The selection of this method was based on a skewness coefficient (Cs) of 0.301, which meets the requirements of the Log Pearson III distribution and better describes the characteristics of rainfall data with positive skewness. Therefore, the design rainfall values from the Log Pearson III Distribution are used as the basis for calculating rainfall intensity and design runoff discharge using the Rational Method in the next analysis stage.

4.3 Evaluation of the Existing Drainage Network Condition Based on a Comparison of Design Runoff Discharge and Channel Capacity

The drainage network evaluation was carried out to determine the ability of the existing drainage channels to accommodate and convey the runoff discharge generated from the rainfall catchment areas in the Universitas Pahlawan Campus area. This evaluation was carried out by comparing the design runoff discharge (Qr) obtained from the hydrological analysis with the existing channel capacity (Qs) calculated using Manning's Equation. If Qs > Qr, the drainage channel is declared able to accommodate the design runoff discharge; if Qs < Qr, the drainage channel is declared unable to accommodate the design runoff discharge and has the potential to cause waterlogging. Thus, the evaluation results can be used to determine the condition of the existing drainage network and to decide whether repairs or channel capacity improvements are needed.

Overall, the analysis results show that differences in channel capacity are influenced by a combination of cross-sectional area, hydraulic radius, and flow velocity. The larger the cross-sectional area and the higher the flow velocity, the greater the discharge capacity that the channel can convey. The channel capacity values (Q Existing) obtained from this analysis are then used as the basis for comparison with the design runoff discharge (Q Design), so that it can be determined whether the capacity of each channel is still able to accommodate rainfall runoff under design conditions or requires further treatment.

The following Table 5 presents a recapitulation of the geometric dimensions, Manning roughness coefficient (n), design discharge (Q design), and channel capacity (Q capacity) for all 12 drainage channel segments evaluated in this study as follows:

4.4 Discussion of Results

Table 4. Interpretation of Results in the Context of Theory

Channel name	Width (m)	Height (m)	Slope (S)	Manning (n)	QExisting(m^3/s)	QDesign (m^3/s)
Channel 1	0.90	0.72	0.042	0.02	2.834	0.604
Channel 3	0.96	0.60	0.044	0.02	2.529	0.892
Channel 4	0.94	0.62	0.044	0.02	2.517	1.149
Channel 5	0.97	0.62	0.089	0.02	3.750	1.709
Channel 6	0.51	0.43	0.137	0.02	1.206	1.604
Channel 7	0.58	0.59	0.014	0.02	0.670	0.348
Channel 8	0.54	0.61	0.039	0.02	1.070	0.611
Channel 9	0.61	0.56	0.014	0.02	0.680	0.348
Channel 10	0.65	0.53	0.040	0.02	1.068	0.847
Channel 11	0.62	0.43	0.014	0.02	0.513	0.491
Channel 12	0.60	0.53	0.017	0.02	0.698	0.194

Source: Processed research data, 2026

Hydrology and Hydraulics. The results of this study prove that evaluating a drainage system cannot be based only on partial comparisons of individual capacities, but must be analyzed systemically within a single *catchment area network.*

Theoretically, the runoff discharge calculation using the Rational Method (Q = 0.00278.C.I.A) and the capacity evaluation using Manning's Equation show that all 12 channel segments individually have a high safety ratio ($Q_{eksisting} > Q_{rencana}$). However, in accordance with the basic concept of spatial hydrology (Suripin, 2010), water flows by gravity from the upstream catchment areas toward the lowest elevation point. The accumulation of runoff from the four upstream zones (A1, A2, A3, and A4), which is concentrated simultaneously at Channel 10, triggers overtopping. Channel 10, whose original capacity is only 0.513 m^3, is forced to receive the accumulated upstream existing discharge load of 13.506 m^3.

Comparison with Previous Studies and Factors Causing the Differences. The findings of this study share both similarities and significant differences with the results of previous studies. The finding that the individual capacity of the channels is still adequate is in line with the study by Ramdhani & Yustiana (2023) at the ITENAS Campus, which found that the existing runoff discharge was still below the maximum capacity of the channels.

However, this study found systemically contradictory results (failure at the convergence point), caused by a physical infrastructure error, namely the position of the box culvert structure, which was not placed precisely at the junction where the four flows meet. The failure of the box culvert to distribute the combined discharge is the main differentiating factor from ideal drainage conditions. On the other hand, the findings of this study are in line with Sianipar (2022) and Tambunan (2024), who state that drainage failure is often triggered by a reduction in the wetted cross-section due to sedimentation. Field observations confirmed that the accumulation of sediment, leaves, and garbage, as well as the absence of a regular maintenance schedule, increases the channel roughness coefficient and slows the flow velocity, which in turn validates complaints of waterlogging during high-intensity rainfall. This is also relevant to the study by Azizah et al. (2021), which highlighted the increase in impervious pavement area in educational areas as the main trigger of increased peak discharge.

This study makes a theoretical contribution by demonstrating that "partial capacity safety" in hydraulic calculations does not guarantee "overall network system safety" if not accompanied by precision at the topographic confluence point. In practical terms, this finding provides

5. Conclusion

Based on the results of the hydrological and hydraulic analysis and field observations, as the basis for the Evaluation of the Drainage Network of Universitas Pahlawan Campus Based on Rainfall Catchment Area Analysis, the researchers can conclude as follows:

a. The results of the rainfall catchment area (catchment area) delineation show that the Universitas Pahlawan Campus area is divided into four rainfall catchment zones, namely A1, A2, A3, and A4, with a total area of 4,27 ha. Based on the rainfall frequency analysis, the most suitable distribution to use is the Log Pearson III Distribution, with a 10-year return period design rainfall of 150.31 mm.

b. Of the 12 channels evaluated, all channels are individually capable of accommodating the design runoff discharge, but overtopping was identified at Channel 10.

c. Based on field observations and interviews with campus staff and students, the waterlogging problem is influenced not only by channel capacity but also by sedimentation, garbage accumulation, and delays in carrying out channel maintenance. These conditions can reduce the effective cross-sectional area of the channels and thereby hinder water flow.

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