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Study on Antecedent Moisture Condition for Seolma Stream Basin

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Abstract

Curve number (CN), originally developed, compiled by 'The Natural Resources Conservation Service (NRCS)', and has been widely used throughout the world. However, there is the uncertainty of CN derived from the use of antecedent moisture condition (AMC)/Antecedent Runoff Condition (ARC). As in Korea where nearly 70% covered by mountainous area, it is still not sufficient handbook precedent to guide or support the estimation of AMC/ARC. The failure to develop formal criteria of applying AMC/ ARC will be a gaping profession and results not only in uncertainty of CN estimation in particular, but also in designing appropriate structures in Korea as a whole. This paper is aiming at presenting a critical review of AMC/ARC and deriving a procedure to deal more realistically with event rainfall-runoff over wider variety of initial conditions. Proposed methods have been developed. It is based on modifying estimated runoff to observed runoff with coefficient of determination and then applying different algebraic expression with the verification of AMC by antecedent rainfall table of NEH-1964. The result shows that algebraic expression by Arnold et al. (1996) is the most appropriate for AMC/ARC and the results of AMC/ARC estimation criteria are generally very close to each other. Therefore, this algebraic expression might be applied in South Korea condition properly.

Keywords : *Antecedent Moisture Condition (AMC), Antecedent Runoff Condition (ARC), Asymptotic CN, Base flow Separation, Curve Number*

1. Introduction

The accuracy of the Curve Number Method has not been thoroughly determined (Ponce and Hawkins 1996, McCutcheon et al. 2006) and empirical evidence suggests that with the current NRCS (2001) curve number table, hydrologic infrastructure is being over- designed by billions of dollars annually (Schneider and McCuen 2005). Furthermore, SCS-CN main weak points are including it does not consider the impact of rainfall intensity and its temporal distribution. It does not address the effects of spatial scale, it is highly sensitive to changes in values of its sole parameter; and it does not address clearly the effect of adjacent moisture condition (Hawkins, 1993; Ponce and Hawkins, 1996; Michel et al., 2005). In addition to that, use of the Curve Number Method to simulate runoff volume from forested watersheds would likely result in an inaccurate estimate of runoff volume from a given volume of rainfall (Ponce and Hawkins 1996, McCutcheon 2003, Garen and Moore 2005, Schneider and McCuen 2005, Michel et al. 2005, McCutcheon et al. 2006).

One of the several problems (Ponce and Hawkins 1996, King et al. 1999) is that the Method does not contain any expression for time and a result ignores the impact of rainfall intensity as well as antecedent runoff condition (ARC). So far, there is no concrete guidebook for estimating the antecedent runoff conditions. More importantly, the procedure to identify the ARC has been applied within the US soil condition and for decades. For mountainous topographical area like South Korea, there will be encountered the variation and bias. Misestimating the runoff depth will lead to the failure in design structure; consequently there will dramatically damage ranging from capital loss to human loss. Also, driving force of economic development will be getting down unavoidable.

In this proposed research, ARC is considered as AMC. From SCS, three AMCs are considered. They are above dry, wet and normal condition corresponding statistically to 90%, 10% and 50% respectively, of cumulative probability of exceedance of runoff depth for a given rainfall (Hjelmfelt et al., 1982).

It is apparent that the CN-variability is primarily attributed to the antecedent moisture, and it has led to statistical and stochastic considerations of the curve

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number, undermining the physical basis of the SCS-CN methodology. Furthermore, incorporation of the antecedent moisture in the existing SCS-CN method in the terms of the three AMC levels allows unreasonable sudden jumps in the CN variation. Therefore, the determination of the antecedent moisture condition plays an important role in selecting the appropriate CN value.

This objective of this paper is to present a critical review of antecedent runoff condition AMC/ARC and highlight several inconsistencies when used in continuous models, and derive a procedure to deal more realistically with event rainfall-runoff over wider variety of initial conditions.

2. Methodology

2.1 Study basin

The Seolma Cheon River Watershed is selected for this study. The watershed were selected because it is a test delta managed by a South Korean construction technology researcher fellow who is situated at the Kyonggido Paju city Juksungmyun which is about 46 km upstream from the Imjin river estuary. Seolma River is arborization form to the Imjin River's first tributary and has a river channel length of 11.3 km, and basin area of 18.5 km^2. Rainfall-runoff data of the Seolma river basin elected as the examination basin was selected as the recorded data of that operation of the examination basin in 2000 and hydrologic characteristics were investigated.

The topography characteristics of the basin were investigated by each sub watershed at the inundation level observatory. It is better to use a large scale map for various topography factors of the basin because the whole basin area is only 8.50km^2. The calculated topography factors are sub watershed area, channel length, basin average range, shape factor, and basin's centeretc.

2.2 Data collection and data management

Rainfall and runoff volume record used for this study were obtained from the daily record at the experiment area to get precisely and accurately measured result. The number of select rainfall-runoff data is 12 records year with 10 second interval time (12 years for CN estimation and 2 years for validation and calibration). Then rainfall-runoff records are converted to daily rainfall-runoff record.

There are some limitations to the data, as most of the detailed management records related to these studies are difficult to access. In our study, rainfall (P) data was explicitly matched to the runoff (Q) data. Unreasonable and clearly wrongly recorded data were removed manually, such as Q data with missing P data. In addition, the daily Q data was manually matched to runoff generating storms in the P data. To account for possible differences in season, the data was split in summer season data to represent different land uses.

The direct runoff was computed by separating the base flow from the total flow using WHAT (Web based Hydrograph Analysis Tool) and compare with different digital filters to find the best practices.

The process is ranging from the curve number estimation by completing all the input data to the determination of runoff depth. The data required for this process are including rainfall data from the observation year and outflow flow from the observation year.

Rainfall data are characterized as daily rainfall at station for the 12 years for input data and for the year of 2009 and 2010 for validation process.

2.3 The Curve Number Method

Originally, this technique was originally derived from the examination of annual flood event data. Implicit in the reasoning of Mockus (1949) and Andrews (1954), the curve number runoff equation can be derived from a watershed water balance for a storm event written as :

$$P = I_a + F + Q \qquad (1)$$

where P is the storm event rainfall; Ia is the initial abstraction (includes interception, depression storage, and infiltration losses prior to ponding and the commencement of overland flow); F is the cumulative watershed retention of water; and Q is the total runoff from the rain event.

Victor Mockus (Ponce 1996) hypothesized that the ratio of actual runoff to the maximum potential runoff is equal to the ratio of the actual retention of water during a rainstorm to maximum potential retention S in a catchment (Ponce and Hawkins 1996) or

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

To reduce the number of unknown parameters (3) in Equations (1) and (2), the SCS hypothesized that:

$$I_a = \lambda S \tag{3}$$

Where λ is the initial abstraction ratio or coefficient, I_a is the initial abstraction, and S is maximum potential retention.

As the Method is currently practiced, runoff can be computed using the tabulated curve numbers based on the land use and condition, hydrologic soil group, and the rainfall depth from combining Equations (1) and (2) as

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

Equation (4) is valid for precipitation P > Ia. For P < Ia, Q = 0 such that no runoff occurs when the rainfall depth is less than or equal to the initial abstraction Ia. With initial abstraction included in Equation (4), the actual retention F = P − Q asymptotically approaches a constant value of S + Ia as the rainfall increases.

Using the value of λ = 0.2, Equation (4) becomes

$$\begin{aligned} Q &= \frac{(P - 0.2S)^2}{(P + 0.8S)} && \text{for } P > 0.2 \\ Q &= 0 && \text{for } P \le 0.2S \end{aligned} \tag{5}$$

Equation (5) contains only one parameter (maximum potential retention S), which varies conceptually between 0 and ∞. For convenience in practical applications, maximum potential retention S is defined in terms of a dimensionless parameter CN (curve number) that varies over the more restricted range of 0 < CN < 100

$$S = \frac{1000}{CN} - 10 \Rightarrow CN = \frac{1000}{S + 10} \tag{6a}$$

$$S = \frac{25400}{CN} - 254 \Rightarrow CN = \frac{25400}{S + 254} \tag{6b}$$

The numbers 1000 and 10 (in inches) as expressed in Equation (6a) or 25400 and 254 (in millimeters) as expressed in Equation (6b).

Watershed curve numbers are estimated by cross referencing land use, hydrologic condition, and hydrologic soil group for ungagged watersheds in standard tables (NRCS 2001) or calculated for gaged watersheds by algebraic rearrangement of Equations (5) and (6) as

$$CN = \frac{1000}{5\left[P + 2Q - \sqrt{4Q^2 + 5PQ}\right] + 10} \tag{7a}$$

$$CN = \frac{25400}{5\left[P + 2Q - \sqrt{4Q^2 + 5PQ}\right] + 254} \tag{7b}$$

Measured pairs of rainfall volume P and runoff volume Q from an individual storm event are used with Equation (7) to determine the watershed curve number CN. The measured rainfall and runoff are expressed in inches or millimeters for Equations (7a) and (7b), respectively.

2.4 Web-based Hydrograph Analysis Tool (WHAT)

The Web GIS-based Hydrograph Analysis Tool (WHAT) was developed (Lim et al., 2005) to provide a Web GIS interface for the 48 continental states in the USA for base flow separation using a local minimum method, the BFLOW digital filter method, and the Eckhardt filter method. The Nash-Sutcliffe coefficient were used for both calibration and validation periods.

Equation (8) shows the digital filter used for base flow separation (Lyne and Hollick, 1979; Nathan and McMahon, 1990; Arnold and Allen, 1999; Arnold et al., 2000).

$$q_t = \alpha \times q_{t-1} + \frac{1+\alpha}{2} \times (Q_t - Q_{t-1}) \tag{8}$$

where, q_t is the filtered direct runoff at the t time step (m^3/s); q_{t-1} is the filtered direct runoff at the t-1 time step (m^3/s); α is the filter parameter; Q_t is the total stream flow at the t time step (m^3/s); and Q_{t-1} is the total stream flow at the t-1 time step (m^3/s).

The Eckhardt filter separates the base flow from stream flow with Equation 9 as shown below:

$$\begin{aligned} b_t &= \frac{3\alpha - 1}{3 - \alpha} \times b_{t-1} + \frac{1-\alpha}{3-\alpha} \times (Q_t + Q_{t-1}) \\ b_t &= \frac{\alpha}{2-\alpha} \times b_{t-1} + \frac{1-\alpha}{2-\alpha} \times Q_t \end{aligned} \tag{9}$$

where b_t is the filtered base flow at the t time step; bt-1 is the filtered base flow at the t-1 time step; α is the filter parameter, Q_t is the total stream flow at the t time step (m^3/s); and Q_{t-1} is the total stream flow at the t-1 time step (m^3/s).

$$b_t = \frac{(1 - BFI_{max}) \times \alpha + b_{t-1} + (1-\alpha) \times BFI_{max} \times Q_t}{1 - \alpha \times BFI_{max}} \tag{10}$$

where b_t is the filtered base flow at the t time step; b_{t-1} is the filtered base flow at the t-1 time step; BFImax is the maximum value of long-term ratio of base flow to total stream flow; α is the filter parameter; and Q_t is the total stream flow at the t time step.

BFImax is a new variable introduced in the digital filter method by Eckhardt (2005). To reduce the subjective influence of using BFImax on base flow separation, representative BFImax values were estimated for different hydrological and hydrogeological situations by comparing the base flow from conventional separation methods with those of the Eckhardt digital filter method (Eckhardt, 2005).

2.5 Evaluation of the curve number method & base flow separation method

Measured rainfall and runoff volumes for the event were used to determine a curve number for each year of record on watersheds. Representative watershed curve numbers for gaged watersheds were selected from a set of curve numbers determined using the (1) arithmetic mean, (2) median, (3) geometric mean, (4) and asymptotic value. To access the accuracy of NRCS (2001) Curve Number Method these calibrated values were compared to the NRCS (2001) tabulated curve numbers for the specific hydrologic soil group (Group A, B, C, or D), cover-complex (land use, treatment, or practice), and hydrologic condition (poor, fair, or good) on each gaged watershed.

Arithmetic curve number: The curve number for each year of record for a particular watershed is averaged to determine the representative curve number.

Median curve number: The median was originally determined for the NRCS (2001) curve number tables using the Graphical Method. The direct runoff was plotted versus the rainfall volume to determine the curve that divides the plotted points into two equal groups. The curve number for that curve is the median curve number.

Geometric mean curve number: The NRCS (2001) Statistical Method determines the geometric mean curve number (Yuan 1939) from a lognormal distribution of annual watershed curve numbers about the median (Hjelmfelt et al. 1982, Hauser and Jones 1991, Hjelmfelt 1991).

Asymptotic Method: the 'Hawkins's method, CN calculated using Equation (6) and (7) are plotted against the respective P values, and the asymptotic value at high rainfalls is taken as the final CN.

Coefficient of determination and goodness of fit such as Normalized Root Mean Square Error (NRMSE), Relative Error (RE), R-Square (R^2) and Nash Sutcliffe coefficient (E) were used to evaluate curve number estimation.

In many cases of hydrologic modeling, one needs to compute R^2 and Nash-Sutcliffe coefficients to calibrate/ validate the model. The Web-based statistics module provides such a tool for fast computation of these coefficients.

2.6 Estimation of Thresholds for AMC/ARC

The original NEH4 exposition of the CN contained the AMC motion in two forms, both seemingly independent. First, as a climatic definition presented in the since discontinued NEH4 Table 4.2 or based on discontinued NEH4 Table 4.2, indicating AMC status (I,II, and III) based on 5-day prior rainfall depths and season. Second as an undocumented table (Table 10.1 in NEH4) that gave the I, II, and III equivalents. This was linked to explaining that observed variation in direct runoff between events.

AMC conversion values: The correspondence between CN at three AMC status levels was stated in NEH4 Table 10.1 without explanatory background or hydrologic reference: the original data sources and the deviation technique have not been located

However, determination of antecedent moisture condition content and classification into the antecedent moisture classes AMC I, AMC II, and AMC III, representing dry, average, and wet conditions, is an essential matter for the application of the SCS curve number procedure that is without a clear answer yet. Hjelmfelt (1991) noted that the SCS gives three definitions for AMC II:

- Average conditions (NEH-4, 1964). The SCS defines the antecedent moisture condition as an index of basin wetness. In particular AMC II is defined as "the average condition." However, Hjelmfelt (1991) pointed out that it is not clear if this is to be quantitative or qualitative definition, and, if quantitative.
- Median curve number (NEH-4, 1964). The curve number that divides the plotting of the relationship between direct runoff and the corresponding rainstorm into two equal numbers of points (the median) is associated with AMC II. AMC I and AMC II are defined by envelope curve.

- Antecedent rainfall table (NEH-4, 1964). The appropriate moisture group AMC I, AMC II, AMC III is based on a five-day antecedent rainfall amount and season category (dormant, and growing seasons).

Table 1: Seasonal rainfall limits for AMC (Source: NEH-4, 1964)

AMC group	Total 5-day antecedent rainfall (mm): Dormant season	Growing season
I	Less than 13	Less than 36
II	13 to 28	36 to 53
III	More than 28	More than 53

To reduce uncertainties in the CN method, new rainfall thresholds for the definition of the AMC class where computed. The new thresholds have been evaluated by applying algebraic expression of NEH4 such as algebraic express for CN (I) and CN (III) developed by Sobhani 1975, Hawkins et al. 1985, Chow et al. 1988 and Arnold et al. 1990.

Algebraic expression by Sobhani 1975

$$CN(I) = CN(II)/[2.334 - 0.01334CN(II)] \qquad (11a)$$
$$CN(III) = CN(II)/[0.4036 + 0.0059CN(II) \qquad (11b)$$

Algebraic expression by Hawkins et al. 1985

$$CN(I) = CN(II)/[2.281 - 0.01381CN(II)] \qquad (12a)$$
$$CN(III) = CN(II)/[0.427 + 0.00573CN(II) \qquad (12b)$$

Algebraic expression by Chow et al. 1988

$$CN(I) \ = 4.2CN(II)/\left[10 - 0.058CN(II)\right] \qquad (13a)$$
$$CN(III) = 23CN(III) = 23CN(II)/\left[10 + 0.13CN(II)\right] \qquad (13b)$$

Algebraic expression by Arnold et al. 1988

$$CN(I) = CN(II) - F(CN(II)) \qquad (14a)$$
$$CN(III) = CN(II) * \exp[0.00673(100 - CN(II)] \qquad (14b)$$
$$F(CN(II) = 20(100 - CN(II)/[100 - CN(II) + \exp(2.533 - 0.0636(100 - CN(II)]$$

Once curve numbers are defined and algebraic expression are determined, coefficient of determination and goodness of fit such as Normalized Root Mean Square Error (NRMSE), Relative Error (RE), R-Square (R^2) and Nash Sutcliffe coefficient (E) were used to evaluate antecedent moisture condition estimation criteria.

3. Results and Discussions

The determination of antecedent moisture condition criteria can be defined by going through the following steps:

Firstly, direct runoff is necessary to be separated from total runoff. By applying base flow separation known as Web Based Hydrograph Tools (WHAT), the base flow and direct runoff can be separated. The data are derived from the Juksungmyun examinational rainfall station from 2000 to 2011.

After identifying direct runoff from total runoff, curve number estimation can be calculated from equation 7 by knowing daily rainfall and matched direct runoff. However, further consideration is necessary to take into account. That is, to test the accuracy of curve number. To test the accuracy of curve number determination, curve numbers are computed depending upon four different procedures including arithmetic mean, median, geometric mean, and asymptotic fit. Except for the asymptotic method, unranked paired rainfall and runoff volumes from the maximum peal flow event each year of record were used to compute the calibrated curve number.

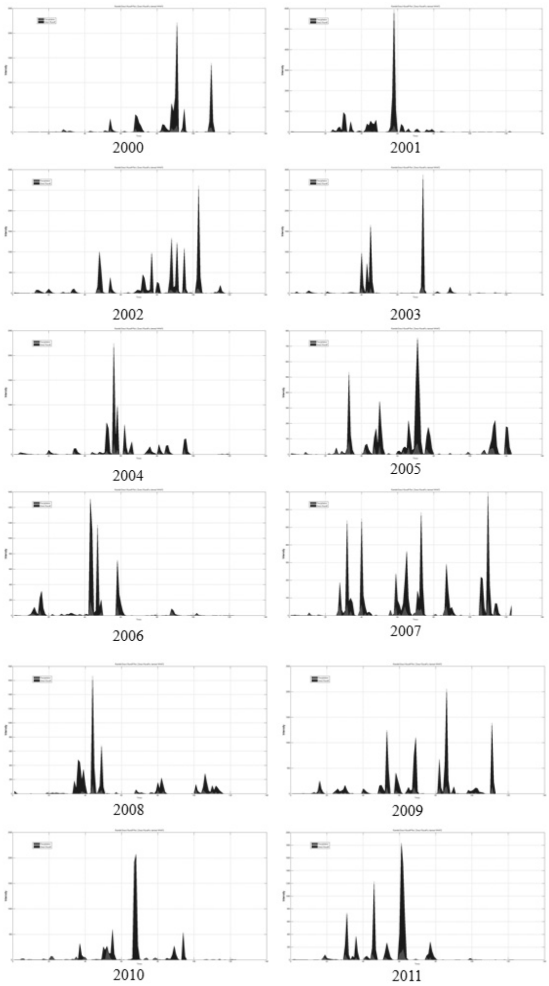

Fig. 1: Rainfall versus Direct Runoff Plot annually from 2000 to 2011 (12 years period)

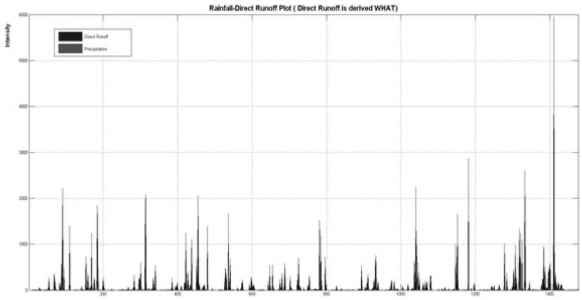

Fig. 2: Rainfall versus Direct Runoff Plot from 2000 to 2011

Table 2: Watershed Curve Number by all procedures from 2000 to 2011

Year	Arithmetic Mean	Median	Geomtric Mean	Asymptotic Fit
2000	93.8	97.73	97.5	71
2001	93.85	97.13	96.97	85.86
2002	80.85	87.9	89.55	40.83
2003	92.13	93.55	94.97	N/A
2004	93.63	96.49	96.6	89.81
2005	86.99	89.25	92.73	N/A
2006	91.87	94.03	94.48	86.26
2007	92.97	93.42	95.27	91.26
2008	92.47	91.86	94.8	88.95
2009	92.03	93.58	95.74	78.31
2010	90.6	94.25	95.88	82.08
2011	94.72	95.31	96.63	90.37

Table 3: Overall Watershed Curve Number by all Procedures

CN Estimation Procedure	CN	R^2	RE	NRMSE	E
Arithmetic Mean	90.5	0.5814	1.2572	0.068	-0.39
Median	93.65	0.5544	1.3642	0.0712	-0.68
Geometric Mean	95.13	0.5439	1.414	0.0736	-0.87
Asymptotic Fit	**77.17**	**0.7148**	**0.7994**	**0.073**	**-0.2**

Table 2 and 3 indicate the determination of curve number based on theirs procedures. The curve numbers computed based on the arithmetic mean, median, geometric mean, and asymptotic fit.

The geometric mean curve numbers of all year were greater than the curve numbers based on the other calculation procedures. However, the geometric mean and median curve numbers do not seem to be significantly different as expected if the watershed curve number distribution are logarithmic. In addition, the arithmetic mean curve numbers generally are close in magnitude to median curve number. The mean, median and geometric mean derived curve number do not seem to be significantly different.

The asymptotic curve numbers were smaller than the curve number based on the other procedures and some of them are not available due to the fitting points of rainfall and estimated curve number by equation 7. It is remarkable that, asymptotic curve numbers are expected to be smaller because set of curve number that are not too scattered are associated with the largest numbers rainfall volume observed or infinitely large volumes. Remarkable is that the asymptotic fit is biased to smaller curve number with very low frequencies of occurrence.

Based on the graphic representation on figure 3, asymptotic curve number is 77.17 with regression equation:

$$CN = 77.17 + (100 - 77.17)e^{-0.0569p}$$

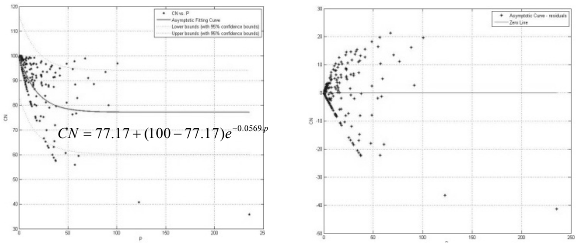

Fig. 3: Curve number versus Rainfall plot & Asymptotic Fitting Curve plot for Seolma Cheon River Watershed

The relative accuracy and correlation of rainfall-runoff derived curve numbers based on four procedures are determined from coefficient of determination and goodness of fit such as Normalized Root Mean Square Error (NRMSE), Relative Error (RE), R-Square (R^2) and Nash Sutcliffe coefficient (E).

Based on the tests shown in table 3, the asymptotic procedure is the best for curve number estimation. In addition to that, the curve number derived by the three procedures known as arithmetic mean, median and geometric mean are in general not very different, these finding only serve to highlight that one highlight that one procedure is as similar as another. Hence, curve number derived from asymptotic method is used for further analysis.

After the curve number is estimated, the next step is to simulate antecedent moisture condition by applying all the proposed algebraic expression of NEH4 with the consideration of 5 day prior to rainfall (definition of AMC using antecedent rainfall table). Next is to validate and calibrate among the proposed procedure to figure out the estimator of antecedent moisture condition criteria.

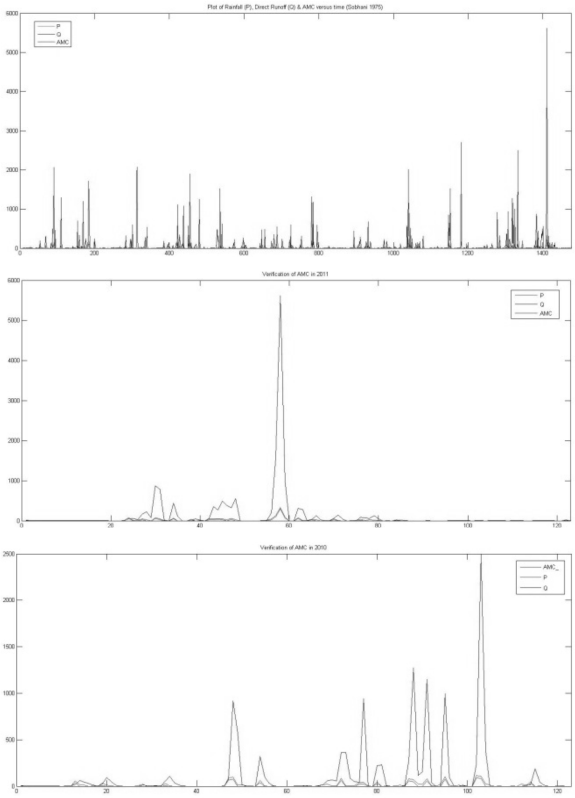

Fig. 4: Plot of Rainfall, Direct Runoff and AMC versus time using algebraic expression developed by Sobhani 1975 (The above graph is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September)

Table 4: Coefficient of determination of AMC by Sobhani 1975

AMC	NRMSE	R^2	RE
2000-2011	0.85213	0.55799	0.9455
2011	1.7144	0.9131	0.9455
2010	3.4681	0.49867	0.96396

Fig. 4 shows about the plot of rainfall, direct runoff and AMC versus time in different time period. That is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September. In other words, they are plotted during summer season.

With the value of R-square 0.55799, it is denoted that it fairly explains the observed direct runoff. Also, with RE equal to 0.9455, it is indicated that model overestimate observed data (direct runoff) by 94.55%. However, model performance is fairly fit among validated value across the year 2011 and 2010.

Regarding to validation and calibration of the estimated model (direct runoff estimation), in 2011, it fairly well describes the observed direct runoff with R-square equal to 0.9131 yet it model overestimate observed data by 91.31 percent. In 2010, it shows the value close to the estimation of 12 years period ranging from 2000 to 2011.

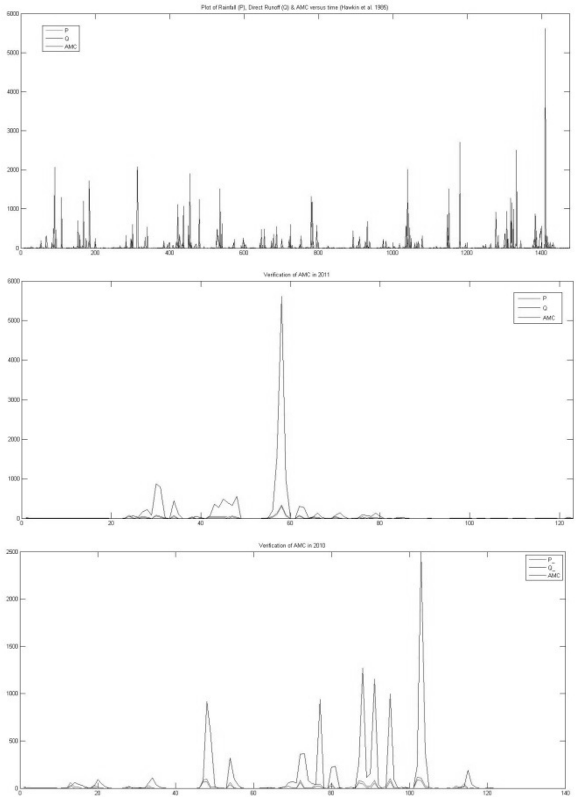

Fig. 5: Plot of Rainfall, Direct Runoff and AMC versus time using algebraic expression developed by Hawkin et al 1985 (The above graph is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September)

Table 5: Coefficient of determination of AMC by Hawkin et al 1985

AMC	NRMSE	R^2	RE
2000-2011	0.86623	0.5646	0.94609
2011	1.734	0.92513	0.94609
2010	3.5774	0.50491	0.96501

Fig. 5 shows about the plot of rainfall, direct runoff and AMC versus time in different time period by the application of Hawkin et al 1985. That is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September in summer.

With the value of R-square 0.5646, it is denoted that it fairly explains the observed. Also, with RE equal to 0.94609, it is indicated that model overestimate observed data (direct runoff) by 94.609%. However, model performance is fairly fit among validated value across the year 2011 and 2010.

Regarding to validation and calibration of the estimated model (direct runoff estimation), in 2011, it fairly well describes the observed direct runoff yet it model overestimate observed runoff.

Overall, algebraic equations by Hawkins at el. seem to be more reliable than by Sobhani. Remarkable is that the two proposed equations are very close to one another in term of reliability.

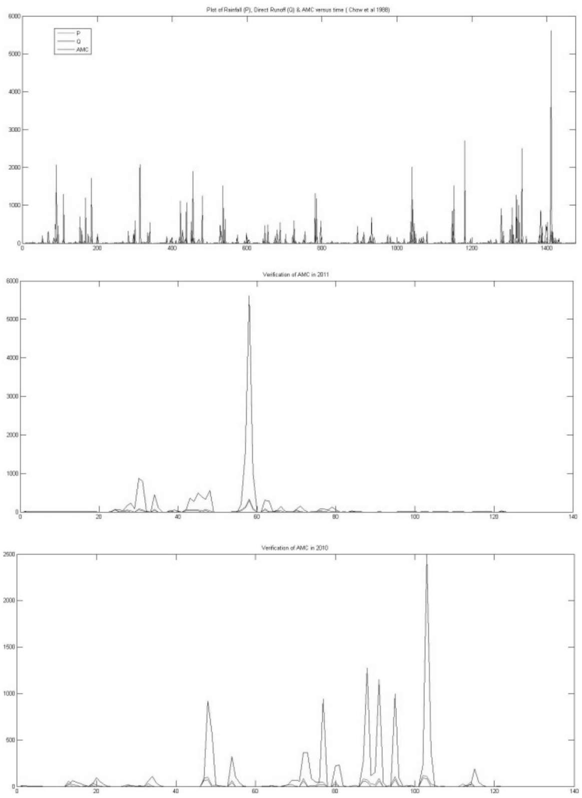

Fig. 6: Plot of rainfall, direct runoff and AMC versus time using algebraic expression developed by Chow et al 1988 (The above graph is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September)

Table 6: Coefficient of determination of AMC by Chow et al 1988

AMC	NRMSE	R^2	RE
2000-2011	0.86419	0.56152	0.94618
2011	1.77377	0.91973	0.94618
2010	3.5961	0.49965	0.96518

Graphic representation in figure 6 indicates the rainfall, direct runoff and AMC versus time relationship different time period by the application of Chow et al 1988. That is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively in summer.

With the same consideration as in previous description (as in figure 5 and figure 6), overall, the simulated direct runoff with algebraic equation represented CN I and CN III by Chow et al 1988 is closely similar to the two other proposed equation. Closely look into the coefficient of determination, simulation of direct runoff is somewhere in between the two proposed methods. It is noticeably that also overestimate the observed direct runoff by 94.618%.

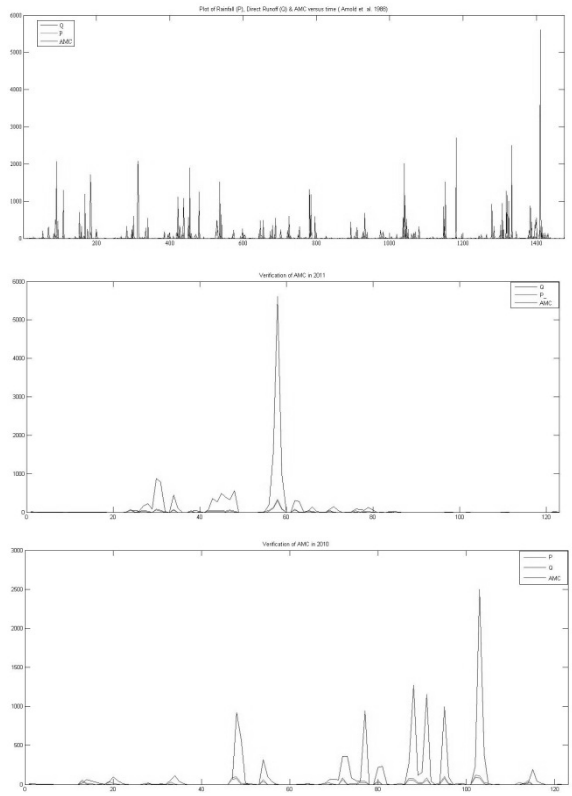

Fig. 7 : Plot of Rainfall, direct runoff and AMC versus time using algebraic expression developed by Arnold et al. 1990 (The above graph is 12 year of daily record and the below graph are the plot of daily record in 2011 and 2010 respectively from June to September)

Table 7: Coefficient of determination of AMC by Arnold et al. 1990

AMC	NRMSE	R^2	RE
2000-2011	0.85051	0.52616	0.94541
2011	1.7106	0.9009	0.94541
2010	3.4498	0.48317	0.96379

Figure 7 represents plot of rainfall, direct runoff and simulated direct runoff by AMC taking into account of algebraic equation developed by Arnold et al. 1990.

With the value of R-square 0.52616, it is denoted that it fairly explains the observed direct runoff. Also, with RE equal to 0.94514, it is indicated that model overestimate observed data (direct runoff) by 94.514%. However, model performance is fairly fit among validated value across the year 2011 and 2010.

Regarding to validation and calibration of the estimated model (direct runoff estimation), in 2011, it fairly describes the observed direct runoff yet it model overestimate observed data.

Table 7 present results of coefficient of determination of AMC from the four different proposed equations.

Clearly indicated in the table 8 for 12 years period analysis, normalized root mean square error is best described by the application of algebraic expression by Arnold et al. at the value of 0.85051. However, overall, calculated coefficients of determination among proposed method are very close to each other. In the other words, it remarkably indicates the least residual variance.

In addition to that, with RE equal to 0.94541, it is indicated that model overestimate observed data (direct runoff) by 94.45% which is the most preferable condition for the direct runoff estimation in comparison to each proposed method. However, in terms of estimation performance, proposed expression by Arnold et al. fairly explains the observed direct runoff more reliable than others proposed expressions. With regarding to R-square, proposed method by Hawkins et al. is the most reliable.

For the verification, observed and estimated runoff data from 2010 and 2011 have been conducted. As results from the comparison of coefficient of determination, Arnold et al. is the most favorable estimation of antecedent moisture condition criteria.

Proposed methods are overall is very close to one and another, it is implied that all the application of proposed method can be used to describe the antecedent moisture condition criteria. Also, the antecedent rainfall table from NEH report.

Table 8: Results of coefficient of determination of AMC from the four different proposed equations

AMC	Coefficient of Determination	Algebraic Expression			
		Sobhani	Hawkins et al	Chow et al.	Arnold et al.
2000-2011	NRMSE	0.85213	0.86623	0.86419	**0.85051**
	R^2	0.55799	**0.5646**	0.56152	0.52616
	RE	0.9455	0.94609	0.94618	**0.94541**
2011	NRMSE	1.7144	1.734	1.77377	**1.7106**
	R^2	0.9131	0.92513	0.91973	**0.9009**
	RE	0.9455	0.94609	0.94618	**0.94541**
2010	NRMSE	3.4681	3.5774	3.5961	**3.4498**
	R^2	0.49867	**0.50491**	0.49965	0.48317
	RE	0.96396	0.96501	0.96518	**0.96379**

4. Conclusion

From results and the validation of AMC, it is implied that the determination of AMC has some inconsistency from one to another. Thus, for long time period of time, determination of AMC might be acceptedS for further usage.

Application of curve number procedures and evaluation of each procedure by the coefficient of determination, it is found that asymptotic CN number is the most appropriate procedure in Seolma Cheon River watershed with the value of 77.17.

Proposed methods are developed by modifying estimated runoff to observed runoff with coefficient of determination and then applying different algebraic expression developed. The result shows that algebraic expression by Arnold et al. is the most appropriate for antecedent moisture condition criteria. Therefore, this algebraic expression might be used in South Korea condition properly.

In addition, by choosing precipitation from antecedent moisture condition due to the 5 prior to rainfall (NEH-1964 AMC definition), it is indicated that the overall results of estimated runoff is nearly double to the observed runoff. The reason is originated from the selection of precipitation according antecedent rainfall table.

For further study, it is recommended to compare the Base flow Separation and CN Estimation Method for determining ARC and AMC as well as to figure out the best practices for identifying ARC and AMC. By applying different base flow digital filter, the research might find out the better results of ARC and AMC, in turn, it might be useful to get better understanding about ARC and AMC as well as the optimization value of AMC and ARC with regards to Korea condition.

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