ESTIMATING RUNOFF COEFFICIENTS IN SMALL CATCHMENTS: SEASONAL DIFFERENCES AND METHODOLOGICAL APPROACHES

LYNDA PAULÍKOVÁ [1*], SILVIA KOHNOVÁ [1]

1 Slovak University of Technology in Bratislava, Department of Land and Water Resources Management , Radlinského 11, 810 05, Bratislava.

* lynda.paulikova@stuba.sk

The study was supported by the Program for Motivation and Support for Increasing the Quality and Efficiency of Scientific Research Activities of Young Scientific Researchers (AVSOS), Vega 1/0577/23 and APVV 23-0332.

INTRODUCTION

Can different methods yield different estimates of the runoff coefficient? If we answer this question "**yes**", another question arises: *Which method should we use?*

The runoff coefficient is a dimensionless number that indicates how much precipitation in a catchment is converted into direct runoff. Even though it is a key input for determining runoff, it is highly ambiguous. Many hydrologists and engineers debate which method to use for his estimation. Although direct methods, based on direct observations of precipitation and runoff data within a catchment, appear to be the most accurate, their use in practice is not widespread. The reason is the lack of data, or the data series is too short to estimate the runoff coefficient, especially for coefficients for a return period of 100 years or more.

Indirect methods may seem like a solution. For example, the rational equation remains popular despite being around since the 19th century. Many studies have attempted to modify the equation. New methods have been developed to estimate the time of concentration or to determine the intensity of the design rainfall. Despite progress, we still do not fully understand all the hydrological processes in a catchment. Not to mention that few engineers would choose a runoff coefficient greater than 1, although there are studies that have shown that it is possible.

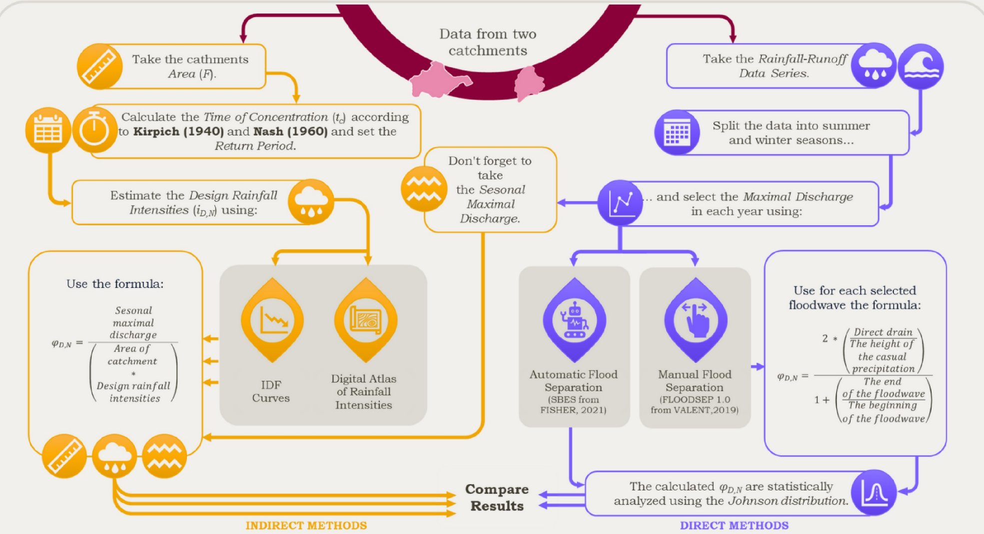
The study aims to analyse the peak runoff coefficient for a return period of once in 100 years ($\varphi100$) in small catchments using two estimation methods: the INDIRECT method and the DIRECT method. The study aims to understand the extent to which seasonality contributes to the estimates of the runoff coefficient obtained by different methods.

STUDY AREA

The subject of the analysis are two catchments: [A] the Horné Orečany - Parná Stream (37,9 square kilometers) and [B] the Liptovský Mikuláš - Jalovecký creek (22,2 square kilometers).

The first part of the study estimates the peak runoff coefficient using the so-called INDIRECT method. As input data were used time of concentration according to the authors Kirpich (1940) and Nash (1960) and two methods of determination of rainfall intensity: IDF curves and the Digital Atlas of Rainfall Intensities.

The second part of the study focuses on the DIRECT method. For this method, we used observed rainfall-runoff data series from 1989 to 2021. The data were divided into summer and winter seasons. Two programs were used to determine the duration and peak of the maximum flood wave in each year: FLOODSEP (waves are chosen manually) and the SBES method (an automatic flood wave separation program). The results show that the methods are affected by seasonality.



METHODOLOGY

WHAT IS THE INDIRECT AND DIRECT METHOD?

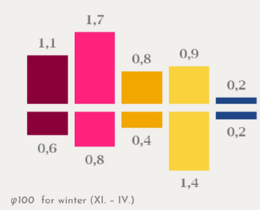
The **INDIRECT** method in this study is represented by a rational formula created in 1851 by Thomas J. Mulvany. The method expresses a simplified principle for generating runoff in a catchment: a N-year flood is caused by rain that occurs once every N years. For this equation, it is prime to know the intensity of a rainfall event (iN,t), the area of a catchment (F) and the amount of time it takes for water to flow from the most remote point in a catchment to the watershed outlet, the so-called time of concentration (tc).

The **DIRECT** method analyses observed rainfall-runoff data series in a catchment for a specific time window. In this study, we used data from 33 years measured in daily steps and hourly steps. The final runoff event coefficient is then statistically processed (for example, this study used Johnson's distribution).

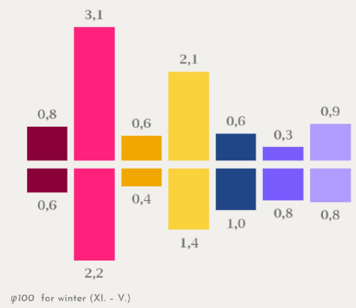
RESULTS

HOW MUCH PRECIPITATION WATER WILL BE CONVERTED INTO DIRECT RUNOFF?

[A] Horné Orešany - stream Parná



[B] Liptovský Mikuláš - Jalovecký creek



LEGEND:
IDF curves (Kirpich)
IDF curves (Nash)
Digital Atlas (Kirpich)
Digital Atlas (Nash)
FLOODSEP (observed rainfall-runoff data 1989 - 2021) in daily step
FLOODSEP (observed rainfall-runoff data 2012 - 2023) in hourly step
SBES (observed rainfall-runoff data 2012 - 2023) in hourly step

Horné Orešany - stream Parná is a rural catchment predominantly represented by deciduous forests. The average elevation is around 388 m above sea level, and the average slope is around 12°. The most noticeable differences were the height of the $\varphi100$ and the selected time of concentration (tc). Methods that use Nash's equation to estimate tc have larger $\varphi100$. The equation gives more importance to the slope of the catchment than its size. As a result, the time of concentration is larger than in the Kirpich equation, which is strongly reflected in the resulting estimate.

The results also show that the indirect estimation is much higher than that calculated from observed rainfall-runoff data. Such results may be caused by the short data collection window. The window captured the maximum flows but not the maximum possible flows.

Liptovský Mikuláš - Jalovecký potok possesses more detailed measured data. With an average elevation of 1502 m above sea level and with a slope of 30° it represents a mountain catchment. The results show that the rational equation overestimates the summer season, while the statistical data processing overestimates the winter season. These differences may be caused by melting spring snow, which cannot be excluded from the measurements at present.

The question is: ***Can the indirect method be used in practical hydrology?*** Results greater than one indicate that the methodology for generating runoff in a catchment contains many gaps that are difficult to fill. Currently, many catchments do not have sufficiently long data series. Nevertheless, it is recommended to abandon the indirect method in practice and to focus on direct methods of estimating the runoff coefficient in future studies.