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# Hydraulic Performance Evaluation of the Existing Culverts for Creek Overflow Management

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**ABSTRACT:** Flooding in small catchments is often linked to inadequate drainage capacity and increased surface runoff caused by urbanization and intense rainfall. This study evaluates the hydraulic performance of an existing culvert along the Labni Creek, Penaranda, Nueva Ecija using field data and analytical methods. High-resolution topographic data were collected using RTK GNSS to define catchment characteristics such as flow paths, slope, and drainage area. The time of concentration was computed using the Kirpich equation, while rainfall intensity was derived from (Philippine Atmospheric, Geophysical and Astronomical Services Administration Rainfall Intensity-Duration-Frequency) PAGASA RIDF data. Peak runoff was estimated using the Rational Method for various return periods to evaluate the response of the catchment under different rainfall conditions. This method calculates the maximum runoff by considering the rainfall intensity corresponding to a selected return period. Results show peak discharges ranging from 4.3809 $m^3/s$ to 11.1195 $m^3/s$ for the primary catchment and 5.9643 $m^3/s$ to 15.1627 $m^3/s$ for the secondary catchment. The culvert capacity, computed using Manning's equation, was 3.814 $m^3/s$ and 4.192 $m^3/s$. Comparison indicates that the existing culvert is hydraulically inadequate under most conditions, posing a high risk of overflow. The study highlights the need for drainage improvements and demonstrates the effectiveness of integrating field surveying with standard hydraulic analysis methods.

**KEYWORDS:** Culvert Capacity, Peak Runoff, Drainage Analysis, Flood Risk, Rational Method

## I. INTRODUCTION

Flooding is one of the major environmental problems affecting many communities, particularly in areas with inadequate drainage systems and increasing surface runoff caused by urbanization and intense rainfall. Culverts play an important role in conveying stormwater beneath roads and embankments; however, many existing structures are no longer capable of handling present runoff conditions due to aging infrastructure, sediment accumulation, and changing land use. As a result, creek overflow and localized flooding frequently occur during heavy rainfall events.

Labni Creek in Barangay Las Piñas, Peñaranda, Nueva Ecija serves as a natural drainage channel that conveys runoff from surrounding areas. The existing culvert along the creek is suspected to have inadequate hydraulic capacity during periods of intense rainfall, primarily due to structural deterioration and the impacts of urbanization. resulting in overflow conditions within the area. Evaluating the hydraulic performance of the culvert is therefore necessary to determine whether it can safely accommodate the estimated peak runoff. This study evaluates the hydraulic performance of the existing culvert along Labni Creek using established hydrologic and hydraulic analysis methods. High-resolution topographic data were obtained through Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) surveying to accurately define catchment characteristics and flow geometry. Rainfall intensity values were derived from rainfall intensity–duration–frequency (RIDF) data to represent design storm conditions. Peak runoff was estimated using the Rational Method, while the discharge capacity of the culvert was determined using Manning's Equation based on measured geometric and hydraulic parameters. The findings of the study provide a technical basis for assessing culvert adequacy and support drainage improvement and flood mitigation efforts within the study area.

Furthermore, this study supports the achievement of several United Nations Sustainable Development Goals (SDGs), particularly SDG 6: Clean Water and Sanitation**,** by promoting effective stormwater management and reducing water-related hazards; SDG 9: Industry, Innovation and Infrastructure, through the assessment and improvement of resilient drainage infrastructure**;** SDG 11: Sustainable Cities and Communities, by contributing to flood risk reduction and community safety; and SDG 13: Climate Action, by addressing the impacts of extreme rainfall events and enhancing local adaptation measures against climate-related flooding.

## II. OBJECTIVES

### A. General Objective

To evaluate the hydraulic performance of the existing culvert along Labni Creek in Barangay Las Piñas, Peñaranda, Nueva Ecija, and determine its adequacy in conveying peak runoff for creek overflow management.

### B. Specific Objective

1. To determine the existing culvert dimensions, slopes, roughness coefficients, and capacity that influence flow behavior during rainfall events.
2. To determine the existing creek characteristics, including slope, channel length, catchment area, surface roughness, and peak runoff for the specified return periods.
3. To identify sections of the creek with insufficient or exceeded hydraulic capacity.

## III. METHODOLOGY

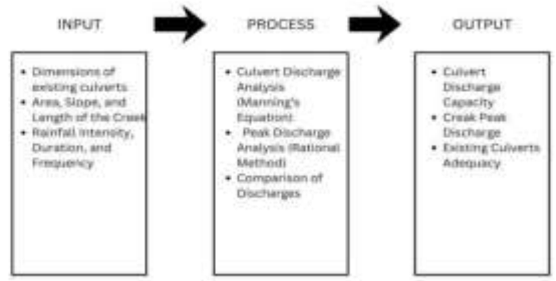


**FIGURE III-I. Research Flow**

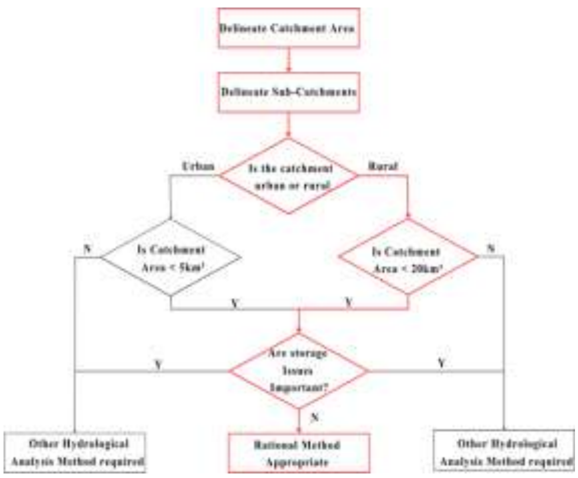


**FIGURE III-II. Overview of Rational Formula Applicability**

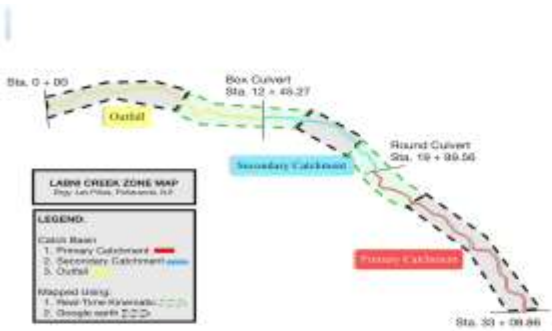


**FIGURE III- III. Labni Creek Zone Map**

This study utilized a quantitative and descriptive research approach to evaluate the hydraulic performance of the existing culvert along Labni Creek in Barangay Las Piñas, Peñaranda, Nueva Ecija. Field inspections and surveys were conducted to gather the necessary geometric and topographic data of the creek and culvert system. Measurements of the culvert dimensions, channel width, slope, and flow path were obtained using Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) surveying and basic field measuring tools.

Rainfall data were obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), specifically the Rainfall Intensity–Duration–Frequency (RIDF) records. The contributing catchment area and runoff flow paths were identified using Google Earth and RTK survey data. The time of concentration was computed based on watershed characteristics, while runoff coefficients were assigned according to existing land use and surface conditions within the catchment.

Peak runoff discharge was estimated using the Rational Method. The hydraulic capacity of the existing culvert was determined using Manning's Equation based on the measured dimensions, slope, and roughness coefficient of the structure. The computed peak runoff was then compared with the culvert discharge capacity to evaluate the adequacy of the drainage structure and determine the possibility of overflow during heavy rainfall events.

## IV. RESULT AND DISCUSSION

**TABLE IV-I. Computed extreme values ( in mm ) of precipitation**

| T | 10 | 20 | 30 | 1 | 2 | 3 | 6 | 12 | 24 |
|---|---|---|---|---|---|---|---|---|---|
| YRS | mins | mins | mins | hrs | hrs | hrs | hrs | hrs | hrs |
| 2.0 | 19.3 | 30.8 | 39.0 | 53.9 | 69.5 | 77.5 | 92.6 | 108.8 | 128.0 |
| 5.0 | 26.7 | 43.6 | 54.7 | 78.9 | 99.6 | 110.0 | 131.0 | 157.3 | 187.6 |
| 10.0 | 31.6 | 52.1 | 65.2 | 95.4 | 119.6 | 131.5 | 156.5 | 189.4 | 227.0 |
| 15.0 | 34.4 | 56.9 | 71.0 | 104.7 | 130.9 | 143.6 | 170.9 | 207.5 | 249.3 |
| 20.0 | 36.3 | 60.2 | 75.2 | 111.2 | 138.8 | 152.1 | 181.0 | 220.2 | 264.9 |
| 25.0 | 37.8 | 62.8 | 78.3 | 116.3 | 144.8 | 158.6 | 188.7 | 230.0 | 276.9 |
| 50.0 | 42.4 | 70.8 | 88.1 | 131.8 | 163.5 | 178.8 | 212.6 | 260.1 | 313.9 |
| 100.0 | 47.0 | 78.7 | 97.8 | 147.1 | 182.1 | 198.8 | 236.3 | 289.9 | 350.6 |

Rainfall Intensity–Duration–Frequency (RIDF) analysis was used to determine rainfall intensity for peak runoff estimation. Results indicate that intensity increases with return period and decreases with storm duration. Selected rainfall intensities were based on the computed time of concentration (Tc), ensuring accurate representation of conditions when the entire catchment contributes to runoff.

**TABLE IV-I1. Computed maximum capacity ( in m³/s ) in culverts**

| | Dimension | Unit | A | n | S | L (m) | R | Q ($m^3$/s) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Two Round Culverts | 25 ⌀<br>30 ⌀ | In<br>in | 0.4560<br>0.3167 | 0.0130<br>0.0130 | 0.0325<br>0.0736 | 1.6300<br>1.6300 | 0.1905<br>0.1323 | 3.8104 |
| Box Culvert | 116 x 45 | in | 3.3677 | 0.0130 | 0.0009 | 2.3400 | 0.4118 | 4.1918 |

The existing culvert was identified as a reinforced concrete structure, for which a Manning’s roughness coefficient (n) of 0.013 was adopted in accordance with standard values for finished concrete surfaces. Hydraulic analysis indicates that the culvert has a maximum discharge capacity of 3.814 m³/s for the circular section and 4.192 m³/s for the box section.

**TABLE IV-III. Computed peak runoff ( in m³/s ) in primary catchment**

| Return Period | S | L( m ) | Tc (mins) | Dmax | i (mm/hr) | C | A (km²) | Q (m³/s ) |
|---|---|---|---|---|---|---|---|---|
| 2 | .0183 | 1328.1929 | 23.0637 | 33.3122 | 86.6615 | 0.75 | 0.2427 | 4.3809 |
| 5 | .0183 | 1328.1929 | 23.0637 | 47.0007 | 122.2719 | 0.75 | 0.2427 | 6.1811 |
| 10 | .0183 | 1328.1929 | 23.0637 | 56.1135 | 145.9786 | 0.75 | 0.2427 | 7.3795 |
| 15 | .0183 | 1328.1929 | 23.0637 | 61.2198 | 159.2628 | 0.75 | 0.2427 | 8.0511 |
| 20 | .0183 | 1328.1929 | 23.0637 | 64.7956 | 168.5650 | 0.75 | 0.2427 | 8.5213 |
| 25 | .0183 | 1328.1929 | 23.0637 | 67.5487 | 175.7274 | 0.75 | 0.2427 | 8.8834 |
| 50 | .0183 | 1328.1929 | 23.0637 | 76.1002 | 197.9739 | 0.75 | 0.2427 | 10.008 |
| 100 | .0183 | 1328.1929 | 23.0637 | 84.5517 | 219.9603 | 0.75 | 0.2427 | 11.1195 |

A field survey identified predominantly silt and sand soils, leading to the selection of a runoff coefficient (C) of 0.75, indicating low infiltration and high surface runoff potential, which increases discharge and flood risk. Flow paths were determined through terrain analysis, with maximum lengths measured using Real-Time Kinematic (RTK GNSS) data and supplemented by Google Earth for inaccessible areas. The primary catchment has a flow path length of 1,328.19 m, a time of concentration of 23.06 minutes, and an area of 0.24265 km², forming the basis for peak runoff estimation.

**TABLE IV-IV. Computed peak runoff (in m³/s) in secondary catchment**

| Return Period | S | L( m ) | Tc ( mins ) | Dmax | i (mm/hr) | C | A (km^2) | Q (m^3/s) |
|---|---|---|---|---|---|---|---|---|
| 2 | 0.0085 | 740.8828 | 19.7809 | 30.5481 | 92.6591 | 0.75 | 0.0820 | 5.9643 |
| 5 | 0.0085 | 740.8828 | 19.7809 | 43.2298 | 131.1256 | 0.75 | 0.0820 | 8.4218 |
| 10 | 0.0085 | 740.8828 | 19.7809 | 51.6509 | 156.6688 | 0.75 | 0.0820 | 10.0567 |
| 15 | 0.0085 | 740.8828 | 19.7809 | 56.4071 | 171.0954 | 0.75 | 0.0820 | 10.9748 |
| 20 | 0.0085 | 740.8828 | 19.7809 | 59.6764 | 181.0120 | 0.75 | 0.0820 | 11.6145 |
| 25 | 0.0085 | 740.8828 | 19.7809 | 62.2523 | 188.8253 | 0.75 | 0.0820 | 12.1101 |
| 50 | 0.0085 | 740.8828 | 19.7809 | 70.1779 | 212.8651 | 0.75 | 0.0820 | 13.6455 |
| 100 | 0.0085 | 740.8828 | 19.7809 | 78.0056 | 236.6083 | 0.75 | 0.0820 | 15.1627 |

The secondary catchment, despite its smaller area, generates higher peak runoff due to the combined inflow from the upstream primary catchment, making it a receiving zone for accumulated discharge. Runoff from both areas converges, increasing downstream flow. Additionally, shorter flow paths and steeper slopes in the secondary catchment reduce the time of concentration (Tc), allowing faster runoff and further elevating peak discharge. This highlights the importance of accounting for upstream contributions and flow connectivity in hydrologic analysis.

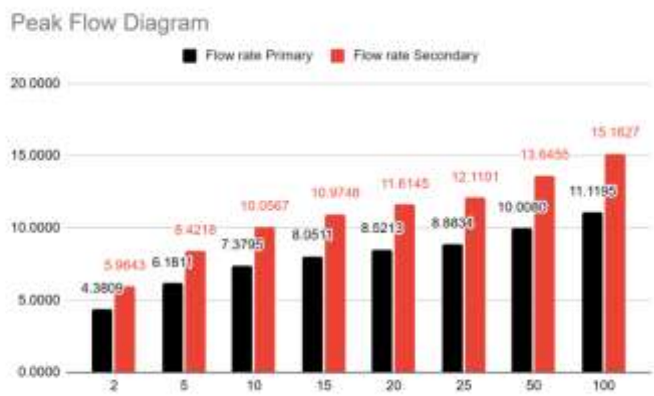


**FIGURE IV-I. Peak flow curve**

The return period shows a direct relationship with peak runoff, where longer return periods correspond to higher discharge due to more intense and less frequent rainfall events. Increased rainfall intensity, combined with low soil infiltration, results in greater surface runoff and higher peak discharge. Extreme events can exceed drainage capacity, further amplifying runoff. Consequently, higher return periods produce greater flood risk and are essential considerations in hydraulic design.

## V. CONCLUSIONS

The study concludes that the existing culvert is undersized, as computed peak runoff exceeds its capacity even at the 2-year return period, with increasing discrepancies at higher return periods leading to greater risks of overtopping and flooding. Peak discharge in the secondary catchment is further intensified by upstream contributions, highlighting the need to consider flow connectivity in design. The integration of RTK GNSS and Google Earth enabled accurate catchment and flow path analysis.

Overall, the drainage system poses significant flood risks, necessitating culvert redesign or replacement. Recommended improvements include increasing culvert size, adding multiple barrels, or adopting a larger box culvert designed for at least a 25-year return period. Regular maintenance is also essential to sustain hydraulic performance and prevent blockage.

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