# EFFECTS OF SEASONAL VARIATION ON RUNOFF CURVE NUMBER FOR SELECTED WATERSHEDS OF GEORGIA - PRELIMINARY STUDY

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**Abstract.** This study examined seasonal effects on the runoff Curve Number for five forested watersheds in Georgia. The periods between April-October and November-March were defined as the growing and dormant seasons, respectively. Annual maximum peak runoff data were used to select one pair of rainfall and runoff volumes for each water year. The Curve Number method was used to determine Curve Numbers using these observed precipitation and runoff values. Based on the date that rainfall and runoff volume were observed, the Curve Number values were grouped to their respective seasons for statistical analysis. The results from all watersheds showed higher mean Curve Numbers for the dormant season compared to the growing season. However, statistically significant differences between mean Curve Number values for the growing and dormant season were detected for only two of the five watersheds. Depending on the availability of data, selecting two or three representative months for each season would likely result in a better prediction by avoiding transition periods between the two seasons.

## INTRODUCTION

The Curve Number method is one of the most widely used techniques in watershed hydrology. The extensive use of the method is based on convenience and simplicity. Three easily obtained watershed properties are used: (1) soil group, (2) land use and treatment, and (3) surface conditions. The method was first introduced 1954 (NRCS, 2001). Originally, the method was derived for agricultural applications in which runoff forecasts from rainfall were needed.

A parameter that includes the effect of seasonal variation on forecasting runoff volume has not been incorporated in the Curve Number method and as a result ignores the impact of seasonal variation on evaporation, transpiration and interception. Although the Curve Number method is well documented and widely used, as Jacobs and Srinivasan (2005) pointed out, a need to use the method as a guideline and interpret inputs on a more local and regional level combined with seasonal variation is essential. Runoff simulation with annually consistent parameters has limited application because watershed response varies remarkably from season to season (Paik *et al*. 2005). The seasonal tank model developed by Paik *et al*. (2005) showed better performance compared to the non seasonal tank model because it can successfully simulate runoff with little error. Varying the Curve Number on a seasonal basis, therefore, may also result in more accurate runoff estimation and improve the Curve Number performance.

The objective of this study is to investigate the effect of seasonal variation on the Curve Number for selected Georgia forested watersheds based on observed rainfall and runoff volume data. There are two seasons that affect runoff-rainfall relationships for deciduous forests in Georgia. These seasons are classified as the growing season and dormant season. The growing season (April-October) is characterized by a full cover of the forest canopy that maximizes evapotranspiration and interception of rainfall by plant leaves. The dormant season (November-March) characterized by no leaves, lower evapotranspiration, and less rainfall interception by vegetation.

## THEORY

Estimation of runoff depth (*Q*) from rainfall depth (*P*) using the Curve Number method is well established in hydrologic and environmental impact analyses for urban and agricultural land use (Ponce and Hawkins, 1996; Schneider and McCuen, 2005; Garen and Moore, 2005; and Michel *et al.* 2005; McCutcheon *et al.* 2006). The method can be based on the water balance equation (1) and two other equations (2) and (3).

$$P = I_a + F + Q \tag{1}$$

$$\frac{Q}{P - I_a} = \frac{F}{S} \qquad (2)$$

$$I_a = \lambda S \qquad (3)$$

where $I_a$ is the initial abstraction (rainfall intercepted by vegetation, litter, and ground surface depressions); $F$ is the cumulative retention; $\lambda$ is the initial abstraction ratio or coefficient; and $S$ is the maximum retention capacity.

As the method is practiced today, Q can be computed with the CN based on the land use and hydrologic soil group, and rainfall depth by combining equations (1) and (2) as:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \qquad (4)$$

Equation (4) is valid for $P > I_a$ and $Q = 0$ otherwise. With the initial abstraction included in equation (4), the actual retention $P - Q$ asymptotically approaches a constant value of $S + I_a$ as the rainfall increases unbounded.

Using the value of $\lambda = 0.2$, equation (4) becomes

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \text{for} \quad P > 0.2S$$

$$Q = 0 \qquad \text{for } P \leq 0.2S \qquad (5)$$

Equation (5) is subject to $P > 0.2S$ and $Q = 0$ otherwise. Equation (4) now contains only one parameter (potential retention, $S$), which ranges between 0 to ∞. For convenience in practical applications, $S$ is defined in terms of a dimensionless parameter, CN (Curve Number), which varies in a more restricted range $100 \geq CN \geq 0$

$$S = \frac{1{,}000}{CN} - 10 \Rightarrow CN = \frac{1{,}000}{S + 10} \qquad (6a)$$

where the unit of S is in inches, or in mm:

$$S = \frac{25{,}400}{CN} - 254 \Rightarrow CN = \frac{25{,}400}{S + 254} \qquad (6b)$$

CN = 100 represents a condition of zero potential retention ($S$ = 0), that is an impermeable watershed. Conversely, CN = 0 a theoretical upper bound to the potential retention ($S$ = ∞), which is an infinitely abstracting watershed. If an event rainfall depth and the CN of a watershed are known, the runoff volume can easily be determined using equation (5) and (6).

The potential maximum retention ($S$) for each of the maximum annual storm volumes, $Q$, and the rainfall volume, $P$, will be computed using

$$S = 5\left(P + 2Q - \sqrt{4Q^2 + 5PQ}\right) \qquad (7)$$

This equation is an algebraic rearrangement of the runoff equation (5). For gauged watersheds where both rainfall and runoff volumes are known the Curve Number values can be determined using equations (6) and (7)

## METHODS

The study watersheds include five forested watersheds in North Georgia, including the Chattahoochee River near Leaf; Chattooga River near Summerville; Chestatee River near Dahlonega; Middle Oconee River near Athens; and Toccoa River near Dial. Table (1) summarizes the selected watersheds. The rainfall and runoff of data from USGS water supply paper 1813 (Dalrymple, 1965) was used for the analysis. The selected watersheds have more than twenty years of rainfall and runoff data that will be used for analysis.

The Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) framework that incorporates geographic information system (GIS) and soil and water assessment tool (SWAT) was used to extract the required watershed characteristics data for the selected Georgia watersheds. A pair of annual maximum rainfall-runoff volume was selected for each year based on the maximum peak flow rate. Therefore, the number of selected rainfall-runoff data points was equal to the number of years of record for each watershed. As a result, an equal number of simulated values for runoff volume were generated using the Curve Number procedure.

To investigate the seasonal variation of a Curve Numbers, the observed rainfall and runoff volume datasets were divided according to the two seasons and treated separately for statistical analysis. The Curve Number for each season was computed using equations (6) and (7) for all watersheds.

The Curve Number values for the growing season were compared statistically to the Curve Number values of the dormant season, using the analysis of variance (ANOVA) test at 0.05-level of significance. The P-value was used to reject or accept the research or alternate hypotheses. The research hypothesis will be accepted if P-value is greater than the 0.05. The research hypothesis states that there is significant difference between Curve Number values for the two seasons.

**Table 1** Watershed characteristics of selected watersheds.
(Land cover codes: FRSD = Deciduous, FRSE = Evergreen FRST = Mixed forests)

| Watershed (County) | Location (Gauge ID) (Area in mi$^2$) | Coordinates | | Land cover |
|---|---|---|---|---|
| | | Latitude (N) | Longitude (W) | |
| Chattahoochee (Habersham) | near Leaf (7327) (150) | 34$^o$ 35' | 83$^o$ 38' | FRSD (43.6%) FRSE (13.9%) FRST (41.1%) |
| Chattooga (Chattooga) | near Summerville (7161)(193) | 34$^o$ 28' | 85$^o$ 20' | FRSD (38.7%) FRSE (11.5%) FRST (49.7%) |
| Chestatee (Lumpkin) | near Dahlonega (7404) (153) | 34$^o$ 32' | 83$^o$ 56' | FRSD (49.1%) FRSE (12.2%) FRST (37.5%) |
| Middle Oconee (Clarke) | near Athens (7170) (398) | 33$^o$ 58' | 83$^o$ 25' | FRSD (44.3%) FRSE (9.3%) FRST (43.1%) |
| Toccoa (Fannin) | near Dial (7250) (177) | 34$^o$ 47' 24" | 84$^o$ 14' 24" | FRSD (60.4%) FRSE (14.4%) FRST (22.8%) |

## RESULTS AND DISCUSSION

As shown in figure (1), Curve Numbers computed for the growing seasons are lower than those for the dormant seasons for all watersheds. However, the analyses of statistical tests (Table 2) show that the mean Curve Numbers of the growing seasons computed from only two watersheds (Chattahoochee and Middle Oconee) are significantly different from that of the dormant season mean Curve Numbers at 0.05 level of significance. No significant difference in mean Curve Numbers were observed for the Chattooga, Chestatee, and Toccoa watersheds. While the observed difference in the mean Curve Number value was only 4.1 for the Toccoa watershed, the effect in computing runoff volume is still substantial.

The Curve Number values from Chestatee watershed are almost equal for the growing and dormant season. This watershed has the highest percentage of deciduous forest cover (table 1) compared to the other the watersheds, and the fact that there is no significant difference suggests that there is no need to vary the value of the Curve Number seasonally for such watersheds. Variations of Curve Number values on a seasonal basis may improve the overall performance of the Curve Number method based on findings from the Chattahoochee and Middle Oconee watersheds.

The observed lack of significant differences in Curve Number values from season to season for some watersheds may possibly result from the inclusion of rainfall and runoff data set from the seasonal transition period. Excluding two or more transitional months may improve results because these periods exhibit the same characteristics of both seasons. Depending on the availability of data, if the rainfall and runoff volume from the month of October and November are not included in computing the Curve Number considering these months as a seasonal transition period from the dormant to the growing season; and in the same way, the data sets from March and April are not included in the computation considering these months as a transition period from the growing season to the dormant season, a better result may be achieved. In the future small forested watershed from Coweeta, North Carolina; Hubbard Brook, New Hampshire; and Fernow, west Virginia will be analyzed to come up with a solid conclusion on effect of seasonal variation on curve number values.

**Fig. 1 Curve number for growing and dormant seasons**

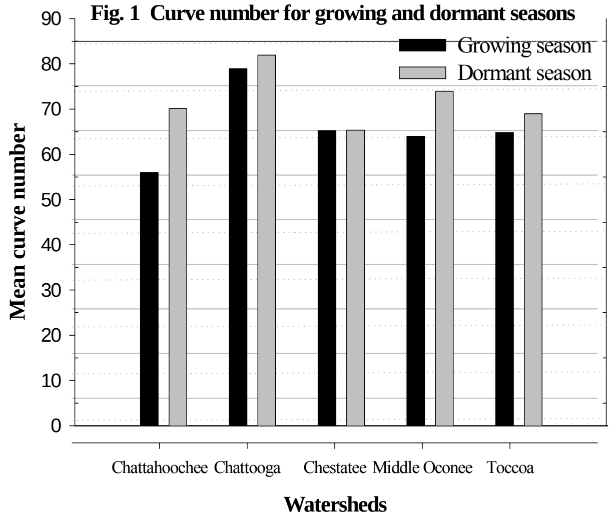


**Table 2** Results of statistical tests

| watershed | F-value | Pr>F |
|---|---|---|
| Chattahoochee | 6.09 | **0.023** |
| Chattooga | 0.8 | 0.379 |
| Chestatee | <0.001 | 0.975 |
| M. Oconee | 4.91 | **0.038** |
| Toccoa | 1.87 | 0.179 |

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