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Analysis of Drainage Channel Capacity in the Perumnas Tlogosari Kulon Area, Semarang City

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Abstract

Tlogosari Kulon Village, Pedurungan District, Semarang City, is a densely populated residential area that regularly experiences inundation and flooding during high rainfall events due to increased surface runoff and suboptimal drainage system performance. This study aims to analyze the hydrological conditions, evaluate the capacity of the existing primary drainage channel, and determine its ability to accommodate the 10-year design flood discharge. The analysis used annual maximum daily rainfall data for 2015–2024 from three rainfall stations, namely Bodri Kuto, Karangroto, and Pucanggading, together with topographic data and field measurements of a 1,787 m-long primary drainage channel. Regional rainfall was estimated using the Thiessen Polygon method, while design flood discharge was determined through frequency analysis using the Gumbel distribution and the Rational Method. Channel capacity was evaluated using the Manning equation. The results indicate that the 10-year design flood discharge is 22.42 m^3/s, whereas the existing channel, with a width of 7.50 m and height of 1.70 m, has a capacity of 36.08 m^3/s and a flow velocity of 2.83 m/s. The capacity margin of 13.66 m^3/s indicates that the channel retains sufficient hydraulic capacity under the 10-year design condition. The existing channel is hydraulically adequate, although periodic maintenance is required to control sedimentation, solid-waste accumulation, and channel narrowing.

Keywords: *Drainage Capacity, Design Flood Discharge, Hydraulic Analysis, Hydrological Analysis, Tlogosari Kulon.*

INTRODUCTION

Drainage infrastructure constitutes a fundamental component of urban water management because it is designed to convey, evacuate, and redirect surface water toward receiving water bodies while simultaneously addressing the interconnected challenges of too much water through flooding, too little water through water scarcity, and too dirty water through pollution (Kodoatie & Sjarief, 2010). In contemporary urban areas, the function of drainage systems has become increasingly complex as rapid urbanization, climate variability, and changes in land-cover patterns alter rainfall–runoff relationships and increase the pressure placed on existing hydraulic infrastructure. Indonesia is particularly exposed to these challenges because its high annual rainfall, generally ranging from approximately 2,000 to 3,000 mm, creates substantial surface-water runoff during the wet season, particularly when rainfall intensity exceeds the conveyance capacity of urban drainage networks (Barkonas, 2007). The interaction between high rainfall, limited infiltration, and increasingly dense built-up areas can transform rainfall events that were previously manageable into localized flooding when drainage systems are inadequately dimensioned or poorly maintained. Urban drainage capacity is therefore not merely a question of channel dimensions, but reflects the combined influence of hydrological inputs, hydraulic characteristics, catchment development, and the operational condition of the drainage network. Recent research has increasingly emphasized that reliable flood assessment requires drainage representation that reflects actual conveyance limitations rather than assuming that drainage infrastructure can freely transmit all generated runoff (Singh et al., 2023).

Semarang City represents a particularly relevant urban setting for examining these dynamics because population growth and continuing spatial development have intensified pressure on land and water resources, with the city recording 1,694,743 inhabitants in 2023 (Badan Pusat Statistik Kota Semarang, 2023b). Increasing population density encourages the conversion of permeable and open areas into residential, commercial, and transportation surfaces, reducing infiltration opportunities and increasing the proportion of rainfall converted into direct runoff. Changes in urban land use have been identified as an important determinant of flood-management performance in Semarang, particularly because increased impervious surfaces modify runoff generation and hydraulic loading within drainage and river systems (Arifianto & Andawayanti, 2026). The problem becomes more pronounced in densely populated residential environments where limited open space restricts opportunities for water retention and infiltration while simultaneously increasing the volume of runoff that must be accommodated by existing channels. Urban development and land-use change consequently create a mismatch between the hydraulic conditions for which older drainage systems were designed and the runoff conditions generated by contemporary urbanization. This condition indicates that drainage evaluation should be linked to the characteristics of the surrounding catchment rather than treating channel capacity as an isolated hydraulic variable. The resulting vulnerability is particularly important in neighborhoods where recurrent inundation indicates that the existing drainage network may no longer provide an adequate level of hydraulic service.

One of the areas experiencing recurring flooding is Tlogosari Kulon Village, Pedurungan District, which covers approximately 2.35 km² and had a population of 32,605 inhabitants, making it the second most densely populated village in the district (Badan Pusat Statistik Kota Semarang, 2023a). The high population concentration and extensive residential development place considerable pressure on the local drainage system, particularly because the available land for natural water retention and infiltration is increasingly constrained. Previous drainage assessments in Semarang have demonstrated the relevance of evaluating existing channel capacity against design discharge, as illustrated by the analysis of drainage capacity along Gajah Raya Street, where the hydraulic performance of the drainage system was examined in relation to generated runoff (Sani & Akbar, 2024). Conditions in Tlogosari Kulon are further complicated by the downstream connection of the local drainage network to the Tenggang River, whose channel is affected by substantial sediment accumulation and solid waste that can reduce effective flow conveyance during rainfall events. Such physical obstructions can produce hydraulic restrictions that are not adequately represented when drainage performance is assessed solely from nominal channel dimensions. The combination of dense urbanization, high runoff potential, downstream hydraulic constraints, and recurrent inundation establishes Tlogosari Kulon as an appropriate case for a site-specific investigation of drainage-channel performance.

Existing studies provide important methodological foundations for evaluating whether urban drainage systems remain capable of accommodating design flows, although their findings also reveal substantial differences in analytical focus and local hydraulic conditions. Aziz (2021), for example, evaluated an urban drainage channel along Sukowati Street in Sragen by comparing the capacity of the existing channel with the design discharge generated within its service area. Similar capacity-based assessment was applied by Ramadhan et al. (2025) in evaluating drainage channels along Kolonel Sugiono Street, where the adequacy of channel conveyance was examined against hydrological design requirements. Research in Rawa Jaya, Palembang, further demonstrates that drainage-network capacity assessment can reveal spatial variations in hydraulic performance that are difficult to identify from individual channel observations alone (Nisumanti et al., 2023). More detailed hydraulic modelling has also been adopted, including HEC-RAS-based analysis for urban drainage and river systems, allowing researchers to examine water levels, flow behavior, and the effects of land-use changes on flood propagation (Arifianto & Andawayanti, 2026). Meanwhile, EPA SWMM has been applied to evaluate drainage systems by representing rainfall-runoff processes and network hydraulics, offering a more integrated approach to urban drainage simulation (Armawan & Pribadi, 2025). These approaches collectively indicate that drainage adequacy cannot be inferred from channel geometry alone, yet they also demonstrate that the appropriate analytical framework depends strongly on the hydrological, hydraulic, and spatial characteristics of the study area.

A critical limitation in the existing literature is that many drainage-capacity studies remain geographically fragmented and predominantly assess individual channels or networks under localized conditions, making their findings difficult to transfer directly to densely developed residential environments with distinct downstream constraints. Several studies have concentrated on conventional comparisons between calculated design discharge and existing channel capacity, while other investigations have shifted toward numerical models such as HEC-RAS or EPA SWMM, producing greater hydraulic detail but requiring more extensive spatial and parameter data (Singh et al., 2023).

Studies of drainage normalization also show that improvements in channel performance cannot be separated from surface-runoff characteristics because the effectiveness of a drainage system depends on how runoff is generated and delivered to the network (Ariyani et al., 2024). Research on sustainable drainage systems similarly highlights the need to move beyond a purely conveyance-oriented perspective by considering measures that regulate runoff before it reaches conventional drainage channels (Riswanto et al., 2023). Nevertheless, these developments have not eliminated the empirical gap concerning the actual adequacy of existing primary drainage channels in highly urbanized residential areas of Semarang, particularly Tlogosari Kulon. The gap is important because a channel may satisfy its nominal geometric capacity under ideal conditions while becoming hydraulically inadequate when sedimentation, waste accumulation, increased runoff, or downstream restrictions are incorporated into the assessment. A site-specific capacity analysis is therefore required to determine whether the primary drainage channel serving Perumnas Tlogosari Kulon can accommodate the design flood discharge associated with its current urban catchment.

The scientific and practical urgency of this problem is reinforced by evidence that drainage-capacity evaluation remains essential for identifying locations where existing infrastructure cannot safely convey runoff generated by contemporary urban conditions, including recent assessments of drainage channels in Pontianak and Medan that explicitly compare existing conveyance conditions with hydrological design requirements (Angin et al., 2026; Napitupulu et al., 2026). In flood-prone housing areas, drainage planning has also been shown to require an integrated assessment of rainfall characteristics, runoff generation, channel geometry, and design discharge to determine appropriate flood-prevention strategies (Cahyono et al., 2025). The present study is positioned within this body of research by focusing specifically on the primary drainage channel system serving the Perumnas Tlogosari Kulon area, where recurrent flooding indicates a potential discrepancy between generated runoff and available conveyance capacity. Rather than assuming that flooding is solely attributable to rainfall intensity, the study examines the hydrological conditions and hydraulic capacity of the existing drainage system as interacting determinants of flood conveyance performance. The analysis uses a 10-year return-period design flood as the principal reference for evaluating whether the existing channel remains hydraulically adequate under a representative design-event condition. This approach provides an empirical basis for distinguishing between adequate and inadequate channel capacity while identifying the magnitude of the potential capacity deficit that may contribute to inundation. The study aims to analyze the hydrological characteristics of the Perumnas Tlogosari Kulon catchment, evaluate the hydraulic capacity of the existing drainage channel, and determine its ability to accommodate the 10-year return-period flood discharge, while contributing a site-specific methodological framework for evidence-based drainage-capacity assessment in densely urbanized residential areas.

RESEARCH METHODS

The study was conducted in the Perumnas Tlogosari Kulon area, Pedurungan District, Semarang City, covering approximately 220.27 ha, where the drainage system consists of primary channels located along the main road that collect runoff conveyed from secondary channels on the surrounding residential roads. The empirical system architecture was established by integrating field-based channel measurements with rainfall, topographic, and watershed datasets to represent the hydrological and hydraulic conditions of the study area. Primary data were obtained through direct field measurements of channel geometry, including channel length, width, and depth, together with observations of the physical condition of the drainage infrastructure, while secondary data comprised annual maximum daily rainfall records for 2015–2024 from the Bodri Kuto, Karangroto, and Pucanggading rainfall stations obtained from BMKG Central Java and BBWS Pemali-Juana. Topographic maps and watershed information were obtained from PUSDATARU Central Java Province to define the characteristics of the contributing catchment and support the subsequent hydrological analysis. The data-processing architecture followed a sequential workflow consisting of rainfall-area estimation, frequency-distribution analysis, rainfall-intensity estimation, design-flood calculation, and hydraulic-capacity assessment, consistent with established approaches for drainage-channel evaluation (Safriani et al., 2022). The complete implementation sequence is presented in Figure 1, while Figure 2 presents the geographical location of the study area on Jl. Tlogosari Raya, Tlogosari Kulon.

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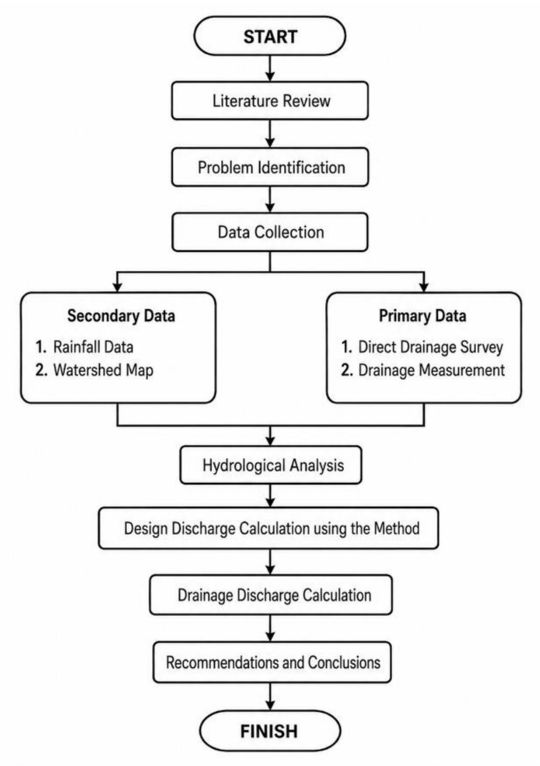

Figure 1. Research Flowchart

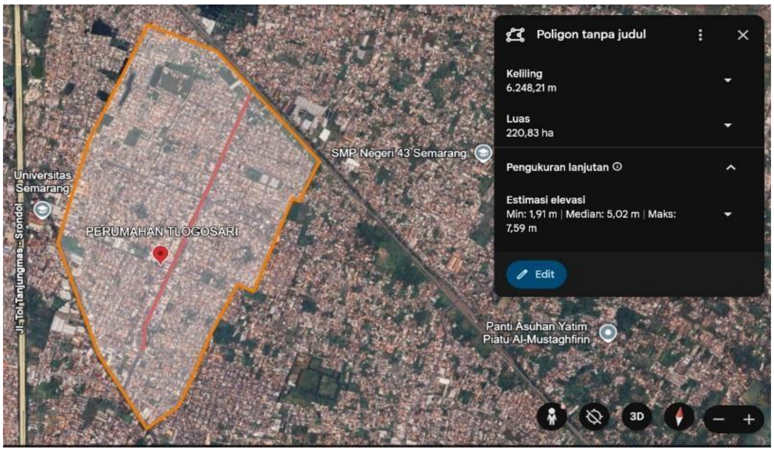

Figure 2. Location Map of the Study Area on Jl. Tlogosari Raya, Tlogosari Kulon

The analytical procedure began by estimating areal rainfall using the Thiessen Polygon method, which assigns rainfall-station influence according to the spatial contribution of each station to the study area. The resulting rainfall series was subsequently tested against Normal, Log Normal, Gumbel, and Log Pearson Type III frequency distributions using the Chi-Square and Smirnov–Kolmogorov goodness-of-fit tests to identify the statistically appropriate distribution for design-rainfall estimation. The selected frequency distribution was then used to determine the 10-year return-period rainfall, after which rainfall intensity was calculated using the Mononobe equation to obtain the rainfall intensity corresponding to the drainage concentration time. The design flood discharge was calculated using the Rational Method by incorporating rainfall intensity, catchment area, and the appropriate runoff coefficient, an approach commonly employed in urban drainage-capacity assessments (Nisumanti et al., 2023). Hydraulic testing of the existing channel was performed using the Manning equation based on the measured channel cross-section, channel slope, and Manning roughness coefficient, with the calculated conveyance capacity representing the maximum discharge that can be accommodated under the evaluated hydraulic conditions (Angin et al., 2026). Drainage performance was validated through comparison between channel capacity (Qs) and the 10-year design flood discharge (QR), with the channel classified as hydraulically adequate when Qs ≥ QR and inadequate when Qs < QR, following the capacity-assessment principle applied in recent drainage studies (Ramadhan et al., 2025).

RESULTS AND DISCUSSION

Regional Rainfall Analysis

The regional rainfall analysis was conducted to characterize the spatial and temporal rainfall conditions contributing to the Perumnas Tlogosari Kulon drainage system, which serves an urban catchment of approximately 220.27 ha. The analysis used annual maximum daily rainfall records from three observation stations, namely Bodri Kuto, Pucanggading, and Karangroto, covering the 2015–2024 observation period. Because rainfall observations represent point measurements while runoff generation occurs across a spatially distributed catchment, an areal rainfall estimation procedure was required before the rainfall data could be used for frequency analysis. The Thiessen Polygon method was selected to account for the unequal spatial influence of the three rainfall stations within the regional catchment. This approach is widely applied in hydrological analysis because it converts point-based rainfall observations into a weighted areal rainfall value based on the proportional area represented by each station (Triatmodjo, 2008). The resulting spatial distribution provides the hydrological input required for subsequent determination of design rainfall and flood discharge.

The Thiessen Polygon analysis produced influence areas of 13.736 km² for Bodri Kuto, 15.866 km² for Pucanggading, and 7.509 km² for Karangroto, resulting in a total polygon area of 37.111 km². The difference in polygon areas indicates that the three stations do not contribute equally to the regional rainfall estimate, with Pucanggading exerting the largest spatial weighting and Karangroto the smallest. The spatial relationship among the stations and their respective areas of influence is illustrated in Figure 3.

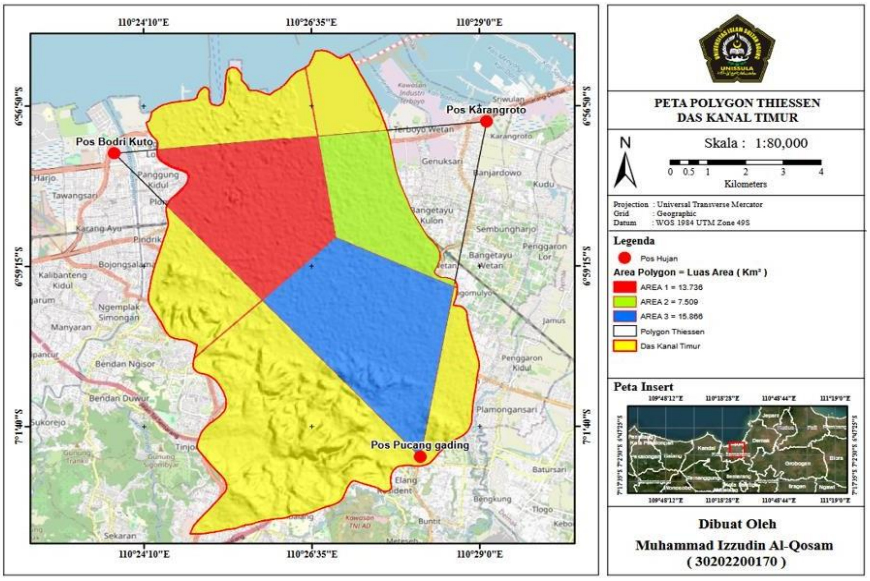

Figure 3. Thiessen Polygon Distribution Map of the Three Rainfall Stations

The configuration shown in Figure 3 demonstrates that regional rainfall cannot appropriately be represented by selecting the observation from a single rainfall station because the study region is influenced by multiple spatially distributed rainfall inputs. The weighted rainfall obtained from this configuration was subsequently organized into an annual maximum series to establish a consistent dataset for statistical analysis. Spatial rainfall estimation is particularly relevant to drainage assessment because variations in rainfall input directly influence runoff magnitude and consequently the hydraulic loading imposed on drainage channels (Nisumanti et al., 2023).

The calculated regional average maximum rainfall for the ten-year observation period is presented in Table 1, where the annual values range from 83 mm to 184 mm. The series demonstrates considerable interannual variability, indicating that the hydrological input to the drainage system is not characterized by a uniform annual rainfall condition. The highest regional maximum rainfall occurred in 2024 at 184 mm, whereas the lowest value occurred in 2020 at 83 mm. The complete annual rainfall series is presented in Table 1.

Table 1. Regional Average Maximum Rainfall, 2015–2024

No.	Year	Regional Average Maximum Rainfall (mm)
1	2015	129
2	2016	111
3	2017	89
4	2018	102
5	2019	98
6	2020	83
7	2021	151
8	2022	152
9	2023	106
10	2024	184

Source: Planning Calculation, 2026

The rainfall series in Table 1 shows that maximum rainfall generally fluctuated substantially throughout the observation period, with a pronounced increase beginning in 2021 compared with the preceding two years. The values increased from 83 mm in 2020 to 151 mm in 2021 and 152 mm in 2022, before declining to 106 mm in 2023 and subsequently reaching 184 mm in 2024. This pattern demonstrates that the occurrence of a high rainfall event is not adequately represented by a simple average of annual observations, particularly when the objective is to establish a design condition for drainage infrastructure. Extreme rainfall values are more relevant for drainage-capacity evaluation because the occurrence of intense rainfall can increase direct runoff and impose hydraulic loads substantially greater than those associated with ordinary rainfall events (Safriani et al., 2022). The 2024 value of 184 mm is particularly significant because it constitutes the maximum observed regional rainfall within the dataset and consequently contributes strongly to the statistical characterization of rainfall extremes.

The temporal variability observed in the regional rainfall series also provides an important basis for interpreting the subsequent frequency-distribution analysis, since the reliability of design rainfall depends on how effectively the selected probability model represents the observed extreme values. A ten-year annual maximum series is relatively limited for extreme-value estimation, so the statistical testing must be performed carefully to avoid selecting a distribution solely from the magnitude of the largest observed event. Frequency analysis is intended to transform the observed rainfall series into rainfall estimates associated with specified return periods, allowing the hydrological demand imposed on the drainage system to be evaluated under standardized design conditions. This procedure is consistent with drainage-capacity assessments in which observed rainfall data are first transformed into design rainfall before being used to calculate design flood discharge (Ramadhan et al., 2025). The resulting rainfall characteristics therefore serve as the empirical foundation for determining the probability distribution and estimating the 2-, 5-, and 10-year design rainfall values in the next stage of analysis.

From an urban drainage perspective, the regional rainfall results indicate that the Perumnas Tlogosari Kulon system is exposed to highly variable rainfall inputs that can produce substantially different runoff responses between rainfall events. The spatial weighting of the three stations improves the representativeness of the rainfall input, while the annual maximum series provides the basis for distinguishing ordinary variations from rainfall conditions relevant to drainage design. Such an approach is consistent with the principle that drainage performance should be assessed against hydrological loads derived from the characteristics of the contributing catchment rather than solely from the geometric properties of the channel (Angin et al., 2026). The regional rainfall analysis therefore establishes the quantitative input required for the next analytical stage, namely statistical distribution testing and determination of the design rainfall corresponding to selected return periods. The identified maximum value of 184 mm in 2024 does not itself constitute the design rainfall for the drainage system, because design rainfall must be derived through a statistically appropriate frequency distribution rather than directly adopting the largest observed value. The next stage consequently evaluates the suitability of several probability distributions to obtain a statistically defensible rainfall estimate for hydraulic capacity assessment.

Frequency Distribution Analysis and Design Rainfall

The frequency distribution analysis was conducted to identify the probability distribution that most appropriately represents the annual maximum regional rainfall series obtained from the three rainfall stations. The analysis considered four commonly applied probability distributions, namely Normal, Log Normal, Gumbel Type I, and Log Pearson Type III. Selection of the appropriate distribution is important because the resulting design rainfall directly affects the magnitude of the design flood discharge used to evaluate drainage-channel performance. The statistical characteristics of the observed rainfall series were first examined to identify distributions that were theoretically compatible with the dataset. The candidate distributions were subsequently evaluated using goodness-of-fit tests rather than being selected solely from their theoretical characteristics. This procedure provides a statistical basis for determining the rainfall values associated with the selected return periods and is consistent with the general approach used in hydrological design analysis (Soemarto, 1999). The evaluation was continued using Chi-Square and Smirnov–Kolmogorov tests to determine the degree of agreement between the observed rainfall series and each candidate distribution.

The preliminary statistical assessment indicated that the Gumbel Type I and Log Pearson Type III distributions were the principal candidates for further evaluation. The Normal and Log Normal distributions did not provide the statistical characteristics required for continued consideration in the subsequent goodness-of-fit assessment. The two remaining distributions were then tested using the Chi-Square method to evaluate whether the differences between the observed and theoretical frequencies remained within the statistically acceptable range. The decision criterion was based on comparing the calculated Chi-Square statistic with the critical value at the selected significance level. A distribution was considered acceptable when its calculated statistic was lower than the corresponding critical value. The results of the Chi-Square test for the two candidate distributions are presented in Table 2.

Table 2. Summary of Chi-Square Test Results

Distribution	X^2calc	X^2critical	Result
Gumbel Type I	2.0000	3.8410	Meets
Log Pearson Type III	4.4000	3.8410	Does not meet

The Chi-Square results demonstrate that the Gumbel Type I distribution satisfies the goodness-of-fit criterion, with an X^2calc value of 2.0000, which is lower than the critical value of 3.8410. In contrast, the Log Pearson Type III distribution produces an X^2calc value of 4.4000, exceeding the critical value and consequently failing the acceptance criterion. The difference indicates that the observed rainfall frequency pattern is statistically more compatible with the Gumbel distribution than with the Log Pearson Type III distribution under the Chi-Square assessment. Nevertheless, the selection was not based on a single goodness-of-fit test because hydrological frequency analysis can be sensitive to the statistical characteristics and sample size of the available rainfall series. A second test using the Smirnov–Kolmogorov method was therefore applied to evaluate the agreement between the empirical and theoretical cumulative distributions. The results of this additional assessment are shown in Table 3.

Table 3. Summary of Smirnov–Kolmogorov Test Results

Distribution	Dmax	Dcritical	Result
Gumbel Type I	0.2020	0.4090	Meets
Log Pearson Type III	0.8889	0.4090	Does not meet

The Smirnov–Kolmogorov test provides further evidence supporting the selection of the Gumbel Type I distribution. The Gumbel distribution produces a Dmax value of 0.2020, which is substantially lower than the critical value of 0.4090, indicating that the empirical rainfall distribution is within the acceptable deviation from the theoretical distribution. The Log Pearson Type III distribution, in contrast, generates a Dmax value of 0.8889, which is considerably greater than the critical value and consequently fails the goodness-of-fit criterion. The consistency of the two independent tests is important because both Chi-Square and Smirnov–Kolmogorov identify Gumbel Type I as acceptable while rejecting Log Pearson Type III. The selection of Gumbel Type I is consequently considered statistically defensible for estimating design rainfall in the Perumnas Tlogosari Kulon drainage catchment. Similar drainage-capacity studies have emphasized the importance of selecting a statistically appropriate rainfall distribution before converting rainfall characteristics into design runoff for hydraulic evaluation (Napitupulu et al., 2026).

After the Gumbel Type I distribution was selected, design rainfall values were determined for return periods of 2, 5, and 10 years. These return periods were selected to represent different levels of hydrological loading for evaluating the performance of the existing urban drainage channel. The resulting 24-hour design rainfall values (R24) were 116.067 mm for the 2-year return period, 155.086 mm for the 5-year return period, and 180.921 mm for the 10-year return period. These rainfall values were subsequently transformed into rainfall intensity using the Mononobe relationship, with a concentration time (Tc) of 1.31 hours and a runoff coefficient (C) of 0.70. The complete calculation parameters and resulting rainfall intensities are presented in Table 4.

Table 4. Rainfall Intensity Calculation

Return Period (year)	R24 (mm)	C	Tc (hour)	I (mm/hour)
2	116.067	0.70	1.31	33.60
5	155.086	0.70	1.31	44.90

The values in Table 4 show a systematic increase in rainfall intensity as the return period increases, from 33.60 mm/hour for the 2-year event to 52.38 mm/hour for the 10-year event. This increase reflects the greater rainfall magnitude associated with less frequent but more severe hydrological events and becomes the principal rainfall input for the subsequent Rational Method calculation. The fixed runoff coefficient of 0.70 represents the combined runoff response of the predominantly developed catchment, while the constant concentration time reflects the established longest flow path and catchment slope. The resulting rainfall intensities provide a consistent basis for comparing runoff demand across the three design scenarios. The 10-year rainfall intensity is particularly important for evaluating the upper design condition because it produces the largest expected runoff contribution among the return periods considered. The frequency-distribution analysis therefore establishes a direct quantitative connection between the observed rainfall record and the hydraulic demand subsequently imposed on the existing drainage channel.

Design Flood Discharge Analysis

The design flood discharge analysis was conducted to quantify the runoff generated by the Perumnas Tlogosari Kulon catchment under selected return-period rainfall events. The calculation began with the determination of concentration time, which represents the time required for runoff from the hydraulically most distant point of the catchment to reach the drainage outlet. Based on the Kirpich equation, the longest flow path was identified as 1,600 m with an average channel or terrain slope of 0.0011. These parameters resulted in a concentration time (Tc) of 1.31 hours. The concentration time was subsequently used to convert the 24-hour design rainfall obtained from the Gumbel distribution into rainfall intensity using the Mononobe relationship. The resulting rainfall intensity values were 33.60 mm/hour, 44.90 mm/hour, and 52.38 mm/hour for the 2-, 5-, and 10-year return periods, respectively. Determination of Tc is particularly important because the selected duration influences the rainfall intensity used in estimating peak runoff from an urban catchment (Triatmodjo, 2008).

The concentration time of 1.31 hours indicates that runoff generated across the 220.27 ha catchment can contribute to the drainage outlet within a relatively defined hydrological response period. A longer concentration time generally corresponds to a lower rainfall intensity when rainfall duration is converted from a 24-hour value, while a shorter concentration time produces a higher intensity for the same design rainfall. In the present analysis, the same Tc value was applied to all return periods because the physical characteristics of the catchment and the longest flow path remain unchanged between design scenarios. The rainfall intensity therefore varies primarily as a consequence of the different design rainfall magnitudes associated with the selected return periods. The resulting intensities establish the rainfall input for estimating peak runoff using the Rational Method. This approach is commonly applied in urban drainage assessment because it relates catchment area, runoff coefficient, and rainfall intensity directly to the peak design discharge (Hasmar, 2011).

The Rational Method was subsequently applied using a catchment area of 220.27 ha and a runoff coefficient of 0.70. The relatively high runoff coefficient reflects the developed character of the Perumnas Tlogosari Kulon area, where residential development and associated impervious surfaces promote relatively rapid conversion of rainfall into surface runoff. The peak discharge was calculated separately for each return period using the rainfall intensities derived from the Mononobe relationship. The calculation produced design discharges of 14.38 m^3/s for the 2-year event, 19.22 m^3/s for the 5-year event, and 22.42 m^3/s for the 10-year event. These values represent the estimated peak hydrological loads that must be conveyed by the existing primary drainage channel. The complete design discharge results are presented in Table 5.

Table 5. Design Flood Discharge in the Perumnas Tlogosari Kulon Area, Semarang City

Return Period	Design Flood Discharge (m^3/s)
2 years	14.38
5 years	19.22
10 years	22.42

The results in Table 5 demonstrate a clear increase in peak discharge as the return period increases. The design discharge rises by approximately 33.7% from 14.38 m^3/s for the 2-year event to 19.22 m^3/s for the 5-year event, while the 10-year event produces a further increase to 22.42 m^3/s. This pattern is consistent with the increase in design rainfall intensity from 33.60 mm/hour to 52.38 mm/hour across the three return periods. The relationship confirms that rainfall intensity is a major determinant of the peak runoff generated by the study catchment when the catchment area and runoff coefficient remain constant. Comparable drainage evaluations have demonstrated that increasing return periods produce greater design discharges, which subsequently become the basis for determining whether existing channels can accommodate expected hydraulic loading (Sani & Akbar, 2024). The 10-year event consequently represents the most demanding hydrological condition considered in the present assessment.

The magnitude of the calculated discharge also illustrates the importance of evaluating the drainage system against more than a single rainfall scenario. A channel that remains adequate under a 2-year event may experience substantially greater hydraulic loading during a 5- or 10-year event, particularly in densely developed urban areas where infiltration opportunities are limited. The 22.42 m^3/s discharge obtained for the 10-year return period therefore serves as the critical design demand for comparison with the hydraulic capacity of the existing primary channel. This comparison is essential because drainage performance depends on the relationship between incoming runoff and the conveyance capacity of the receiving channel rather than on rainfall characteristics alone. Previous drainage-capacity assessments have similarly used design flood discharge as the principal benchmark for determining whether existing channels require normalization, enlargement, or continued maintenance (Ariyani et al., 2024). The calculated discharges in this study consequently provide the hydrological basis for the subsequent hydraulic evaluation of the existing drainage channel.

From a drainage-system perspective, the design flood discharge results indicate that the hydrological burden imposed on the Perumnas Tlogosari Kulon drainage network increases considerably under less frequent rainfall events. The 10-year discharge of 22.42 m^3/s is approximately 56% higher than the 2-year discharge of 14.38 m^3/s, illustrating the sensitivity of peak runoff to the selected return period. This difference is important for evaluating infrastructure reliability because hydraulic adequacy should be assessed against the design event appropriate to the intended level of protection. The resulting discharge values also provide a direct quantitative benchmark for comparing hydrological demand with the conveyance capacity calculated from the existing channel dimensions, bed slope, and Manning roughness coefficient. Such capacity-based assessment is central to determining whether an existing urban drainage channel can safely accommodate design runoff without requiring structural modification (Singh et al., 2023). The subsequent analysis therefore focuses on the hydraulic capacity of the existing primary drainage channel and its performance relative to the 2-, 5-, and 10-year design flood discharges.

Existing Drainage Channel Capacity and Hydraulic Performance

The evaluation of the existing drainage channel began with an assessment of its physical condition and hydraulic function in the Perumnas Tlogosari Kulon area. The primary channel serves as the main conveyance structure that receives runoff from secondary drainage channels located along the surrounding residential roads. Field observations were conducted to identify the physical characteristics of the channel and potential conditions that could influence its flow capacity. The inspection indicated that the channel remains physically functional as the principal drainage route, although sediment deposition and solid-waste accumulation were observed at several locations. These conditions are relevant to hydraulic performance because obstructions within the flow section can reduce the effective area available for water conveyance. Evaluation of existing drainage capacity should consequently consider both theoretical hydraulic characteristics and the physical condition observed in the field (Angin et al., 2026). The general condition of the existing primary drainage channel is presented in Figure 4.

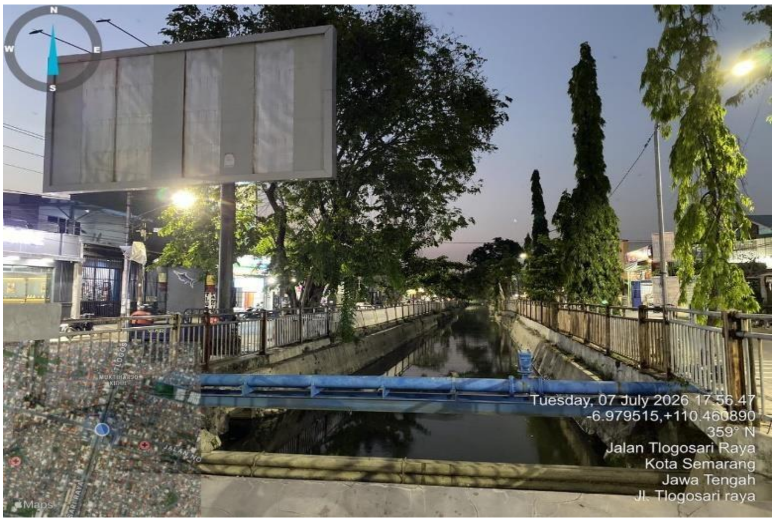

Figure 4. Existing Drainage Condition

Figure 4 illustrates the existing physical condition of the primary drainage channel observed during the field survey. The visual inspection was followed by direct measurement to obtain the geometric dimensions required for hydraulic capacity analysis. The principal dimensions measured in the field included channel width, channel height, and channel length. The existing primary channel has a width of 7.50 m, a height of 1.70 m, and a length of approximately 1,787 m. These dimensions provide the basis for determining the cross-sectional flow area, wetted perimeter, and hydraulic radius under the analyzed flow condition. Direct field measurement is important in existing drainage assessment because actual channel dimensions may differ from planned dimensions as a result of physical changes and maintenance conditions (Safriani et al., 2022). The field measurement process is presented in Figure 5.

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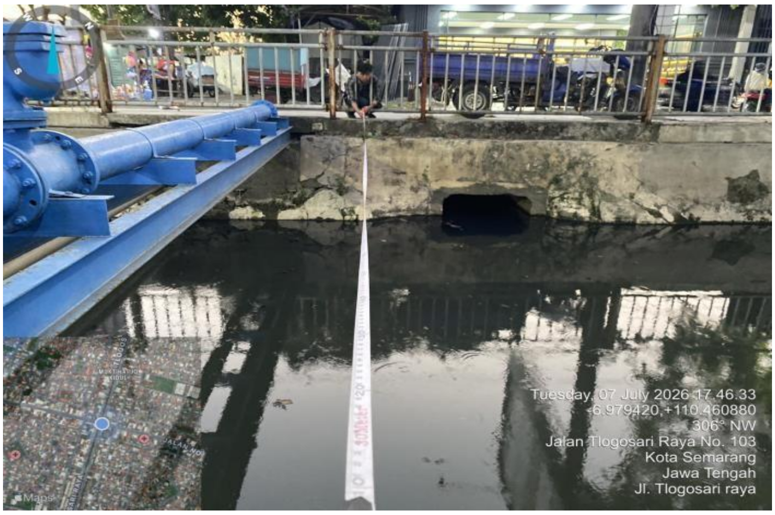

Figure 5. Measurement of Existing Drainage Conditions in the Study Area

The measured geometric characteristics were subsequently used to establish the hydraulic parameters required for the Manning equation. The calculated cross-sectional area was 12.75 m², while the wetted perimeter was 10.90 m, resulting in a hydraulic radius of 1.17 m. The channel bed slope was determined as 0.0011, while the Manning roughness coefficient was set at 0.013 based on the assumed hydraulic characteristics of the existing channel. These parameters were used to determine the flow velocity and theoretical conveyance capacity of the primary channel. The calculated flow velocity was 2.83 m/s, producing a channel capacity of 36.082 m³/s. The complete geometric and hydraulic parameters obtained from the field measurements and Manning analysis are summarized in Table 6.

Table 6. Existing Drainage Channel Condition

Parameter	Value
Channel Width	7.50 m
Channel Height	1.70 m
Channel Length	1,787 m
Cross-sectional Area (A)	12.75 m²
Wetted Perimeter (P)	10.90 m
Hydraulic Radius (R)	1.17 m
Channel Slope (S)	0.0011
Manning Roughness Coefficient (n)	0.013
Flow Velocity (V)	2.83 m/s
Channel Capacity (Qs)	36.082 m³/s

The Manning calculation indicates that the existing primary channel has a theoretical conveyance capacity of 36.082 m³/s. This value was then compared with the design flood discharges obtained from the hydrological analysis for the 2-, 5-, and 10-year return periods. The comparison is required to determine whether the available hydraulic capacity is sufficient to accommodate the runoff generated by the design rainfall events. The channel capacity exceeds the 2-year design discharge of 14.38 m³/s, the 5-year design discharge of 19.22 m³/s, and the 10-year design discharge of 22.42 m³/s. The relationship between the available channel capacity and the design flood discharges is presented in Table 7. The comparison follows the capacity-based approach commonly applied in drainage evaluation, where the adequacy of a channel is determined by comparing available conveyance with design runoff (Napitupulu et al., 2026).

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Table 7. Existing Drainage Condition of Perumnas Tlogosari Kulon

Channel Name	Storage Capacity Q	Design Flood Discharge			Description
		2 Years	5 Years	10 Years	
Primary Channel	36.082 m³/s	14.38 m³/s	19.22 m³/s	22.42 m³/s	Safe

The comparison in Table 7 shows that the existing primary channel is classified as Safe/Adequate for all three analyzed return periods. For the 2-year event, the available capacity exceeds the design discharge by 21.702 m³/s, while the capacity margin is 16.862 m³/s for the 5-year event. Under the 10-year event, which represents the highest hydrological loading considered in this study, the remaining capacity is 13.662 m³/s. The channel therefore maintains a substantial hydraulic margin even under the 10-year design condition. This result indicates that structural enlargement of the primary channel is not required based solely on the calculated hydraulic capacity. Similar drainage studies have used the comparison between existing channel capacity and design discharge as the basis for determining the adequacy of drainage infrastructure (Sani & Akbar, 2024).

Although the theoretical hydraulic capacity indicates adequate performance, the physical condition of the channel remains an important factor in determining its actual operational capacity. Sediment accumulation can reduce the effective cross-sectional area, while solid waste may obstruct the flow path and increase localized hydraulic resistance. If these conditions become more severe, the effective discharge capacity may decline from the calculated value of 36.082 m³/s. The difference between theoretical capacity and effective field capacity is particularly relevant during high-intensity rainfall events because the 10-year design discharge already reaches 22.42 m³/s. Previous research has emphasized that drainage performance should be evaluated not only from hydraulic calculations but also from field conditions and maintenance requirements that can influence the available conveyance capacity (Ariyani et al., 2024). The existing primary channel can consequently be considered Safe/Adequate, provided that regular maintenance, sediment removal, and solid-waste management are implemented to preserve the effective flow section and maintain its hydraulic performance.

CONCLUSION

The hydrological analysis of the Perumnas Tlogosari Kulon drainage system using the Gumbel distribution and Rational Method produced design flood discharges of 14.38 m³/s for the 2-year return period, 19.22 m³/s for the 5-year return period, and 22.42 m³/s for the 10-year return period. The analysis used a concentration time of 1.31 hours, with rainfall intensities of 33.60 mm/hour, 44.90 mm/hour, and 52.38 mm/hour for the respective return periods. Hydraulic analysis of the existing primary drainage channel, with a width of 7.50 m and a depth of 1.70 m, resulted in a flow velocity of 2.83 m/s. The calculated channel capacity reached 36.082 m³/s, which exceeds the design flood discharge for all analyzed return periods. The capacity margin under the 10-year return period remained 13.662 m³/s, indicating sufficient conveyance capacity under the highest design condition. Based on the criterion $Qs \geq QR$, the existing primary drainage channel is classified as Safe/Adequate and remains capable of accommodating the 10-year design flood discharge. These findings indicate that structural enlargement of the existing primary channel is not required based solely on its calculated hydraulic capacity.

Despite the adequate theoretical capacity, field observations identified sedimentation and solid-waste accumulation that may reduce the effective cross-sectional area and actual conveyance capacity of the channel. These physical conditions require attention because continued deposition and obstruction could gradually reduce the hydraulic safety margin identified from the Manning calculation. Periodic inspection and maintenance, including sediment removal and solid-waste management, are therefore necessary to maintain the effective capacity of the existing drainage system. The present analysis is also constrained by the relatively limited 10-year rainfall observation period used for frequency analysis. Future research should employ rainfall records covering at least 20 years to improve the reliability of design rainfall estimation and extreme-event characterization. More detailed hydraulic assessment is also recommended through the use of modeling software such as HEC-RAS to simulate flow behavior and identify potential localized hydraulic constraints along the drainage network. Such extended analysis and continuous field evaluation can provide a stronger basis for maintaining the long-term performance and resilience of the Perumnas Tlogosari Kulon drainage system.

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