FLASH FLOOD GUIDANCE OF A TYPOON "RUSA"

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Abstract: The severe flood disaster by a typoon Rusa was occurred in the last year in Korea. The Rusa brought the rainfall of 870.5mm per a day in the city of Kangnung, Kangwon-do, Korea and this rainfall amount is 62% of the annual mean rainfall in this area. Our focus is to investigate the flash flood guidance and the sediment yield for the basins of small streams of Yangyang town in Kangnung area. Say, the flash flood guidance and the sediment yield by the Rusa are estimated and compared with the given informations obtained from the past flood events. As the results, the flash flood guidance and sediment yield in the study area showed much bigger values than the given informations and so we could know that the Rusa influenced the severe flood of the study area.

Keywords: Typoon Rusa, Flash Flood Guidance, Threshold Runoff, Uncertainty, Sediment Yield

1. INTRODUCTION

Since the latter half of the 1990s the flash flood has became one of the frequently occurred natural disasters in Korea. The government has prepared against the flood disaster with the structural and nonstructural measures such as dams, levees, and flood forecasting and warning systems. However, since the flood forecasting and warning system requires the rainfall observations as the input data of a rainfall-runoff model it is not a realistic system for the flash flood which is occurred in the small basins with the short travel time of flood flow. Therefore, the flash flood warning system should be constructed for providing the realistic alternative plan for the flash flood. To do so, we may need more works and reliable data on the flash flood in Korea.

The typoon Rusa passed through the Korean peninsula from the west-southern part to the east-northern part in the summer season of 2002. The flash flood due to the Rusa was occurred over the Korean peninsula and especially the damage was concentrated in Kangnung, Yangyang, Kosung, and Jeongsun areas of Kangwon-Do. The maximum daily rainfall was recorded as 870.5mm and this is 62% of the annual mean rainfall of Kangnung area. The maximum hourly rainfall was 100.5mm. The damages occurred in the areas of Kangnung, Yangyang, Kosung, and Jeongsun twons in Kangwon-Do occupied the 46% in currency, 58% in casualties, and 82% in flood sufferers comparing with overall damages of Korea by the Rusa.

In recent an understandable work for the flash flood was performed by Carpenter et al.(1999). They analyzed the methodologies for the estimation of threshold runoff which is needed for the computation of flash flood guidance(FFG). In Korea Bae et al.(2001) estimated the threshold runoff for each stage station in Pyungchang river watershed and mentioned that the algorithm which can estimate the threshold runoff for more detailed watershed is needed for the flash flood warning system. One of the objective of this study is also to investigate the FFG in Yangyang area around Kangnung. Say, three small streams of Namdae cheon, Powol cheon, and Haesong cheon in Yangyang area are studied for the estimation of FFG. The other objective is to investigate the sediment yield in those streams.

2. FLASH FLOOD GUIDANCE AND SEDIMENT YIELD

2.1 Threshold Runoff

Threshold runoff may be defined as the amount of excess rainfall accumulated during a given time period over a basin that is just enough to cause flooding at the outlet of the draining stream(Carpenter et al., 1999) or the excess rainfall corresponding to over bank flow accumulated during a given time period. Referencing the work of Carpenter et al.(1999), the bankfull flow, Q_p can be represented as the following equation:

$$Q_p = q_{pr}\, R\, A \tag{1}$$

where, the q_{pr} is the peak flow per unit area for a unit graph, R is the excess rainfall which corresponds to the threshold runoff, and A is the watershed area. Therefore the threshold runoff, R, can be obtained from the equation (1) as follows:

$$R = \frac{Q_P}{q_{PR} \cdot A} \tag{2}$$

$$Q_p = \frac{S_c^{0.5}\, B_b}{n}\left[\frac{y_b}{m+1}\right]^{5/3} \tag{3}$$

where, y_b is a depth, B_b is width, m is (coefficient of shape, and Q_p is estimated by the equation (3) from Manning's equation which uses the sectional characteristics of a stream. Since the small streams are mostly in the un-gaged watershed the peak flow, q_{pr} of a unit graph is computed by using the synthetic unit graph such as the Snyder method or the GIUH. However, this study uses the HEC-HMS for the computation of the peak flow.

2.2 Flash Flood Guidance

The FFG is the rainfall corresponding to the threshold runoff in the relationship of the rainfall and runoff curve. If there is no impervious area we can represent the relationship between the R and FFG as follows:

$$R = f(p) = f(\mathrm{FFG}) \tag{4}$$

where, R is the threshold runoff (mm), FFG is the flash flood guidance (mm), and $f(\ )$ is the rainfall-runoff process.

2.3 Sediment Yield

This study uses the RUSLE (Rivsed Universal

Soil Loss Equation) for the estimation of the sediment yield. The RUSLE is the improved version of the USLE with the addition of many field data. However the RUSLE requires the detailed field data for the estimations of the coverage of soil(C) and the soil conservation plan(P) and so there is a difficulty in the application in Korea. Therefore we use the USLE suggested by the National Institute of Disaster Prevention of Korea(1998) for the estimations of C and P, and the other factors are estimated by the RUSLE presented as follows:

$$Y = Ra\ K \cdot L \cdot S \cdot C \cdot P \cdot A \quad (5)$$

where, Y is the average annual soil loss predicted by the RUSLE, Ra the rainfall erosion index, K the Soil erodibility, L the slope length factor, S the slope steepness factor, C the cover-management factor, and P the support practice factor.

3. FLOOD ANALYSIS FOR THE RUSA

3.1 Study Area

Study area is located at the middle of Kangwon-Do, Korea and this area had a severe damage by the Rusa. The streams in the area are investigated for the rainfall, runoff, and sediment yield through the analysis. The streams are Namdaecheon, Powolcheon, and Haesongcheon in Yangyang, Kangwon-Do and the watershed area is shown in Fig. 1.

We examined the rain gages around the study area and collected the needed data through the report of the channel improvement plan. The previous study used the rainfall data of the raingages in the table 1 for the estimation of the

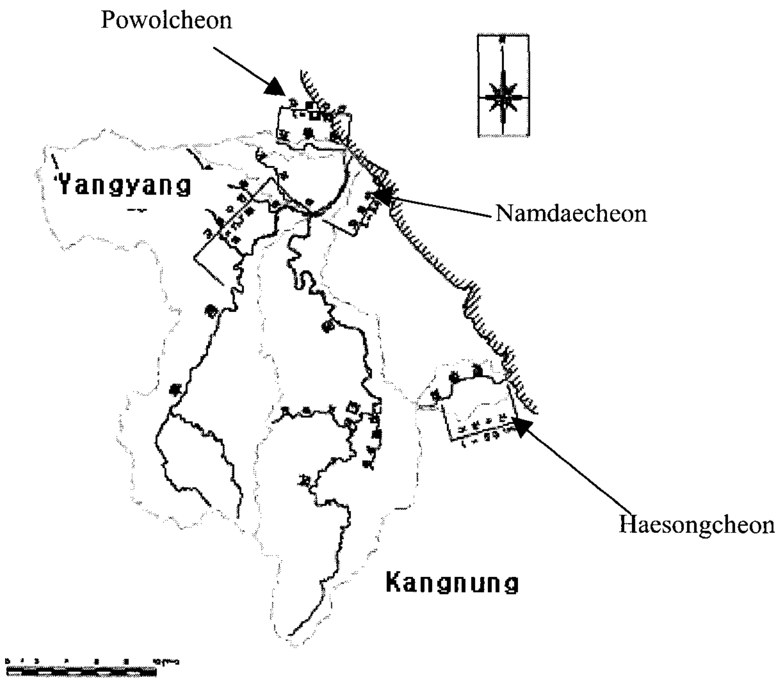


Fig. 1 Study area

flood discharge (Yangyang, 2002). However, the rainfall data of the sites in table 1 for the period of August 30, 1:00 to September 1, 24:00 which the Rusa was occurred could not be obtained and thus the data in table 2 is used for the calculation of the average basin rainfall

3.2 Rainfall Analysis

(1) Maxmum Rainfall in Duration

The data used in this section was obtained from the Korea Institute of Construction Technology (KICT, 2002). The heavy storm of 40mm per hour by the Rusa was continued for 6

Table 1. Raingage station (Yangyang, 2002)

Site	Location		Elevation (EL.m)	Starting Date
	East long.	North long.		
Hangye ryoung	128° 24'20"	38°05'40"	917.0	1983.8
Galcheon	128°30'30"	37°54'15"	450.0	1983.7
Sokcho	128°34'00"	38°15'00"	17.6	1968.1.1
Kangnung	128°54'00"	37°45'00"	26.0	1911.10

Table 2. Raingage station(KICT, 2002)

Site	Period of record
Hyennam-myoun	8/30 01:00 ~ 09/01 00:00
Hyenbuk-myoun	8/30 01:00 ~ 09/02 00:00
Sonyang-myoun	8/30 01:00 ~ 09/02 00:00
Seo-mypun	8/30 01:00 ~ 09/01 00:00
Sokcho	8/30 01:00 ~ 09/02 00:00
Kangrung	8/30 01:00 ~ 09/02 00:00

Table 3. The maximum rainfalls in duration during the typoon Rusa

Duration (Hour)	Hyounnam-myoun Yangyang-gun		Hyounbuk-myoun Yangyang-gun		Sonyang-myoun Yangyang-gun		Seo-myoun Yangyang-gun		Yangyang-up Yangyang-gun	
	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)
1	51	51	44	44	48.6	48.6	84	84	85	85
2	99	49.5	83	41.5	83.7	41.9	168	84	170	85
3	135	45	110	36.7	123.6	41.2	216	72	243	81
6	220	36.7	183	30.5	220.5	36.8	368	61.3	403	37.2
12	322	26.8	280	23.3	361.9	30.2	475	39.6	560	46.7
24	485	20.2	432	18	505.1	21	582	24.3	664	27.7
48	497	10.4	451	9.4	522.9	10.9	590	12.3	679	14.1
Duration (Hour)	Ganghyoun-myoun Yangyang-gun		Sokcho		Jukwang-myoun Goseong-gun		Ganseong-up Goseng-gun			
	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)	max. rainfall (mm)	Intensity (mm/hr)
1	133.5	133.5	53	53	42	42	56	56	53	53
2	239.5	119.8	88	44	63	31.5	108	54	90	45
3	339.5	113.2	121	40.3	79	26.3	162	54	128	42.7
6	533.5	88.9	220.5	36.8	107	17.8	286	47.7	174	29
12	689.5	57.5	321.5	26.8	148	12.3	386	32.2	199	16.6
24	851.5	35.5	407	17	-	-	472	19.7	256	10.7
48	866.5	18.1	421	8.8	-	-	496	10.3	-	-

hours in the areas of Yangyang, Sokcho, and Koseong, Kangwon-Do. The flood damages in those areas were occurred by the heavy storm between 400 and 850 mm during 24 hours. There were no big differences in between the amounts of rainfalls for the durations of 24 and 48 hours and this means that the storm was the event having the duration of 24 hours. Table 3 shows the maximum rainfalls in duration. Table 4 shows the orders of the recorded maximum rainfall amounts at the Sokcho station controlled by the Korea Meteorological Administration (KMA) for each duration of 10 min, 1 hour, and 1 day. As we can see in the table 4, all rainfalls by the Rusa for the three durations are included within the third order. Especially the rainfall for the 1-hour duration is recorded as a biggest one. The rainfalls of Sokcho station were recorded as rather small amount than other areas in Kangwon-Do and so we may guess how much the Rusa influenced the heavy storm in the area.

(2) The Rainfall Frequency

Many studies estimated the rainfall frequency occurred by the Rusa for each duration shown in the table 5 and many cases showed that the frequencies represent over 500 years. Especially, the storm for 6-hour duration represented over 500 years in the return period in almost all the areas(Table 5).

3.3 Peak Flood Estimation by HEC-HMS with Uncertainty

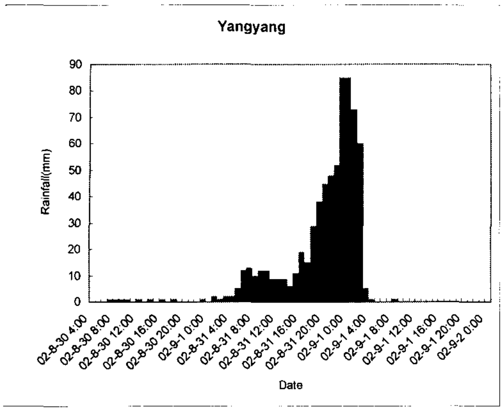
This study uses the HEC-HMS for the estimation of the peak flow and the fig. 2 shows the hyetographs for each raingage station. The ta-

Table 4. The recorded maximum rainfalls at Sokcho Station(KMA)

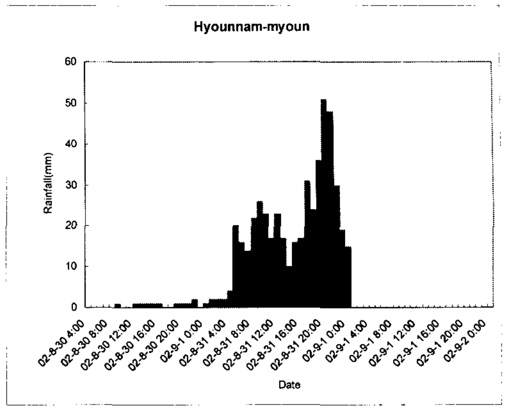
Duration	1st		2nd		3rd	
	rainfall(mm)	Date	rainfall(mm)	Date	rainfall(mm)	Date
10 min	24.5	86.08.21	18.5	02.09.01	16.2	78.07.08
1hour	59	02.09.01	56.8	86.08.21	50.5	84.09.02
1day	314.2	84.09.02	303.3	84.09.01	295.5	02.08.31

Table 5. The estimated frequencies for the rainfall in each station and duration

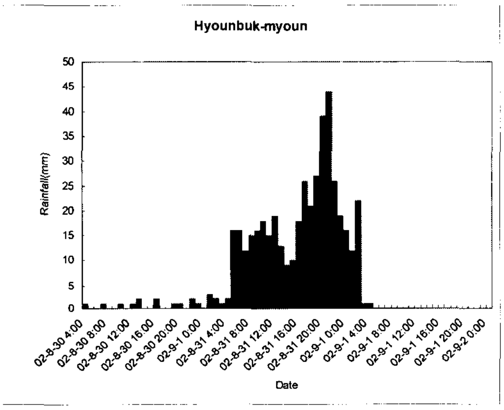
Site	Duration 1hour		Duration 2hour		Duration 3hour		Duration 6hour		Duration 12hour		Duration 24hour	
	Rainfall (mm)	frequency (years)	Rainfall (mm)	freuency (years)	Rainfall (mm)	frequency (years)	Rainfall (mm)	frequency (years)	Rainfall (mm)	frequency (years)	Rainfall (mm)	frequency (years)
Sokcho	53	30	88	50~	121	100	220.5	500~	321.5	500~	407	150
Yangyang -up	85	500~	170	500~	243	500~	403	500~	560	500~	664	500~
Seo -myoun	84	500~	168	500~	216	500~	368	500~	475	500~	582	500~
Sonyang -myoun	48.6	20	83.7	37	123.6	100	220.5	500~	361.9	500~	505.1	500~
Hyounbuk -myoun	44	10	83	37	110	50	183	150	280	240	432	220
Hyounnam -myoun	51	30	99	150	135	230	220	500~	322	500~	495	500~
Ganghyoun -myoun	133.5	500~	239.5	500~	339.5	500~	533.5	500~	689.5	500~	851.5	500~
Ganseong -up	56	50년	108	250	162	500~	286	500~	386	500~	472	500



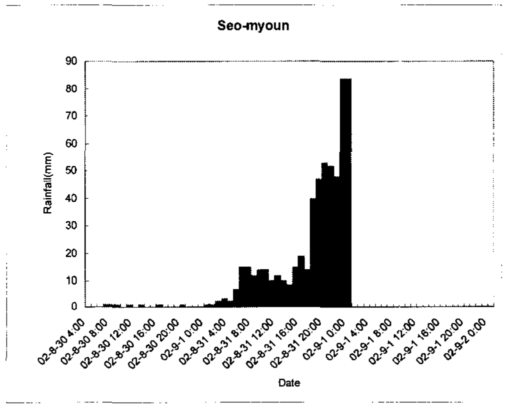
(a) Yangyang



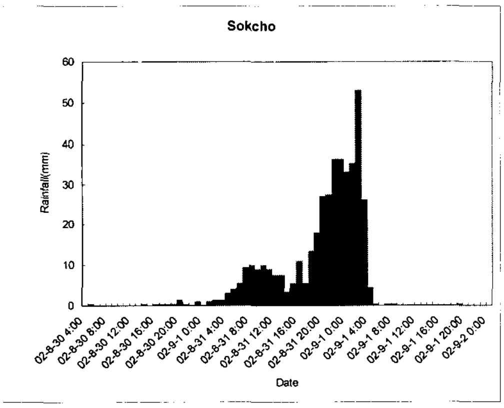
(b) Hyunnam-myeon



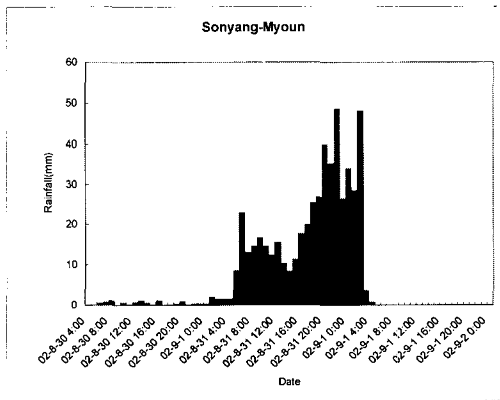
(c) Hyunbuk-myeon



(d) Seo-myeon



(e) Sokcho



(f) Sonyang-myeon

Fig 2. Hyetograph for each raingage station

Table 6. The input parameters of HEC-HMS

Basin	Area (km^2)	Loss Rate Parameter	Clark's Parameter		Baseflow Parameter		
		SCS Curve Number	Time of Concentration (hr)	Storage Coefficient (hr)	Initial Q (cms/km^2)	Recession Constant	Threshhold Q (ratio-to-peak)
Yangyang Namdaecheon	474.3	76.3	5.50	5.50	0.12	0.034934	0.1
Powolcheon	6	73.3	2.26	2.26	0.12	0.034934	0.1
Haesongcheon	15.5	64.7	1.33	1.33	0.12	0.034934	0.1

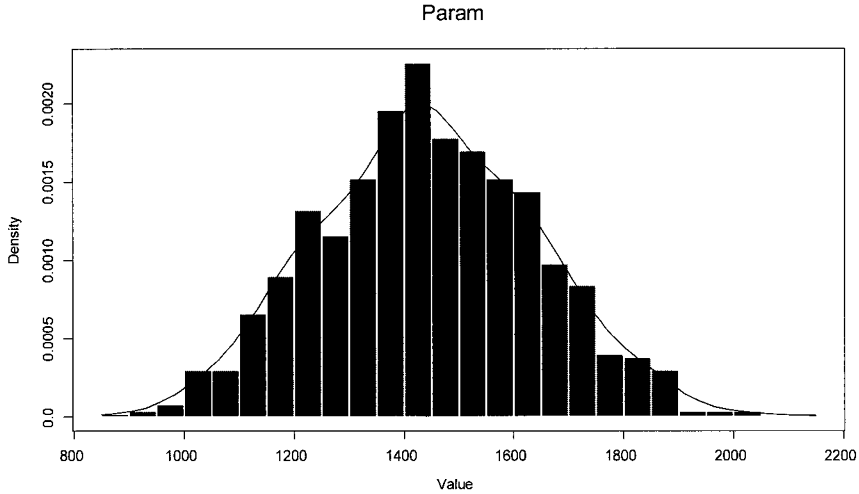


Fig.3 Runoff hydrograph at Namdaecheon

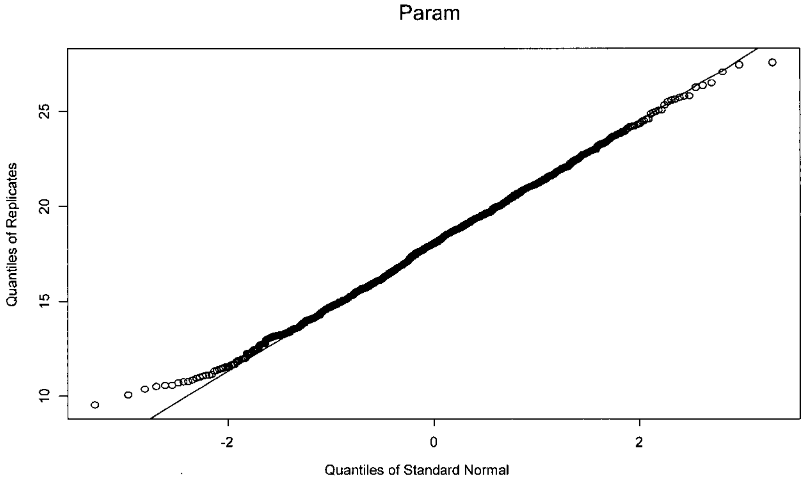


Fig.4 QQ-plot of Namdaecheon

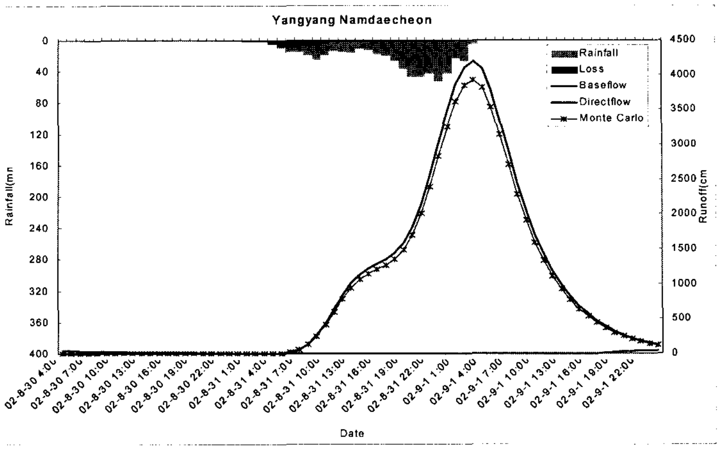


Fig. 5 Namdaecheon flood-runoff curve, Yangyang

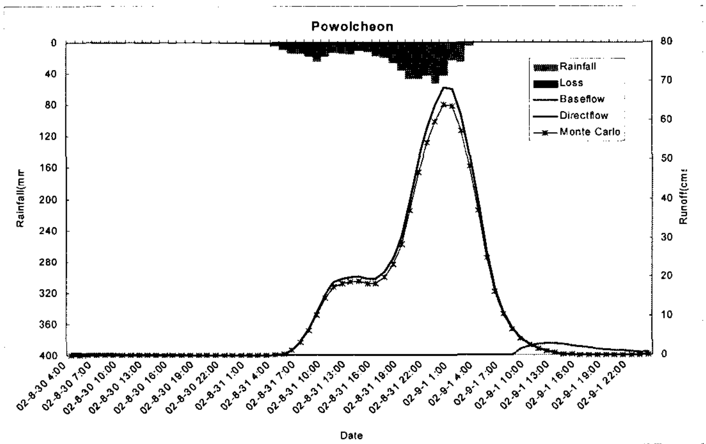


Fig. 6 Powolcheon flood-runoff curve

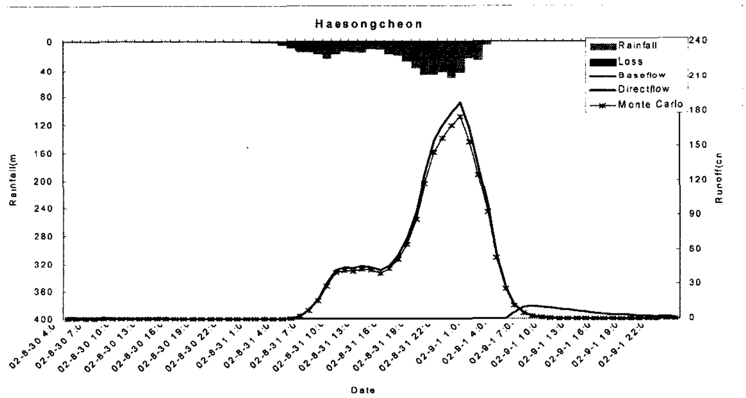


Fig. 7 Haesongcheon flood-runoff curve

bles 6 and 7 represent the input parameters and input data for the HEC-HMS. In the runoff simulation results by the HEC-HMS, the peak flow in Namdae cheon of Yangyang was occurred at 3:00 AM, September 1, 2002.

According to the report of '2002 Big Floods by Typoon Rusa, Kangwon-Do'(KICT, 2002), the peak stage time from a stage hydrograph at Yangyang stage station (August 30 - September 1, 2002) was occurred at 2:00 AM, September 1. If we consider the estuary of Namdae cheon in the distance of 4.4 km from Yangyang stage station, the simulation by the HEC-HMS shows a reasonable result. Also we determine the distribution of the runoff hydrograph by the bootstrap technique to consider the uncertainty of the runoff and Monte Carlo method is used for the uncertainty analysis. From the analysis the runoffs of three streams show the normal distribution and we show an analyzed example in Figs. 3 and 4. The distribution is used for the consideration of uncertainty by Monte Carlo method and the resulted runoff hydrographs are shown in Figs 5 to 7. The peak runoffs are simulated as 4195.6, 68.417, and 187.18 cms respectively at Namdaecheon, Powolchon, and Haesongcheon streams. The peak runoffs with uncertainty are simulated as 3926.1, 64.03, and 175.17 cms at each streams. As the results, the peak runoffs with uncertainty show rather smaller values than the runoffs without uncertainty.

3.4 The Estimation of Threshold Runoff

The bankfull streamflow, Q_p, and peak flow, q_{pr} of a unit graph are estimated for the estimation of the threshold runoff. The peak flow is estimated by the HEC-HMS and the over banked streamflow is estimated by the Manning's equation(Eq. (3)). The data of the sectional characteristics are obtained from 'the Report of Channel Improvment Plan'(Yangyang, 2002) and shown in table 7. The threshold runoffs are estimated from the Eqs.(1) and (2) and shown in table 8.

3.5 The Estimation of Flash Flood Guidance

As we can see the table 9, the threshold runoff for each stream by the typoon Rusa are much bigger than the reported values in 'the report of channel improvement plan'(Yangyang, 2002). Since the threshold runoff and the peak flow are inversely proportional relationship from Eq.(2) the threshold runoffs from the Rusa are bigger than the given values. As mentioned in afore section, the FFG can be estimated as the rainfall determination of rainfall-runoff process corresponding to the threshold runoff. Therefore we represent the relationship between rainfall and runoff in figs. 8 to 10 and the FFG in table 9 is estimated from the relationship and the estimated FFG is also very big.

Table 7. The cross section data of the streams(Yangyan, 2002)

	Stream		
Stream	Yangyang Namdae cheon	Powol cheon	Haesong cheon
n	0.033	0.033	0.033
Width	797	62	131
Sc	0.001754	0.009524	0.023256
Hight of bank	4.08	3.27	5.1
Max. depth of bed elevation	3.46	-0.22	0.3
yb	1.92	1.75	1.46
Qp	2268.345	352.2734	859.9594

Table 8. The estimated threshold runoff for each stream

	Yangyang Namdaecheon	Powolcheon	Haesongcheon
Bank overflow flow(cms)	2268.345	352.27	859.95
Peak flow(cms/km^2/cm)	0.26(0.24)	0.34(0.32)	0.31(0.29)
Threshold runoff(mm)	18.4(19.7)	172.7(184.6)	179.0(191.3)

* ( ) represents the values with uncertainty

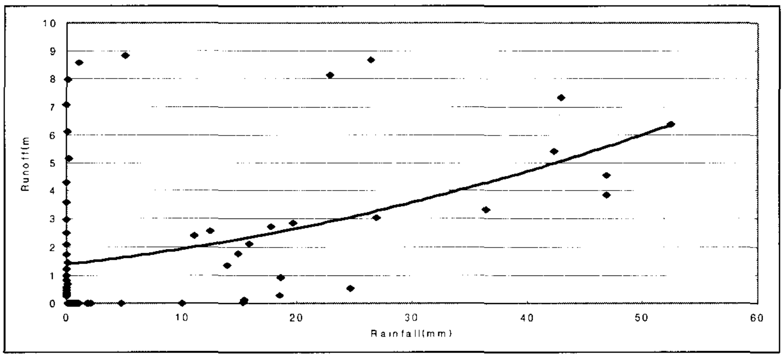


Fig. 8 Yangyang Namdaecheon

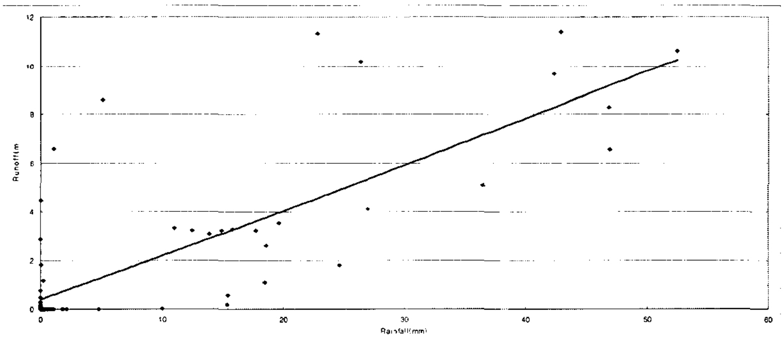


Fig. 9 Powolcheon

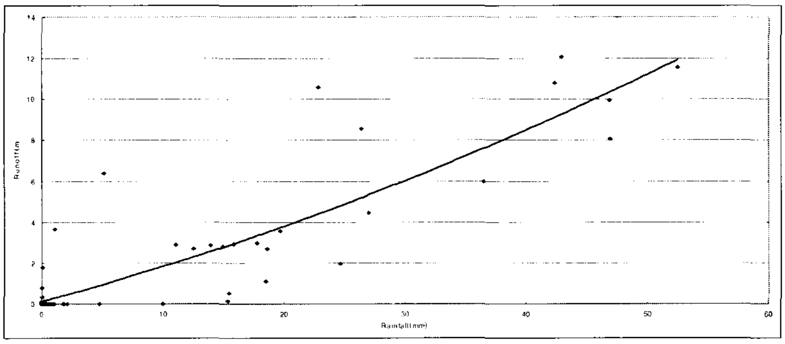


Fig. 10 Haesongcheon

Table 9. The Comparison of the Flash Flood Guidance

	Lusa			Yangyang(2002)		
	Namdaecheon	Powolcheon	Haesongcheon	Namdaecheon	Powolcheon	Haesongcheon
Bank overflow (cms)	2268.345	352.27	859.95	2268.345	352.27	859.95
Peakflow(cms/km²/cm)	0.26	0.34	0.31	0.50	1.38	1.59
Threshold runoff(mm)	18.4(19.7)	172.7(184.6)	179.0(191.31)	9.48	42.54	34.78
FFG(mm)	204.54 (218.76)	995.6 (1060.7)	852.1 (910.59)	82	242.8	164

( ) represents the values with uncertaint

3.6 The Estimation of Sediment Yield

This study assumes the 100% of the eroded soil in the watershed is transferred to the sediment yield. Under the assumption the estimated sediment yield is showed in the tables 10 and 11. In the table 10, the e represents the kinetic energy of rainfall with the unit of Mega Joule/ha/mm, P' is the total depth of rainfall, and E is the total energy of rainfall with the unit of Mega Joule/ha.

The sediment yield, Y is a function of Ra and Ra is a function of rainfall intensity, I. In afore section of 3.2, the analyzed rainfall intensity for the Rusa showed the frequency of over 500 years and the R is estimated as the value of 1201.4(10^7J/ha)(mm/hr)/storm in this study (table 10). This value is much bigger than the previous study for the Kangnung area. Say, the estimated R-value for 53-station of KMA by using the data of 1969-1978 is in Park and Woo(2000) and the R-value for the Kangnung area is 297 (10^7J/ha) (mm/hr) /storm.

Table 10. Rainfall-runoff erosivity index

Duration(hr)	Rainfall(mm)	Intensity	e	P'	E
1	52.50	52.5	0.269	52.50	14.1314201
2	95.50	47.8	0.266	43.00	11.4196982
3	141.70	47.2	0.265	98.70	26.1714798
4	188.65	47.2	0.265	89.95	23.846195
5	231.61	46.3	0.264	141.66	37.458195
6	268.00	44.7	0.263	126.34	33.2329238
7	295.07	42.2	0.261	168.73	44.0127816
8	317.91	39.7	0.259	149.18	38.5796486
total					228.85
R	1201.4(10^7J/ha)(mm/hr)/storm				

Table 11. Sediment yields in the streams due to the Rusa

	R	K	LS	C	P	A	Y (tons/year)
Namdaecheon	1201.4	0.51	23.15	0.02181	1	474.8	146,884
Powolcheon	1201.4	0.51	7.25	**0.19333**	1	6	5,153
Haesongcheon	1201.4	0.51	15.93	0.01334	1	15.5	2,018

4. CLOSING REMARKS

This study has performed the flood analysis such as the FFG and sediment yield for the typoon Rusa. The study areas were the small streams of Namdaecheon, Powolcheon, and Haesongcheon in Yangyang area. When we see the analyzed results, the FFG and sediment yield by the Rusa showed much bigger values than the given informations. So, we may know that the Rusa influenced the big flood of the study area.

This study has used the Manning's equation like previous studies for the estimation of bankfull flow. However, we may use the HEC-RAS for the estimation of bankfull flow using the sectional characteristics in the later study and the limitation of data was a major difficulty in the analysis of the study area.

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