Derivation of Design Flood by Transformation Method(II)

— On the non-annual exceedance series —

변환법에 의한 설계홍수량의 유도(II)

— 비년초과치계열을 중심으로 —

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적 요

첨두유량이 연속적으로 발생하므로 인하여 수리구조물의 파괴에 영향을 끼치는 설계홍수량의 추정을 위해 본 연구에서는 제I보에 이어 2차적으로 부분기간계열인 금강, 영산강 및 섬진강 수계 6개 유역의 비년초과치를 중심으로 하여 변환법인 SMEMAX법, 멱변환(Power Transformation) 및 2단계 멱변환(Two Step Power Transformation, TSPT)법에 의해 빈도분포의 정규화를 시도하고 이들에 의한 정규화 효율성의 비교분석과 설계홍수량 유도를 위한 변환법별 적합도검정을 수행하였다. 왜곡분포의 정규화 시도는 제I보의 결과와 마찬가지로 SMEMAX 및 Power변환법에서는 빈도분포의 정규화가 미흡하였으나 2단계 멱변환법에서는 빈도분포의 만족한 정규화를 기할수 있었다. 또한 3개 변환법에 의해 유도된 설계홍수량의 비교 분석에서는 3개 방법 모두 재현기간 20년 이내의 설계홍수량이 거의 유사한 결과를 나타내었으며 Kolmogorov-Smirnov Test에 의한 3개 변환법별 적합도검정 결과 2단계 멱변환법이 적정 변환법으로 인정되었다.

I. Introduction

A major problem in the design of various engineering works such as spillways, bridges, levees and diversion devices is the selection of design flow that must be accommodated by the works during its life. Since the surface runoff flows vary greatly with time, it is usually uneconomical to build these works with large enough capacity to be able to

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carry all possible flows. Instead, selecting a smaller capacity implies that there is some risk of a flow larger than the design flow that can cause a functional failure of the structure and could result in damages and loss of life. Each of above mentioned structures should be designed for flood peaks corresponding to the return periods to be required. Especially, hydraulic structures including bridges and levees for agricultural water use which have a great influence on the risk of failure by successive flood peaks are in need of partial duration series. It is to be desired that either the annual exceedance series or the non-annual exceedance series can be selected for above mentioned structures when the observed data have long term or short term respectively. Extreme events including annual or non-annual exceedance series can rarely be normally, but is usually distributed asymmetrically. Data arising from various situations form their own distribution. Thus, it is very difficult to select a reliable method of flood frequency analysis. Instead of fitting a known distribution to the data, it is better to find the best fitting distribution for the given data. A promising technique suggested in recent is to transform the observed data into the normally distributed data by using a suitable transformation function. Bethalamy[1] has suggested SMEMAX transformation to normalize the skewed data. This transformation method uses the smallest, median and the largest value of the given data series, and makes the difference between the largest value and the median value equal to that between the median value and the smallest value. But, the SMEMAX transformed series can still have appreciable skewness and kurtosis even though median value is equidistant from the smallest and the largest value. Chander et al[3] have suggested the use of power transformation to normalize the skewed data. It can be seen that the skewness of the power transformed series is reduced to zero or nearly zero, but the value of kurtosis is not three or nearly three. Thus, the resulting series is not truly normalized using power transformation. Because, transformed series is required so that the given data series can be truly normalized by making the coefficient of skewness zero and the coefficient of kurtosis three. Gupta et al[5] have suggested a further transformation procedure of power transformation which is called as two step power transformation. The correction of kurtosis for making the value of three can be achieved through another transformation keeping the coefficient of skewness to be equalled nearly zero in this two step approach.

Consequently, the purpose of this analysis is to estimate rational design flood by the normalization of observed data series through different transformation methods with the non-annual exceedance series from the applied watersheds.

II. Transformation Method

Theoritical description for the transformation methods including SMEMAX, power and two step power transformations is not presented in this paper. Those are already mentioned in author's paper under the title of " Derivation of Design Flood by Transforma tion Method(I)[16]" presented in Journal of the Korean Society of Agricultural Engineers (Vol. 36, No. 4).

III. Data used for application

The data used are the non-annual exceedance series from six selected watersheds. The non-annual exceedance series are used to get the design flood for the hydraulic structures which can be affected by successive flood peaks in this study. \ non-annual exceedance series belongs to the partial-duration series is obtained by taking all flood peaks equal to or greater than a predefined base flood suggested by Water Resources Council[19] in the United States. A major problem encountered when using a non-annual exceedance series is to define flood events to ensure that all events are independent. Since a partial-duration series consists of all events above a specified magnitude, it is necessary to define seperate events. Water Resources Council in United States presented the result that seperate events were arbitrarily defined as events seperated by at least as many days as five plus the natural logarithm of the square miles of drainage area, with the requirement that intermediate flows must drop below 75 percent of the lower of the two seperate maximum daily flows. Physical characteristics of the applied watersheds are shown in Table-1.

Table-1. Gauging stations and watershed physical characteristics

River	Station	Area (Km^2)	Length of main stream (Km)	Average basin width (Km)	Shape factor	Remarks		
						Observed duration (yrs)	Number of data for non-annual exceedance series	Location
Geum	Yongdam	989.5	12.0	82.46	6.87	29	40	Long. 127° 37′ Lati. 35° 58′
	Sootong	1599.3	46.38	34.48	0.74	29	42	Long. 127° 36′ Lati. 36° 03′
Yeong San	Nampyeong	576.2	41.1	14.02	0.34	31	38	Long. 126° 51′ Lati. 35° 03′
	Mareug	683.96	56.0	12.23	0.22	37	41	Long. 126° 50′ Lati. 35° 09′
Seom Jin	Abong	2447.5	162.3	15.08	0.09	35	44	Long. 127° 22′ Lati. 35° 11′
	Songjeong	4255.7	185.7	22.92	0.12	31	40	Long. 127° 34′ Lati. 35° 11′

IV. Results and Discussion

1. Basic statistics

Basic statistics of observed non-annual exceedance series for the applied watersheds are shown in Table-2. Those were within the range of 102.5 to 867.9, 1.540 to 2.468, and 4.401 to 9.154 for standard deviation, coeffi cient of skewness and kurtosis respectively.

Table-2. Basic statistics

River	Station	Mean ($\bar{X}$)	Standard deviation (S)	Coefficient of skewness (C_S)	Kurtosis (C_K)
Geum	Yongdam	630.4	390.1	1.757	5.182
	Sootong	800.5	552.1	1.540	4.401
Yeong San	Nampyeong	337.9	102.5	1.869	6.628
	Mareug	347.8	152.2	2.468	9.154
Seom Jin	Abnog	1608.3	871.3	2.254	8.971
	Songjeong	2900.9	867.9	1.567	6.353

2. Comparison of efficiency for transformations

The non-annual exceedance data from 6 watersheds were used to check the relative efficiency of SMEMAX, power and two step power transformations in transforming the original data into a normally distributed series. The efficiency for transformation is given in Table-3. Since normal distribution has coefficient of skewness and kurtosis equal to zero and to 3 respectively, the efficiency of transformation can be judged by checking whether the coefficient of skewness and kurtosis tend to zero and to 3 in the transformed series respectively. It can be seen that SMEMAX reduces the coefficient of skewness and kurtosis in comparison with those of original data. However, this transformed series still cannot be considered as a normally distributed one. The coefficient of skewness in the power transformation could be reduced to zero which is somewhat satisfactory degree, but the kurtosis are larger or smaller than those from SMEMAX transformation. Thus, the power transformation also cannot truly normalize the observed data. In the two step power transformation, both the coefficient of skewness and kurtosis of the data from all watersheds were appeared to nearly zero and three respectively.

Table-3. Effect of different transformations on coefficient of skewness and kutosis

River	Station	Observed duration (yrs)	Original data		SMEMAX transformed data		Power transformed data			TSPT transformed data			
			Skewness	Kurtosis	Skewness	Kurtosis	Lambda (λ)	Skewness	Kurtosis	Lambda (λ)	Gamma (γ)	Skewness	Kurtosis
Geum	Yongdam	29	1.757	5.182	0.3732	3.1948	-0.493	0.000372	2.8557	0.5906	0.185	-0.000162	3.00025
	Sootong	20	1.540	4.401	0.3796	3.1139	-0.043	0.000329	3.5759	0.7376	0.079	-0.000121	3.0002
Yeong San	Nampyeong	31	1.869	6.628	0.2249	4.2768	-0.874	0.000005	3.7830	0.8109	0.269	-0.000151	3.0049
	Mareug	37	2.468	9.154	0.330	4.0704	-0.890	-0.000574	3.5969	0.7730	0.077	-0.000061	3.0095
Seom Jin	Abnog	35	2.254	8.971	0.1775	3.7795	-0.418	-0.000436	3.1499	0.5302	0.248	-0.000055	2.9986
	Songjeong	31	1.567	6.353	-0.1321	2.3876	-0.598	-0.000789	2.4107	0.473	0.424	-0.000201	3.0033

In the two step power transformation, the value of coefficient of transformation, λ calculated by power transformation was used as an initial trial value and thereafter it was subsequently modified along with the determination of coefficient of transformation, γ iteratively. Consequently, it can be seen that two step power transformation can transform a non-annual exceedance series into a normally distributed series effectively.

3. Comparison of design floods estimated by different transformations

Design floods of different return periods were estimated by SMEMAX, power and two step power transformations as shown in Table-4. The estimated design floods less than twenty years of return period are nearly same in all transformation methods. In order to assess the relative suitabilities of the different transformations, these results are plotted on a normal probability paper as shown in Fig. 1 to Fig. 6. The plotting position is based on the Weibull method which calculates the probability of nonexceedance. The Kolmogorov-Smirnov test was used to estimate the goodness of fit for the transformation methods including SMEMAX, power and two step power transformations. The K-S statistic, D_n for transformations used in this study are all passed in the 5 percent significance level as shown in Table-4. Among these, most of the values of Dn calculated by using two step power transformation are less than those of SMEMAX and power transformation. This is saying that design floods of different return periods using two step power

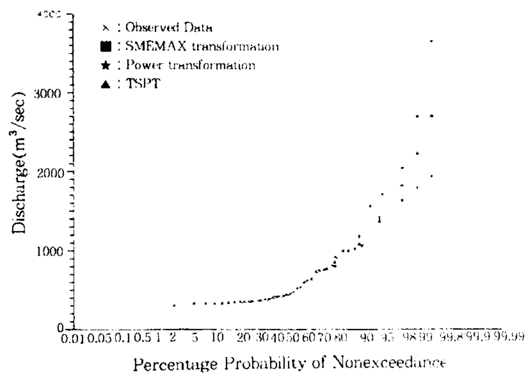

Fig. 1. Comparison of design floods at Yongdam watershed of the Geum river, Korea

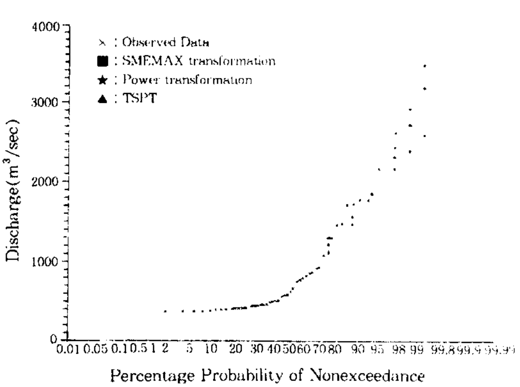

Fig. 2. Comparison of design floods at Sootong watershed of the Geum river, Korea

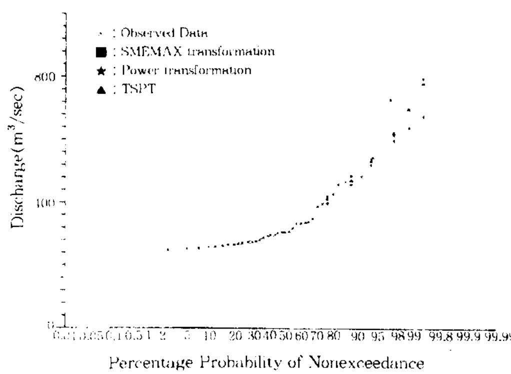

Fig. 3. Comparison of design floods at Nampyeong watershed of the Yeong San river, Korea

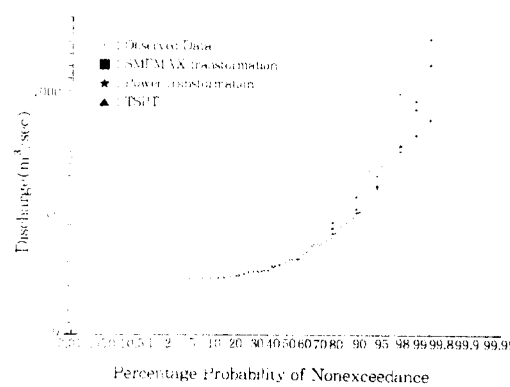

Fig. 4. Comparison of design floods at Mareug watershed of the Yeong San river, Korea

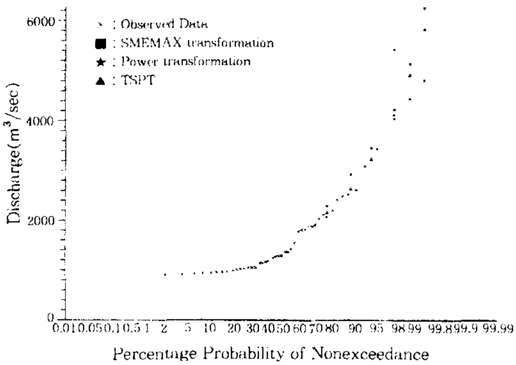

Fig. 5. Comparison of design floods at Abnog watershed of the Seom Jin river, Korea

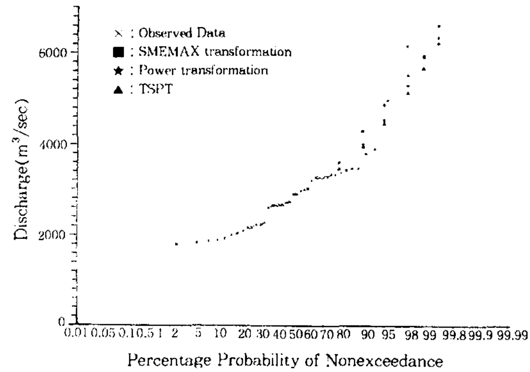

Fig. 6. Comparison of design floods at Songjeong watershed of the Seom Jin river, Korea

transformation are nearer to those using Weibull method of the observed data than the ones calculated using the other transformations.

Table-4. Results of frequency analysis of normally transformed series using SMEMAX, power and two step power transformations and goodness of fit by K-S test

River	Station	Method	Return period(yrs)						Kolmogorov-Smirnov test	
			5	10	20	50	100	100	D_n*	$D_n^{0.05}$**
Geum	Yongdam	SMEMAX	927	1181	1391	1627	1785	1931	0.05	0.21
		Power	810	1081	1421	2037	2699	3650	0.05	
		TSPT	867	1098	1375	1823	2230	2712	0.04	
	Sootong	SMEMAX	1218	1567	1855	2180	2396	2597	0.05	0.21
		Power	1111	1474	1866	2442	2926	3466	0.06	
		TSPT	1312	1575	1875	2335	2737	3199	0.05	
Yeong San	Nampyeong	SMEMAX	420	485	539	599	640	677	0.03	0.22
		Power	398	458	521	616	699	797	0.05	
		TSPT	414	472	535	626	702	784	0.03	
	Mareug	SMEMAX	461	568	657	756	823	884	0.07	0.21
		Power	416	503	605	780	960	1215	0.04	
		TSPT	442	521	619	780	930	1111	0.04	
Seom Jin	Abnog	SMEMAX	2272	2906	3430	4020	4413	4779	0.06	0.21
		Power	2056	2602	3221	4200	5104	6215	0.03	
		TSPT	2143	2638	3212	4106	4893	5800	0.02	
	Songjeong	SMEMAX	3605	4303	4879	5527	5960	6362	0.11	0.21
		Power	3477	4004	4543	5302	5928	6624	0.08	
		TSPT	3484	3973	4471	5152	5688	6252	0.07	

*D_n represents the maximum deviation defined by $D_n = \text{Max} \mid P_x(X) - S_n(X) \mid$

where $P_n(X)$: Theoritical cumulative distribution function under the null hypothesis

$S_n(X)$: Sample cumulative density function based on n observations

** 5 percent significance level of K-S test for the goodness of fit

V. Conclusions

This study was carried out to select the optimal transformation method to transform the asymmetrically distributed data into normally distributed one. Transformation method can be used for the estimation of the reliable design floods by frequency analysis. Three different methods including SMEMAX, Power and Two step power transformation were evaluated by comparing the transformation efficiency and K-S test statistics. Non-annual exeedance series from six watershed were used for this study. The results were analyzed and summarized as follows.

1. The two step power transformation is more efficient than SMEMAX and power transformations in normalizing the skewed distribution of non-annual exceedance series.

2. It can be seen that the estimated design floods less than twenty years of return period are nearly same in all transformation methods.

3. Assessing the relative suitabilities of the three transformation methods by Kolmogorov-Smirnov test for the goodness of fit, it is shown that the computed values based on two step power transformation are nearer to those of the observed data as compared to other methods.

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