Initial Runoff Abstraction in the Curve Number Method using data from the Walnut Gulch Experimental Watershed

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Introduction

Accurate estimation of surface runoff is important for water quality control, sediment yield prediction and for testing the efficiency of soil and water conservation practices. Many hydrologic models are available to estimate surface runoff from precipitation data. However, these models require sufficient data and calibration, which are not available in some regions. The Soil Conservation Service Curve Number (SCS-CN) method, is widely used for estimating surface runoff depths for a given rainfall. Despite its minimal data requirements and simplicity, it has capability to take into consideration morphology, vegetation type and coverage, soil type, and other important factors.

The SCS-CN method is based on a water balance for an event and two fundamental hypotheses which can be expressed as:

$$P = I_a + F + Q, \qquad \frac{Q}{P-Ia} = \frac{F}{S}, \qquad I_a = \lambda S.$$

where P is the total precipitation (mm); I_a is the initial abstraction, which is the rainfall depth that occurs prior to the initiation of runoff (mm); F is the cumulative infiltration during the runoff period; Q is the runoff (mm); S is the potential maximum retention after beginning of the runoff (mm); and λ is the initial abstraction ratio. Combing these equations gives an expression for Q: $Q = \frac{(P-Ia)^2}{P+S-Ia}$. This equation is valid for P> I_a, otherwise, Q=0. If measured values of P, Q, and I_a are known, S may be calculated directly from the data.

Much attention is given to CN because it is an essential element for the SCS-CN method, while I_a is most often assigned the value of 0.2 S. However, the ratio 0.2 of initial abstraction and maximum retention may be questioned for its validity, invoking examination of the Ia-S relationship. For instance, Hawkins (1996) suggested that fixing the initial abstraction ratio at 0.2 may not be the most appropriate approach, and that it may best be interpreted as a regional parameter.

Methods

- Select precipitation and associate runoff events

  Assumption:

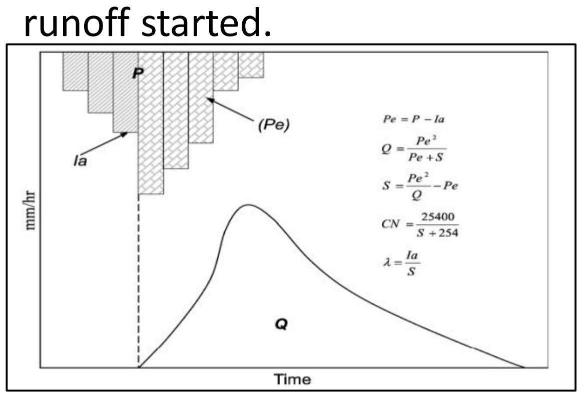
  rainfall is uniformly distributed on the watershed.

  Requirements:

  (a) The event occurs as one continuous rainfall;

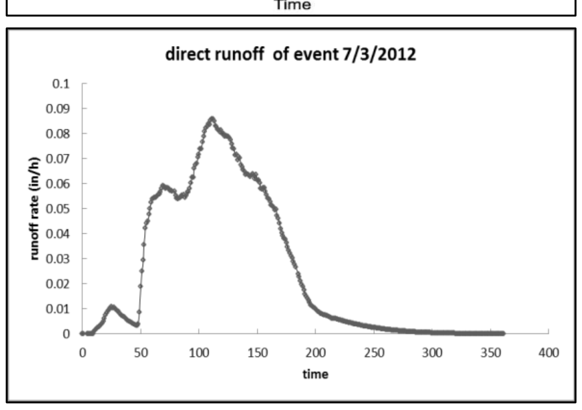
  (b) Only larger events are selected.

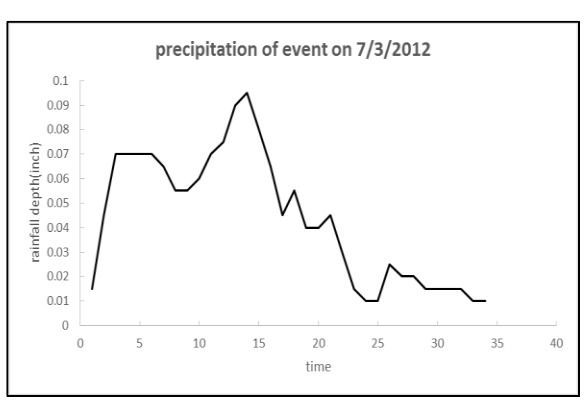
- In this study area there is no subsurface lateral baseflow, hence the runoff volume measured at the flume is equal to the total runoff. Initial abstraction was calculated as the storm rainfall depth before runoff started.



example

Event 7/3/2012:
Precipitation start time: 20:28
Runoff start time: 20:34
The direct runoff hyetography is given as below. Then consider that accumulative rainfall depth from 20:28pm-20:34pm as the initial abstraction. Therefore, the initial abstraction= 0.34inch, the total precipitation of this event is 1.63 inch; the total direct runoff of this event is 0.147inch.





Results

(1) Precipitation, initial abstractions, runoff volumes, and calculated potential maximum retentions and abstraction ratios of the events.

time	P(in)	Ia(in)	Pe(in)	Q(in)	S(in)	ratio
7/3/2012	1.630	0.340	1.290	0.147	10.025	0.034
8/6/2000	0.735	0.395	0.340	0.059	1.623	0.243
8/12/2005	1.225	0.130	1.095	0.019	61.978	0.002
8/17/2006	1.070	0.100	0.970	0.060	14.585	0.007
7/27/2007	0.925	0.135	0.790	0.014	42.945	0.003
9/9/2007	0.705	0.090	0.615	0.007	53.494	0.002
7/22/2008	2.115	0.490	1.625	0.101	24.449	0.020
7/25/2011	0.715	0.305	0.410	0.015	10.864	0.028
7/30/2012	1.320	0.395	0.925	0.007	127.547	0.003
9/12/2013	1.515	0.320	1.195	0.022	65.225	0.005
8/9/2014	0.185	0.016	0.169	0.015	1.779	0.009

(2) The modified SCS-CN equation based on these data indicates an abstraction ratio of approximately 0.032 rather than the commonly used value of 0.2, resulting in: $Q = \frac{(P-0.032S)^2}{P+0.968S}$

Discussion

This project used 11 events from the Walnut Gulch Experimental Watershed to estimate the ratio of the initial abstraction to the maximum retention. The results showed that the ratio I_a/S varied from 0.002 to 0.243, with an average of 0.032. Only for one event was the I_a/S ratio greater than 0.2. These results indicated that the ratio was not a constant, but varied between events. This ratio seems reasonable in comparison to results from previous research, including that of Hawking et al. (2002) and Baltas et al. (2007).

Conclusion

The Curve Number abstraction ratio, $\lambda = I_a/S$, from this study averaged 0.032, which less than the commonly used 0.2, which means that the initial abstraction in the study area would be overestimated by using 0.2 S. This may be because of: A) the relatively low vegetation cover and hence low plant interception, and B) relatively low random roughness and litter cover on the soil surface which reduces the amount of ponding prior to runoff.

Reference

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[4] SWRC brochure, Southwest watershed research center and Walnut Gulch Experimental Watershed, http://www.ars.usda.gov/main/site_main.htm?modecode=20-22-10-00

[5] SCS (Soil Conservation Service), 1972. SCS National Engineering Handbook,

Data source: http://www.tucson.ars.ag.gov/dap/digital/runoff_event.asp.