DESERT

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Online at http://jdesert.ut.ac.ir

DESERT 16 (2011) 69-75

Soil hydrologic group detection based on geomorphologic facieses and slope (Case study: Taleghan Watershed, Iran)

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Received: 4 May 2010; Received in revised form: 30 May 2011; Accepted: 6 July 2011

Abstract

The main goal of this paper is to propose a new practical method for hydrologic soil group estimation in surface runoff process based on geomorphology facieses and slop. The determination of CN based on this method can reduce the time and cost of project. In this research the upstream rivers of Glinak Watershed have been used as a case study to examine the efficiency of proposed method with a comparison with CN method, the Rational and Creager methods. The results show that RSS of estimated flood based on CN method with proposed and tradition CN and Rational to calibrated Creager's method are 31.5, 103.85 and 11.39, respectively. With these results, the new method can be proposed in various climatic conditions to estimate initial curve number in flood modeling and calibration.

Keywords: Curve Number; Flood Discharge; Glinak hydrometric gauge

1. Introduction

In most of the projects such as flood control, watershed management and water resources development, knowing the flood's characteristic is necessary. In regions that there is no hydrometry data, some methods which often are used are: experimental methods such as CN method and rational method, especially in small rural and urban watersheds. Moreover the curve number (CN) is applied in other distribution models. Determination of CN through the usual way, includes Soil science studies have consuming time with high cost; nevertheless several researches are done inside and outside the country (Daliri *et al*, 2010) that obtained CN by usual way method should be optimized and calibrated by the help of asymptotic methods & other similar methods in a specific surface (Nassaji and Mahdavi, 2005). In this case Hawkins (1993) presented asymptotic line method to determine the CN. Thereby three kinds of behaviors functions including selfish behavior, standard behavior and rude behavior of watersheds area are defined, so CN in a watershed for different storms is different and must be calculated according to kind of functions.

It is clear that according to the researches and concept of asymptotic methods, also expertise experiences, the initial estimation of CN from easier and more inexpensive methods is reasonable. Theory of this method is presented for the first time by Daliri (2001) and Daliri *et al*. (2011).

The purpose of this study is to introduce a new practical method for rapid and low expense estimation of soil hydrologic groups based on inventive-empirical method and concepts of geomorphologic facieses and slope.

2. Material and methods

The area of study is located in Veshteh – Zydasht basin in Taleghan with semi-humid cold climate & annual rainfall of 641 mm and

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annual temperature of 9.5 ºC. The total area of the basin is 86.03 square kilometers (Daliri *et al,* 2011). .

In order to determine the curve number in usual way and standard behavior function of watershed, land-use information in the time of crisis, Hydrological conditions (pastures, forests, urban and ...) and soil hydrological groups according to the standard table TR55 are necessary. In this study, land-use map and other information with due regard to the aerial photos and field controls have been provided. Hydrologic groups of soil in conventional methods will be determined with regard to Soil science studies, drilling of profiles, doing Soil tests and necessary interpretations (Ahmadi, 1999). In this present study the above steps are done as following:

After that map of homogenous units is providing 21 profiles of soil samples of about 1 m depth with the horizons of A,B,C were done and sent to soil science laboratory faculty of natural resources, Karaj-University of Tehran. Finally, with regard to the soil texture triangle and standard table (groups of A, B, C, D), soil hydrologic groups were determined. Afterwards facieses of geomorphologic map of the region which was specified for isotope units were integrated with the slop area for two classes less and more than 8 %(Table 1). Threshold of the mentioned slope and geomorphology grouping of facieses has been determined on the basis of experiences, expertise judgment, trial and error and scientific references (Ahmadi, 1999). Finally, with regard to table1, the status of each facieses on the basis of hydrologic groups of soil will be determined. The rest is like the method of determining of usual way and standard curve number. In this regard, geomorphologic facieses will be determined by climate behavior. Obviously it is likely that some of the behaviors of the facieses with regard to litho logy and regional climatic characteristics might behave completely different (such as types of granite). Although the research results is valid for Taleghan region but concept of the study has generality for other regions.

Regular hillside facieses

This facieses contains proper soil and plant cover, and is lack of rill and channel erosion. It may be also in the slops relatively high (20%-40%) but due to the proper condition the pedogenese process is done well and the depth of soil and vegetation covering are in an appropriate condition.

Table 1. Determination of soil hydrologic groups with regard to the type of facieses and slope (Daliri-2001)

Facieses Name of	Hydrologic Groups			
	A	B	C	D
Regular hillside facieses and slop range less than 8%	*			
regular hillside facieses and slop range above 8%		*		
Facieses channel, surface, rill, Badland, Land slid erosion			*	
Facieses dissolution (karst) erosion in wet and cold Climate		*		
Facieses of rock without the joint				*
Facieses of rock and mass stone with the fracture			*	

In the geomorphologic studies of Taleghan watershed (Ahmadi, 1999), facieses of regular hillside in the slop above 40%, has been reported due to the influence of gradual melting of snow and dissolution of Calcareous, then there creating a relatively deep soil and good vegetation covering. The role of this facieses in the production of direct runoff due to the quantity of slope is low (Soil Hydrologic Group A to B).

The hydrologic group of soil related to the Regular hillside facieses

Regarding to Hydrological groups standard table, certainly this facieses can’t behave like asphalt, concrete or loamy clay with hardpan layer in the depth of soil. With attention to slop map, the facieses of regular below 5 degrees (8%) are settled in group A and the facieses above 8% are in group B. In the project region with regard to the slop, all the regular facieses are settled in group B.

Channel and rill erosion facieses

This facieses forms with regard to intensity of storm, soil type, formation, slope, depth and texture of soil etc. Here, water flow moves along the slop instead of penetration and causes concentrated erosion, which various forms of erosions in the different formation such as granites, sandstone are similar to this kind of erosion in aerial photos. It may also create equal runoff or more, in different formations.

In the case of high runoff, these regions are settled in rock mass groups without fractures.

The hydrological group of soil related to channel erosion and rill erosion

The hydrological group of this facieses surly isn't A or D, because to form the rill and specially the channel, two main factors are needed. One of them is specified depth of soil and the other one is concentrated forces of water. When Water is concentrated can overcome to soil shear force. This force obtains from non-infiltrated water in cumulative way in the slop range. Obviously, if the hydrological group of soil be in the range of A and B, this interaction force can't be obtained or will be very low. With attention to the soil hydrological group standard table, the soils of group D don't infiltrate almost all the rain, but this facieses especially in low slops can be settled in threshold between groups B and C. Therefore, it is recommended that all the channel erosion and rill erosion facieses to be exposed in group C. Group B may be selected in region with different climate.

Surface erosion facieses

This facieses is formed by effect of improper use of resources and indicates the loss of soil and reaching to the mother rock (Substratum). It should be noticed that its beginning occurred with hydrolysis action into the soil and coming out sodium, potassium and calcium ions.

The Hydrologic group of soil related to surface erosion facieses

This facieses usually is formed by the effect of agriculture in sharp slops and has a thin soil and wasted herbaceous cover but it can not be settled in Group D such as asphalt and concrete, therefore it is recommended to be settled in group C. It should be noticed that this facieses can also be settled in group B only in low slopes or with considerable wasted cover.

Karst erosion facieses

This facieses has various forms on the Calcareous (calcium and magnesium) formation. Although the permeability is low in this formation, but the existence of proper vegetation in moisture condition and suitable depth of soil, cause to reduce run off and a large volume of water be store in aquifer. It should be noticed that in the dry and hot climate and another types of this formation may behavior reverse.

Hydrologic group of soil related to karst erosion facieses

Selection of hydrologic group for this kind of facieses is not so easy because the permeability of Calcareous is low but hidden cavities and enormous fractures in Calcareous causes are amazing. In this study, the calcareous regions are settled under the domain of Khodkavand watershed (T1), once be suppose in group B and once in group C. In the second case the discharge was calculated too high so that is which was far from the reality Therefore, it is suggested that this facieses being settled in group B or C with caution and regard to the condition of climate and necessary studies. In this study, the mentioned facieses was exposed in group B.

Facieses related to wet mass movements

All facieses of this type of movement are formed from fine grain formation. Facieses such as soul fluxion and Mudflow including fine grain formation such as marl, Basic or Acidic Tuff, silt stone

Hydrological group of soil related to wet mass movements facieses

This facieses operate similar to channels erosion facieses. Therefore, it is settled in group C. It should be considered that in hydrological group's standard table, clay is always settled in group D.

Prolapsus and rock mass facieses

These two facieses often contain low soil or no soil. (Above 70% rock and about 30% soil: rock Mass., above 30% soil: prolapsus of rock) but do not always produce high runoff. Here we should obtain necessary information with regard to the climate, type of formation and fracture in the rock and or field work in this case, there is a high level of facieses.
With the following explanation a hydrological group will be determined for each of facieses.

Hydrological group of soil related to mass rock facieses

The description of this facieses is that: it has low soil and in aerial photos it is shown in the form of rock mass.

Other problem related to this discussion is perhaps the presentation of the different behavior in different climate for Calcareous, granite etc. with a view to the erosion and degradation, and thus in the amount of seam and groove. This issue does not create a problem for low area and it can be settled in group D, but in large surface in the region the discharge will be estimated in a high level.

Hydrological group of soil related to prolapsus of rock facieses

This facieses is considered in ranges of any low and poor production and has more than 30% of soil. It is suggested to be settled in group C (Table 2).

Table 2. The value of CN for 4 basins with usually and innovative method

Method	Basin code	T_1	T_2	T_3	T_4
Usually	CN-II	85	88	86	81
innovative	CN-II	82	79	78	80

The accuracy of the results in innovative and usually methods to determine the curve number (CN) was controlled by the help of hydrological estimate method of direct runoff. In this regard the amount of flood discharge with different return periods based on the curve number method was estimated in two cases with the estimation with usually method and of estimation of innovative and deductive methods.
Relation curve number method:

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \quad (1)$$

$$S = \frac{25400}{CN} - 254 \quad (2)$$

$$Q_{\max} = \frac{2.083AQ}{t_p} \quad (3)$$

$$t_p = \sqrt{t_c} + 0.6t_c \quad (4)$$

$$t_c = 0.0195L^{0.77}s^{-0.385} \quad (5)$$

P: 24-hour shower, S: total pert, A: basin area, Q: runoff height to cm, t_p: peak time in hours in 3 Rd relation), L: main channel length in meters, Q: maximum moment discharge (cms),s: direction slope (m / m), t_c and t_p: respectively the peak time and concentration time which is calculated from formulas 4 and 5 in minutes.
Rational method:

$$Q_{\max} = \frac{1}{360}C.I.A \quad (6)$$

In this relation: coefficient of runoff, I: the maximum rainfall intensity (mm/h) in the basin concentration time by bell equation, A: watershed area (ha). For proper application of Rational or logical relationship, a focus to the selection of relation coefficients and breeding coefficients is recommended (Singh, 1988).
Creager's equation:

$$Q_{\max} = 46CA^{(0.894A^{-0.048})} \quad (7)$$

C: Creager's coefficient, A: Basin area in square miles.
Also in order to control the results, statistics of the flood of Glinak station on Taleghan river (length: 55º 44′ latitude: 36º 10′) in the region was analyzed and then was calibrated for the basins of the area. The results of Creager's method were considered as the base discharge. Amount of flood discharge in the location of Glinak station for return periods of 2, 5,10,25,50 and 100 years is respectively 122.9, 178.4, 219.8, 277.5, 324.6, 375.3 Cubic meter per second, according to Pearson Log III distribution equivalent.
It is remarkable that if empirical relations aren't calibrated, therefore essentially flood discharge will be calculated, in this case, the relative error of issues such as fusion snow should be considered in analyzing the results.
To compare the results of three different methods with each other and the base method from total residual squares ratio (RSS) the following formula is used:

$$RSS = \left[\frac{\sum (Q_e - Q_o)^2}{n-m}\right]^{0.5}$$

Q_e: Estimated value, Q_0: observed value, n: number of data and m: number of distribution parameters which are used.

3. Results

The results of comparison of flood discharge estimation with three experimental methods including: curve number method (innovative and usually), deductive and calibrated Creager are presented as the base in Table 3. As is clear from Table 3, the results of the curve number method (the innovative one) has more acceptable answers in compare with the common method of curve number according to expertise judgment. Moreover the innovative method was launch with lower cost and time in comparison with usual method.

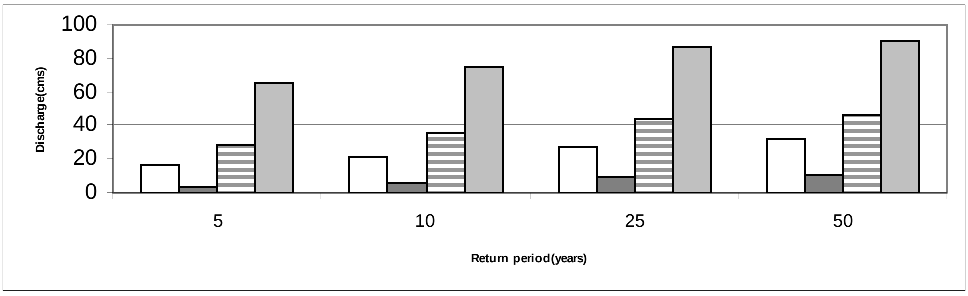
4. Conclusion

In this regard, the results of Mishra (1999) and Hussain *et al*, (1989) were similar to other researchers. They reported that the curve number of SCS table can't be appropriate to estimate the runoff due to rainfall. In this regard, Methods of observation, asymptotic line and modified method of curve number were presented by these researchers. Therefore, the initial estimate of curve number based on similar experimental methods of the present study is more logical. As it is clear from the results of Table 4, the value of RSS of the estimated discharge of the curve number by innovative and deductive methods on the base of separating of the basins and argument on the amount of the total basins is more acceptable. In the meantime the value of total of squares in ordinary method of curve number not only is higher than the two other methods, but also is beyond the acceptable allowed amount. The results of the present study can be extended to the similar regions.

Nevertheless, it is recommended to develop table 1 while controlling it in similar climates for other conditions. One of the weaknesses of innovative method in curve number is when Hardpan layer is close to the earth surface and occupies a wide surface of the region, thus the region behaves like group D. in this case, and the discharge will be estimated less than its real amount. In such cases, we should solve the problem by the help of previous experiences, knowing of the area, knowledge and understanding of the formation mechanism of hardpan and also knowing the formation of the area and or field visit.

Hawkins (1978) has presented a method for correction the curve number due to sudden changes in it with the previous moisture condition changes to sudden change in the height of runoff. The results of the researches of Nassaji and Mahdavi (2005), Hegen (2001) and McQueen (2002) also indicate that, determination of former moisture in curve number method has some errors to calculate the runoff .In this study the maximum flood discharge estimation with innovative method in different cases of antecedent moisture III, II, I, and the return periods of 5, 10, 25 and 50 shows that the estimated discharge in antecedent moisture condition I, III has considerable difference with the base discharge. (Figs. 1 to 4) therefore it is recommended to present a proper indicator for this purpose.

Finally this methodology based on practical work experience and result of the study has been shown the proposed method is appropriate for initial CN estimation in flood modeling and calibration with regard to asymptotic line method concepts.



snowy diagram: datum debit, black gray(AMCI), snowy-black gray(AMCII), snowy gray(AMCIII)

Fig. 1. Comparison of peak discharge obtained from innovative method and datum debit in sub basin of Khokavand T1 (m^3 / s)

snowy diagram: datum debit, black gray(AMCI), snowy-black gray(AMCII), snowy gray(AMCIII)

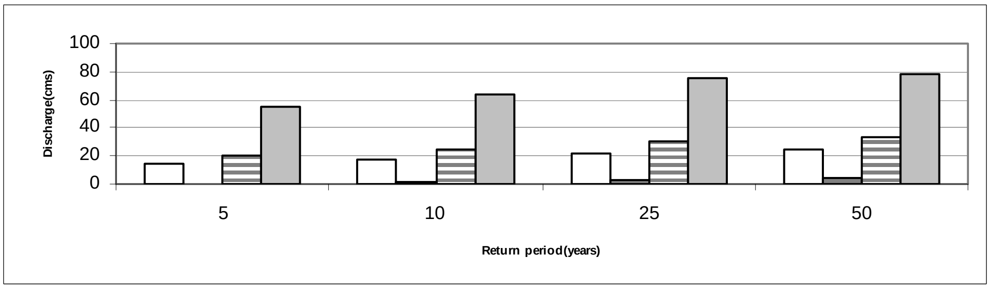
Fig. 2. Comparison of peak discharge obtained from innovative method and datum debit in sub basin of Varkesh T2 (m^3 / s)

Table 3. Comparison of peak discharge obtained from different methods in sub basin of Veshteh &Zydsht watershed (m^3 / s)

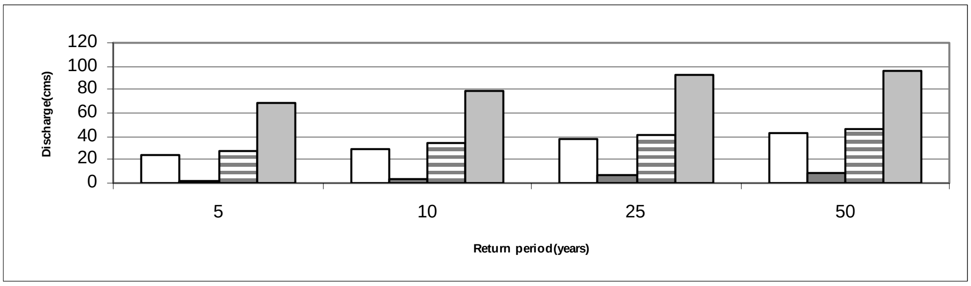
Return period& Method names	Concentration time (hour)	calibrated Creager / Creager Coefficient 5.71	4.95	4.23	3.33	2.72	1.78	(Rational method) Precipitation intensity by bell				(Curve number) Hydrologic group of soil issue of the facieses type (innovative method)				(Curve number) Hydrologic group of soil issue of the soil texture				A.M.C	Surface Area km^2
		Return period						Return period				Return period				Return period (year)					
		100	50	24	10	5	2	50	25	10	5	50	25	10	5	50	20	10	50		
T_1	1.29	36	32	27	21	17	12	30	25	20	16	47	44	36	29	58	54	45	38	A.M.C. II	18.2
T_2	2.25	48	41	35	28	23	16	37	31	24	19	44	41	33	26	82	79	67	57		26.53
T_3	1.23	29	25	22	17	14	9	26	22	17	14	34	31	25	20	60	57	48	40		12.53
T_4	2.48	49	43	37	29	24	16	37	31	24	20	46	42	34	27	49	46	37	30		27.78
T_1												11	9	6	4					A.M.C. I	
T_2												7	6	3	0.72						
T_3												4	3	2	0.55						
T_4												8	7	4	2						
T_1												91	87	75	65					A.M.C. III	
T_2												101	96	83	72						
T_3												78	75	64	55						
T_4												96	92	79	68						

Table 4. Total for the discharge of residual squares estimation

Basin code	CN(Ordinary)	CN(Innovative)	Rational
T_1	24.61	14.85	1.58
T_2	39.92	4.44	4.00
T_3	31.96	8.09	0.50
T_4	7.36	4.12	5.31
Total	103.85	31.5	11.39



snowy diagram: datum debit, black gray (AMCI), snowy-black gray (AMCII), snowy gray (AMCIII)
Fig. 3. Comparison of peak discharge obtained from innovative method and datum debit in sub basin of Barikan T3 (m^3 / s)



Snowy diagram: datum debit, black gray (AMCI), snowy-black gray (AMCII), snowy gray (AMCIII)
Fig. 4. Comparison of peak discharge obtained from innovative method and datum debit in sub basin of Deh job T4 (m^3 / s)

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