Catchment modelling of Darang catchment _ Part A

Module 8 WSE - HI River Flood Analysis and Modelling

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Contents

1. The optimal parameters

1.1 Compute the weights by Thiessen polygons

In this part, we change the rain gauge locations to the following:

Table 1. The coordinates of rain gages

Rain gage locations	X coordinate	Y coordinate
Gage 1	-3837524	10725653
Gage 2	-3856952	10731882
Gage 3	-3816773	10721315

Then we need to create Thiessen polygons using ArcGIS, and the final figure results are as follows:

Figure 1. The division of Gages

Export the data as text file and compute the gage weights for each sub-basin to the following:

Table 2. The weights of different areas

Area	Gage 1	Gage 2	Gage 3
W1	0.50	0.00	99.50
W2	0.00	0.00	100.00
W3	72.31	0.00	27.69
W4	0.00	100.00	0.00
W5	83.18	16.76	0.06
W6	11.56	88.44	0.00

1.2 Build the model

We need to change the meteorological models for each sub-basin. For each sub-basin, we have seven parameters optimized: Initial Discharge; Ratio to Peak; Recession Constant; Curve Number; Initial Abstraction; Peaking Coefficient; Standard lag. The optimization starts from 10Feb2001 00:00 to 11Feb2001 06:00. Its max iterations and tolerance are 500 times and 0.001 respectively. The objective function is to minimize the outlet's discharge by first lag autocorrelation. After that, we click the compute button and get the changing parameters.

Table 3. Changing parameters

Parameter	Element	Initial Value	Optimized Value	Element	Initial Value	Optimized Value	Element	Initial Value	Optimized Value
Initial Discharge	W1	12.97	8.32	W2	6.94	3.91	W3	14.18	6.74
Ratio to Peak	W1	0.3	0.19	W2	0.3	0.18	W3	0.3	0.18
Recession Constant	W1	1	0.97	W2	1	1.00	W3	1	0.99
Curve Number	W1	61	66.99	W2	64	62.59	W3	61	53.05
Initial Abstraction	W1	32.5	34.80	W2	28.6	26.45	W3	32.5	27.59
Peaking Coefficient	W1	0.3	0.12	W2	0.3	0.14	W3	0.3	0.15

Parameter	Element	Initial Value	Optimized Value	Element	Initial Value	Optimized Value	Element	Initial Value	Optimized Value
Initial Discharge	W4	9.21	4.08	W5	9.21	4.11	W6	4.22	2.16
Ratio to Peak	W4	0.3	0.17	W5	0.3	0.15	W6	0.3	0.13
Recession Constant	W4	1	0.96	W5	1	0.95	W6	1	0.98
Curve Number	W4	64	49.68	W5	64	54.43	W6	51	38.87
Initial Abstraction	W4	28.6	26.09	W5	28.6	25.34	W6	48.8	34.36
Peaking Coefficient	W4	0.3	0.16	W5	0.3	0.26	W6	0.3	0.30

The final optimization results are as follows:

Table 4. The final optimization results

Measure	Simulated	Observed	Difference	Percent Difference
Volume (MM)	5.97	5.8	0.17	2.93
Peak Flow (M3/S)	166	164.9	1.1	0.7
Time of Peak	10Feb2001, 08:00	10Feb2001, 10:00		

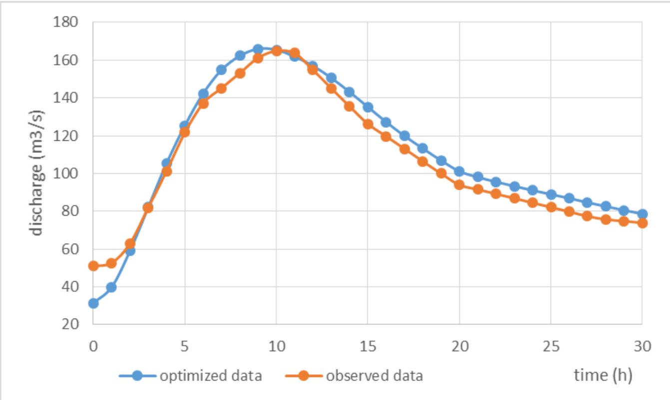

Figure 2. The comparison between optimized data and observed data

The figure shows that the peak flow keeps basically unchanged, and the optimized data is larger than the observed data most of the time. However, the time of its occurrence is inaccurate, which happens earlier two hour compared to the observed peak flow. Overall, the error after optimization is within the allowable range of 5%, proving that this multi-parameter optimization runs successfully.

2. The design flood

2.1 Compute the design rainfall

First, we need to use Log Pearson Type III distribution for frequency analysis, and then estimate the design rainfall with 10-year return period. I calculate the required parameters with the following formulas.

2.1.1 Compute $\mathrm{x} = \mathrm{Log}_{10}(P)$

Table 5. The result of x

P	41.92	56.46	30.80	49.62	35.07	40.21	63.31	45.34	65.02	48.76	68.44	56.46	58.17	58.17	55.55	75.28	41.92	28.23
X	1.62	1.75	1.49	1.70	1.54	1.60	1.80	1.66	1.81	1.69	1.84	1.75	1.76	1.76	1.74	1.88	1.62	1.45
P	82.13	80.42	68.44	53.04	60.74	94.96	54.75	44.49	54.75	29.09	26.20	48.76	78.70	56.46	55.61	53.90	51.33	
X	1.91	1.91	1.84	1.72	1.78	1.98	1.74	1.65	1.74	1.46	1.42	1.69	1.90	1.75	1.75	1.73	1.71	

2.1.2 Compute$\mathrm{x}_{ave} = \sum x/N$, σ and C_s

the standard deviation of x

$$\mathrm{x}_{ave} = \sum x/N = 1.72 \tag{1}$$

the number of data points

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{ave})^2}{n-1}} = 0.13 \tag{2}$$

coefficient of skewness

$$C_s = \frac{N\sum_{i=1}^{N}(x_i - x_{ave})^3}{(N-1)(N-2)\sigma^3} = -0.50 \tag{3}$$

2.1.3 Determine K and compute P

According to 1/T=1/10 and Cs = -0.50, we can get K = 1.217.

$$\mathrm{Log}_{10}(P) = x_{ave} + K\sigma = 1.88 \tag{4}$$

$$\mathrm{P} = 10^{\mathrm{Log}_{10}(P)} = 76.03\mathrm{m}^3/s \tag{5}$$

2.1.4 Estimate the design rainfall at Gages

Table 6. The design rainfall at Gages

Date	Time	Gage 1	Gage 2	Gage 3
10-Feb-01	0:00	0.00	0.00	0.00
10-Feb-01	1:00	9.26	10.64	8.33
10-Feb-01	2:00	10.58	12.16	9.52
10-Feb-01	3:00	13.22	15.21	11.90
10-Feb-01	4:00	10.58	12.16	9.52
10-Feb-01	5:00	8.59	9.88	7.74
10-Feb-01	6:00	5.95	6.84	5.36
10-Feb-01	7:00	3.97	4.56	3.57
10-Feb-01	8:00	2.64	3.04	2.38
10-Feb-01	9:00	1.32	1.52	1.19

2.2 Run the model and analyse the result

In this calculation, we apply the optimized parameters to rerun the model. The final volume on the simulated outflow at the outlet of Darang is 11.71mm. The peak discharge is 242m^3/s happening at 10Feb2001, 07:30.

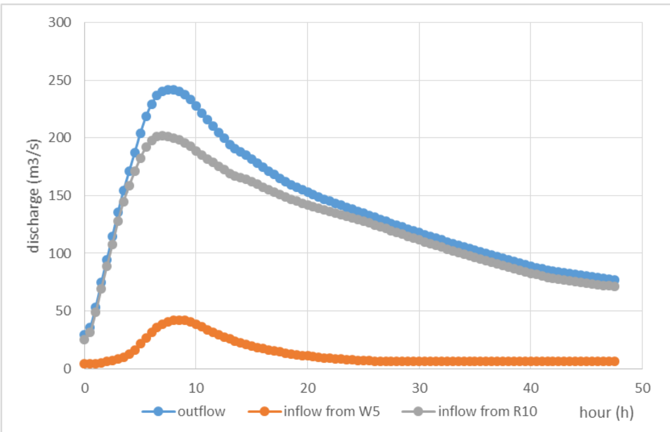

Figure 3. The discharge of the outlet

The flood occurs earlier 30 mins than the original one, and the discharge increases by around 80 m^3/s. At the upper limb, the curve is very steep, and then it decline slowly. By speculation, the flow will return to the original value (about 50) after 150h. The 80% inflow comes from river flow (inflow from R10), and the rest is provided by precipitation (inflow from W5). The peak of inflow from R10 and W5 appear at 7:00 and 8:30 respectively.

3. Urbanising the hydrologically upper-most sub-basin

We need to set the percentage of impervious land to 20 and keep other input data and parameters unchanged. The final result is as follows.

Table 7. The comparison of changing one and original one

Measure	Changing one	Original one	Difference	Percent Difference
Volume (MM)	20.38	11.71	8.67	74
Peak Flow (M3/S)	434.9	242	192.9	80
Time of Peak	10FEB2001,08:30	10FEB2001,07:30		

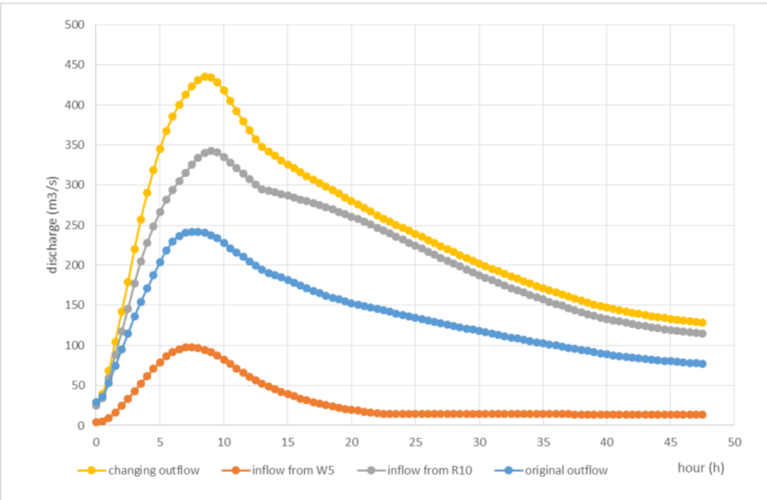

Figure 4. The comparison of changing one and original one

Due to the increase in the impervious layer, less water become loss as infiltration in the whole sub-basin, but this part changed to river flow converging at the exit. The inflow from R10 and W5 increases by 100% and 25% respectively. The flood volume and peak flow have doubled the original value. At the same time, the peak occurrence is delayed 1 hour. Overall, the risk of the extreme weather will enhance, and it will damage the existing or future infrastructure or other valuable assets exposed to flooding. To defend against it, the government should widen the required cross section of the river to convey high flow. Or, they can choose to build dikes for flood protection.