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Parameter Estimation of Rainfall-Runoff Model Using Hydrograph Section Separation

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Abstract. It is well known that parameter estimation in model simulation is an essential procedure that significantly affects simulation outputs. Nevertheless, there has not been a standardized methodology and procedure for parameter estimation. It is difficult to select and present the most optimal technique and scenarios for parameter estimation because of the uncertainties and variability in parameters. For these reasons, parameter estimation depends on a selected model, rainfall event, or a model user. For estimating the parameters of a rainfall-runoff model, the problem that is of primary concern is to find the optimal solution accurately, but it is difficult to find the solution because an objective function would not be defined clearly or estimated parameters that use only a few number of rainfall events are not reliable.

In particular, a hydrograph analysis that could reflect the characteristics of runoff as parameter estimation was proposed. For a more accurate and reliable parameter estimation, a hydrograph was divided into three sections at each inflection point: rising limb, crest, and falling limb. A proposed method in this study aims to provide a solution to a problem that has fluctuated in parameter estimation in accordance with the characteristics of rainfall events and runoff. In addition, Generalized Likelihood Uncertainty Estimators (GLUE), an uncertainty analysis method, was applied to present a range of parameters, and it was expected to contribute to the improvement of estimation accuracy and to the enhancement of the applicability of estimated parameters.

The ultimate objective of this study is to improve the parameter estimation procedure, and the proposed methodology shows finding the optimal parameter that can satisfy the objectives of both peak discharge and discharge volume at the same time in consideration of the size of runoff and the discharge moving behavior.

Keywords: parameter estimation, hydrograph section separation, GLUE, optimal parameter

1 Introduction

The objectives of this research are to examine the existing problems in parameter estimation for flood forecasting in field-works and suggest a methodology to provide a solution to those problems. In detail, this research show finding optimal parameters and aims to present a reasonable range for the parameters that are actually used for

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flood forecasting. Moreover a new method is proposed to estimate appropriate parameters, which can be applied constantly without being affected by the features of rainfall events.

Briefly, the objectives of this research are described as follows:

(1) Determine current problems in the existing parameter estimation approach for flood forecasting in field practices, and propose a parameter estimation methodology to improve them

(2) Estimate the parameters for each divided section (rising limb, crest, and falling limb) on a hydrograph to reflect the characteristics of runoff according to change in time and verify the superiority of the proposed methodology

(3) Estimate the optimal parameter by applying a global optimization method and present their reasonable range by conducting an uncertainty analysis so that model users would have a choice on parameters for practical works

In this research, time-series data for all the historical observations were used to extend the scope of applicable rainfall events for parameter estimation instead of using each single event individually. Moreover, instead of the trial-and-error method, a global optimization method that could estimate the parameter set simultaneously was used to provide the optimal parameter, and uncertainty analysis was conducted to present the range for the optimal parameter set. In addition, a hydrograph is examined by dividing it into three sections according to two inflection point on a hydrograph. It is expected that this proposed methodology can improve reliability in parameter estimation for a rainfall-runoff model regardless of a period of rainfall event and the number of events. Moreover, it is expected that accuracy in parameter estimation is improved because each divided section at inflection points can reflect the response patterns of runoff. In this research, a new approach for the estimation of parameters for each section by dividing a hydrograph into three parts is proposed, and it can be applied to flood forecasting for practical works. A conceptual diagram of the research is shown in Figure 1.1.

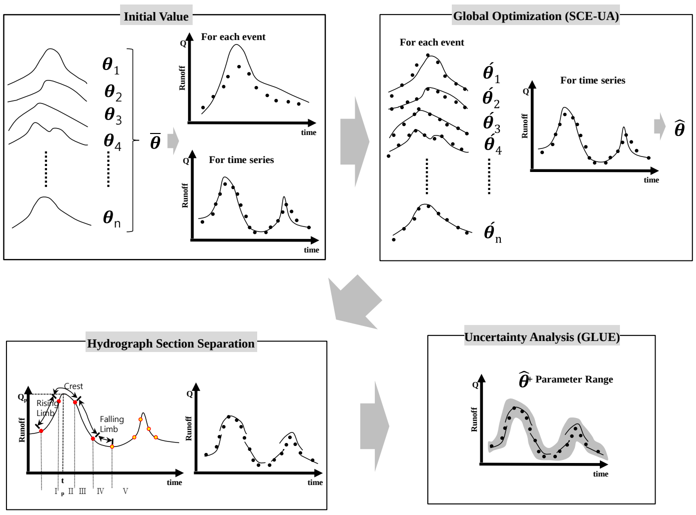
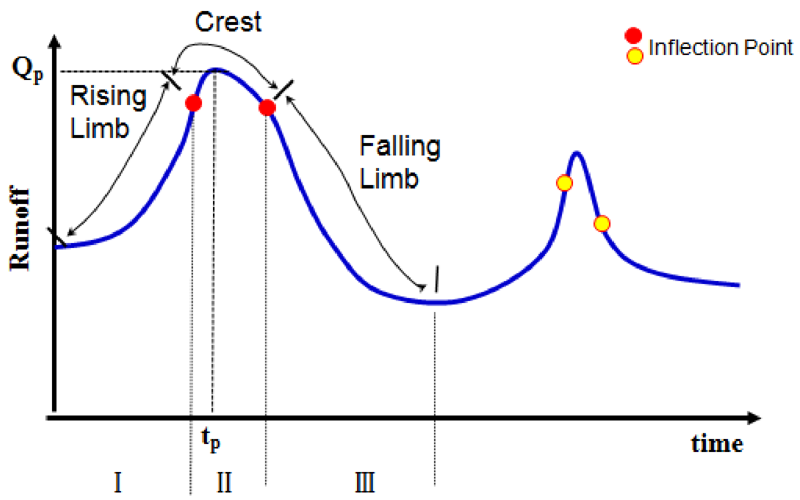


Fig.1.1 Conceptual diagram of the research

2 Hydrograph Section Separation (HSS)

Unlike the existing hydrograph separation methods, HSS, a methodology that, vertically divides a hydrograph into three sections, such as rising limb, crest, and falling limb, was newly proposed and applied in this. The key purpose of this method is reflect runoff characteristics for each section as estimating parameters. Thus, the HSS method is distinct from the conventional hydrograph separation that separates direct runoff and base flow in the longitudinal direction.

To apply the proposed method, primarily, an inflection point in which the direction of a curve changes on a hydrograph should be found (refer to Figure 2.1). Mathematically the definition of inflection point is a point in which the value of its derivative is zero (0) and the sign of the derivative value before and after the point changes (refer to Eq. 2.1).



$$\frac{\partial^2 Q}{\partial t^2} < 0 \rightarrow \frac{\partial^2 Q}{\partial t^2} > 0 \quad \text{or} \quad \frac{\partial^2 Q}{\partial t^2} > 0 \rightarrow \frac{\partial^2 Q}{\partial t^2} < 0, \quad \text{and} \quad \frac{\partial^2 Q}{\partial t^2} = 0 \quad (\text{Eq. } 2.1)$$

Figure 2.1 Conceptual diagram of hydrograph section separation

3 Parameter Estimation Results Using HSS

To attenuate the increase in 30-min-interval flow data, 2-hr moving average was conducted, and the second-order differential value for each data was computed. Calculated values were illustrated, and the location of the first inflection point that appears on the left and right based on the peak flow occurrence was detected. Then, a hydrograph was divided into a rising limb, crest, and falling limb according to the inflection point for parameter estimation in each section.

The results of applying SCE-UA with time-series data is compared to those applying HSS with time-series data as summarized in Table 3.1. By applying the HSS method, the value of NSE was improved, showing 0.799, 0,765 and 0.788 for each section. It means that reliability is also improved. One event from each calibration and verification period, respectively, was selected to determine the efficiency of HSS for each rainfall event. Figure 3.1 and Table 3.2 show the analysis results of parameter estimation by applying SCE-UA and HSS, respectively, to an event that occurs in July 2009. The NSE computed through HSS is 0.765, and the value is significantly improved from the NSE (-2.785) that did not apply HSS.

Table 3.1 Efficiency of the hydrograph section separation

		K	P	Tl	F1	R_{sa}	NSE	RMSE	R_p	R_v
SCE-UA (for time-series)		23.70	0.75	4.60	0.35	167	0.725	47.790	-	-
SCE-UA (for time-series + HSS)	Rising Limb	24.900	0.550	4.500	0.500	124.00	0.799	15.941	-	0.088
	Crest	24.900	0.750	2.700	0.650	38.000	0.765	37.010	0.415	-
	Falling Limb	24.400	0.950	9.200	0.850	82.000	0.788	14.478	-	0.348

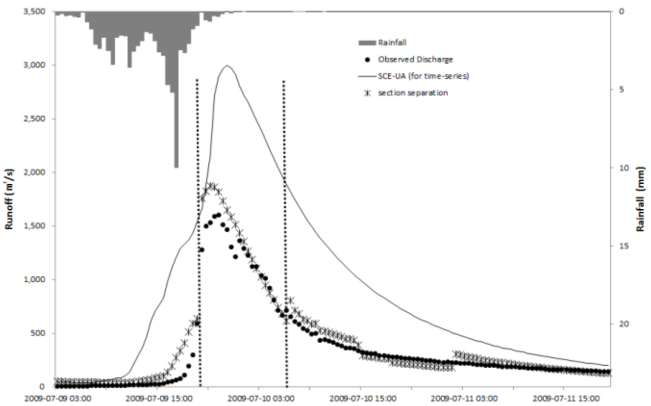


Fig. 3.1 Parameter estimation by SCE-UA for time-series and HSS

Table 3.2 Efficiency of HSS (2009/07/09 03:00-07/11 20:00)

	NSE	RMSE	REp	REv
SCE-UA(for time-series)	-2.785	596.58	1.547	3.307
SCE-UA(for time-series + HSS)	0.765	43.231	1.212	1.536

However, a discretion occurred at the inflection point by synthesizing three separated sections into a hydrograph, so the time series of a hydrograph could not be illustrated smoothly. Despite this, the concern in the occurrence of a discretion was not a serious problem in estimating parameters, and instead, the efficiency of simulation was improved considerably.

In addition, in case of applying HSS to the event in July 2011 out of a verification, the NSE computed through HSS is 0.926, and the value is slightly improved from the NSE (0.879) that did not apply HSS (see Figure 6.22 and Table 6.7). In particular, the NSE value of the objective function in this research was largely increased.

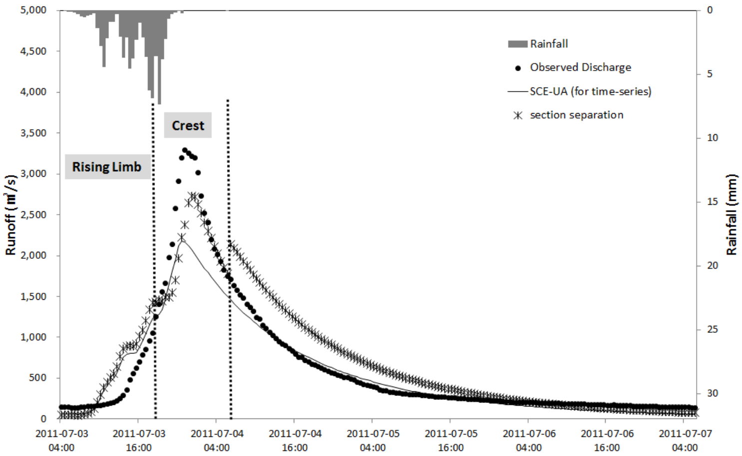


Fig. 3.2 Parameter verification by SCE-UA for time-series and HSS

Table 3.3 Efficiency of HSS (2011/07/03 04:00-07/07 05:30)

	NSE	RMSE	REp	REv
SCE-UA(for time-series)	0.879	258.96	0.340	0.109
SCE-UA(for time-series + HSS)	0.926	81.983	0.171	0.153

4 Conclusions

Despite the parameters estimated by applying SCE-UA based on a time series data were obtained, there were some cases in which the hydrograph generated based on these estimated parameters could not reproduce time-series patterns of observed data. It was determined that this might be because estimated parameters could not sufficiently reflect runoff properties of hydrograph. In this regard, HSS was newly proposed in this research. In short, HSS is a new approach in parameter estimation that separates a hydrograph into three sections that represent different runoff characteristics. To conduct HSS, first, the moving average method was applied to find the overlapping range between each first inflection point appearing at the left and right sides on the basis of occurrence time of peak flow. Then, finally the inflection point to separate each section on a hydrograph was obtained. The applicability of HSS was identified by reviewing various aspects such as the size of peak flow, rainfall duration, and patterns of time series. It is expected that this review and consideration of the various aspects available can somewhat contribute to overcome the limitation of this research, which shows a definitive result obtained from a single basin.

As the value of NSE that indicates the simulation efficiency was different between the rising limb and the falling limb of a hydrograph, a hydrograph was divided into three section: - rising limb, crest and falling limb - according to the inflection point on a hydrograph. Although a concern in which the number of the required parameter should be tripled by applying HSS, it hardly affected the total running time of storage function simulation. Moreover, by applying the HSS method, the NSE showed much improved values, with 0.799, 0,765 and 0.788 for each section. It verifies that reliability was improved as well.

