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## Application Research of Mathematical Model in Tallo River Flood Analysis

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## Application Research of Mathematical Model in Tallo River Flood Analysis

**Maria Triselia Guhar, Muhammad Saleh Pallu, Mukhsan Putra Hatta**

Jurusan Teknik Sipil, Universitas Hasanuddin, Jl. Perintis Kemerdekaan Km. 10,  
Tamalanrea Indah, Tamalanrea, Kota Makassar, Sulawesi Selatan, 90245, Indonesia.

**Abstract.** Rivers are natural elements, and rivers play an important role in shaping the style of the community. The Tallo River in Makassar has advantages in economy, entertainment and transportation. But almost every year, the area along the river is always flood. this problem can be solved by examine the phenomena and conditions of the level of flood watersheds vulnerability using hydrological approach through Muskingum kinematic methods, which is a common flood routing methods. By approaching the hydrological conditions of the Tallo river watershed, the results of this study are expected to provide the best alternative treatment options. The flood discharge value is executed based on the rainfall data that collected from three stations along the river namely Hasanuddin, Malino and Senre. After that, the flood discharge plan is conducted to obtaining the outflow value by using the inflow value through Muskingum method. The length of the river considered in this study is about 20 km, and it is divided into 5 segments every 4 km. The  $x$  value is between 0.1 and 0.3, and the  $K$  value is between 0.16-0.57. The obtained maximum flood discharge from the Muskingum calculation for the 2-year return period occurred at  $801,330 \text{ m}^3/\text{sec}$  with an  $X$  value = 0.1 and  $K = 0.58$ .

**Keywords:** Flooding, Flood Routing, Muskingum method, Tallo River

### 1. Introduction

The river plays an important role in human life, can be used for commercial purposes and has economic value as a source of water in urban areas, as a means of recreation, as a means of transportation [1-4], and so forth. But it cannot be denied, at certain times the river can be detrimental to the people around it. As example, when floods occur which can cause damage to the surrounding agricultural areas and buildings. Likewise with the Tallo River, as one of the main rivers in Makassar City, this river is inevitable from flood events almost every year [5, 6].

Flooding can occur due to high rainfall, intensity or degradation of incorrect sea use. To prevent that from happening, various methods are used to control the flow of the river which requires analysis of flood flow which also covers flood routing. Therefore, the role of flood routing which is part of hydrological analysis becomes quite important.

Flood routing can be interpreted as a procedure to determine or estimate the time and magnitude of a flood at a point based on known data or perceived data. Flood routing techniques can be divided into two categories namely simple hydrological routing and more complex is hydraulics routing [7, 8] Hydrological routing involves balancing inflow, outflow and storage volume using a continuity



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equation. The second relationship that is also needed is the relationship between storage with flow rate between the average flow out and storage system.

Muskingum method is one of the common hydrologic flood routing methods for rivers. Choudhury, Shrivastava, and Narulkar [8] replaced multiple inflows with equivalent single inflows in order to use the Muskingum method to simulate flood flows in the river network. They claim that their model can effectively estimate the parameters of the Muskingum model in a single inflow routing problem. In addition, the results of the model parameter sensitivity analysis indicate that there is a unique set of parameters that will lead to the best performance for a given number of inflows routing problems [8]. Besides that, Samani and Shamsipour [9] did not use trial and error combined with curve fitting techniques to determine the parameters of the Muskingum method, but instead proposed an alternative solution uses nonlinear optimization techniques and applies the de Saint Venant equation [9]. The comparison of the results shows that the consistency between the methods is good.

Like the Tallo River, as one of the major rivers in Makassar City, floods occur almost every year. The flood cause by the river is inevitable. Therefore, this paper aims to examine the Muskingum method in its practice and its application in flood routing on the Tallo River.

## 2. Methodology

This research is a study application of flood phenomenon routing and prediction of maximum flood discharge that will occur. The study target is in the Tallo River Watershed. The research site used is the Tulang Bawang Watershed which is the area of Nipa-Nipa Antang to Tallo sub-district along 20km by dividing the location into 5 segments per 4km (Figure 1).

### 2.1. Location Study

#### 2.1.1. General Description of Study Area Conditions

Makassar City has a relatively flat topography, so that it has the potential to develop residential, commercial, industrial and other activities. As development increases, water catchment areas decrease. This is the reason why several areas in Makassar often experience flooding and inundation during the rainy season as shown in Figure 1. Figure 1 shows that the area which is prone to flooding is the District of Tamalanrea and District of Tallo. Therefore the area used as the study area is the Tallo River Watershed.

#### 2.1.2. Physical condition

##### 2.1.2.1 Climatic Conditions

Climatic conditions in the study area are influenced by tropical winds which bring a lot of rain during the period from November to April with a rainfall of about 75% of the average annual rainfall period, while between May and August is the dry season. The average annual rainfall is 4000 mm in mountainous regions, while the plains and coastal areas range from 2500 mm to 3000 mm.

##### 2.1.2.2 Topographic Conditions

The Tallo River has a catchment area of 407 km<sup>2</sup> starting from Mount Kallapolompo (elevation 725 m), with the length of the main river being 61.2 km. The low-lying area is spread downstream to the Makassar City area. The main stream of the Tallo River is still in the form of natural flow without flood protection work. The Tallo River has a gentle slope of about 1/10000 in the downstream area. The slope of the river from the Tallo Bridge to the upstream is 0.00035 and from the Tallo Bridge to the downstream is 0.0002. The average river slope is 15 km from the estuary of 0.000385. This condition causes downstream areas, especially around the city of Makassar, often inundated by floods due to overflowing rivers.

2.1.2.3 Morphological Condition of the River

Figure 2 shows the Tallo River channel is a meandering channel with sharp turns on the downstream section. The average river width on the Tallo to Hulu Bridge segment is 50 m - 80 m, and from the Tallo Bridge to the Downstream to the estuary segment is 80 m - 300 m. The average river depth from the banks of the banks on the Tallo Bridge to the upstream segment is 4 m, and on the Tallo Bridge to the downstream segment is 6 m. There are no dykes along the river that can prevent flooding during a flood.

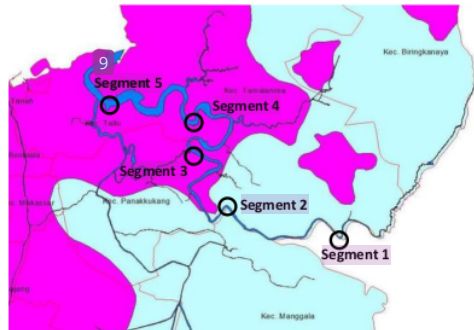


Figure 1. Map of Potential Flood Areas



Figure 2. Tallo River's Morphological Conditions

2.2. Data Collection

The type of data used in this thesis is secondary data obtained from relevant agencies, namely: Rainfall data was obtained from the Public Works Department of Water Resources Development (PSDA) of South Sulawesi Province in the form of rainfall data from 1999 to 2009 at 3 stations adjacent to the study location (Senre Station, Malino Station, and Hasanuddin Station). This data is used to calculate rainfall intensity, and then the intensity is used to calculate surface runoff and calculate Tallo river flood routing.

2.2.1. Rain Station

Rainfall data needed is rain data recorded at the nearest rain station that affects the water flow in the relevant watershed. There are several rain recording stations around the Watershed that represent rain in the area. Rain stations are represented by Malino rain stations, Senre rain stations and Hasanuddin rain stations. The detailed geographical location of the rain stations are shown in Table 1.

Table 1. Location of rain stations

No.	Station Name	Code	Location		Administrator
			Latitude	Longitude	
1	Hasanuddin	19161	05° 04'	119° 33'	BMG
2	Malino	22H	05° 15'	119° 55'	PSDA
3	Senre	24OP	05° 12'	119° 32'	PSDA

2.2.2. Rain data

Of the three available rain stations, the available rainfall data is daily rainfall data. The rain data was obtained from the Public Works Department of South Sulawesi Province. The rain data used were Hasanuddin rain station data for 10 years (1999 to 2008), Malino rain station for 10 years (1999 to 2008) and Senre rain stations for 10 years (1999 to 2008). The maximum daily rainfall data in detail can be seen in Table 2.

Tabel 2. Maximum Daily Rain Data

Year	Hasanuddin	Malino	Senre
1999	222	185	108
2000	197	118	193
2001	270	0	123
2002	148	125	183
2003	128	140	138
2004	139	137	125
2005	208	82	110
2006	139	220	303
2007	0	135	225
2008	0	75	190

2.3. Data Processing and Analysis

In this study there are several analytical methods that use from the results of previous data collection. The steps in completing a flood routing by the Muskingum method are described in Figure 3.

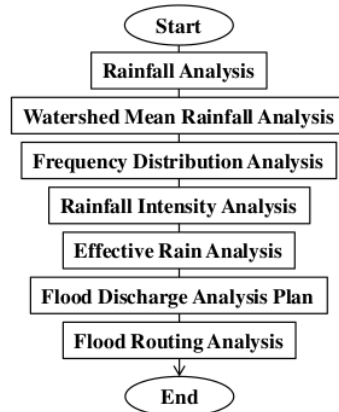


Figure 3. Flood routing analytics scheme

First analytical method used is Rainfall Analysis which is used to determine the amount of rainfall that has a certain probability of occurrence (return period). Secondly is Analysis of Average Rainwater watershed which is used to determine the average rainfall in the watershed through Thiessen Polygon Method. Third is Frequency Distribution Analysis which is used to test the suitability and statistical nature of hydrological data. Match Analysis of Probability Distributions is used to determine the compatibility between the distributions of data with the selected theoretical distribution, and then a goodness of fit test is needed. Distribution match test was carried out by Smimov-Kolmogorov test and Chi-Square test. Repeat Period Analysis was conducted to find out the average time interval that is equaled or exceeded based on long event records / data

Next is Analysis of Rain Distribution Patterns, this analysis is an analysis to determine rainfall intensity based on daily rainfall data using the Mononobe formula. After that is Effective Rain analysis, this analysis aims to determine the net rain or the total rainfall that results in direct run-off. Assuming that the process of transforming rain into runoff is directly follows a linear process and does not change with time. Besides that, Analysis of Design Flood Discharge is conducted. This analysis is to find out the diversification of rain into a flow from the availability of rainfall that is quite long. The Unit Hydrograph Analysis is considered, this analysis is to determine the characteristics of the

watershed with the method used is the Synthetic Unit Hydrograph (SUH) Nakayasu, Gama I and Snyder. Lastly, is Flood Routing Analysis, this analysis is to find outflow outflows downstream of the river which are reviewed based on upstream inflow discharges using the Muskingum method.

**3. Result and discussion**

*3.1. Analysis of Average Rainfall Watersheds*

In general, the rain data obtained are point rain data. In determining the design flood, a mean rainfall is calculated using Thiessen Polygon method. Figure 4 shows the weight distribution of rain stations representing the Tallo watershed is in accordance with the Thiessen Polygon method. Figure 5 demonstrates that the weight of Hasanuddin station is 16.28%, Malino station is 6.11% and Senre station is 77.61%.

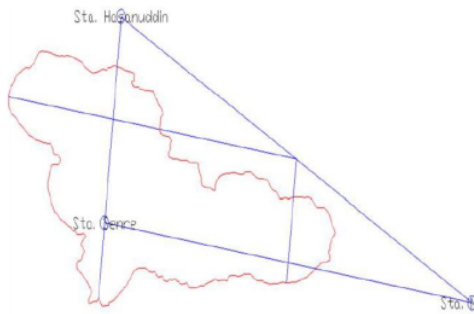


Figure 4. Thiessen's Polygon Method



Figure 5. The Weight of the Rain Station

*3.2. Determination of Data Series*

Determination of data series for frequency analysis can be executed based on the availability of rain data, and then the determination of the rain data series is determined using the maximum annual series (taking one maximum data each year). Table 3 tabulates the maximum average daily rainfall in the Tallo River Watershed.

Table 3. Maximum Average Daily Rainfall in the Tallo River Watershed

Year	Hasanuddin	Malino	Senre	Average (mm)
	16.28%	6.11%	77.61%	
1999	222	185	108	131.27
2000	197	118	193	189.07
2001	270	0	123	139.42
2002	148	125	183	173.76
2003	128	140	138	136.49
2004	139	137	125	128.01
2005	208	82	110	124.25
2006	139	220	303	271.22
2007	0	135	225	182.86
2008	0	75	190	152.03
Total				1628,38

If a hydrological data is available for a location, the statistical parameters of the data can be calculated. Each frequency distribution has unique characteristics so every hydrological data must be

tested for compatibility with its statistical properties. So that it can then examine its probability distribution with the Log Person Type III method as shown in Table 4.

Table 4. Calculation of design rainfall using log person type III method

Return period (Year)	P	Cs	G	Log X	X (mm)
2	50	0.6286	-0.1025	2.2001	158.530
5	20	0.6286	0.7955	2.3091	203.738
10	10	0.6286	1.3262	2.3735	236.304
20	5	0.6286	1.8402	2.4358	272.796
25	4	0.6286	1.9430	2.4483	280.744
50	2	0.6286	2.3684	2.4999	316.174
100	1	0.6286	2.7704	2.5487	353.753

After that, determine the effective rainfall with  $\Phi$  index. Effective rainfall is the part of rain that becomes a direct flow in a river. This effective rain is the same as the total rain that falls on the land surface reduced by water loss. The method used to find the amount of water loss is the  $\Phi$  index method. Table 5 tabulates the result of calculating  $\Phi$  index:

Table 5. Recap of Effective Rainfall

Return period (Year)	Total of rainfall (mm)	Index ( $\Phi$ )	Effective Rainfall (mm)
2	158.530	23.1	135.411
5	203.738	29.7	174.026
10	236.304	34.5	201.844
20	272.796	39.8	233.012
25	280.744	40.9	239.803
50	316.174	46.1	270.066
100	353.753	51.6	302.164

The rain distribution pattern is then determined by comparing the Alternative Block Method (ABM) method with the hyetography determination method by Yusron Lubis. The data of ABM and Yusron Lubis methods are illustrate in Table 6 and Table 7 as well as Figure 6 and Figure 7 respectively. From the results of the comparison of the two methods in, it can be concluded that the Yusron Lubis method is more representative of the distribution of rain in the Tallo River, and will be used in subsequent calculations.

Table 6. Hyetograph table ABM method period 2-year return period

Td (hrs)	$\Delta t$ (hrs)	It (mm/hrs)	ItTd (mm)	$\Delta p$ (mm)	pt (%)	Hyetograph (%) (mm)	
1	0-1	54.96	54.96	54.96	55.05	6.77	10.73
2	1-2	34.62	69.24	14.28	14.30	10.04	15.91
3	2-3	26.42	79.26	10.02	10.04	55.05	87.27
4	3-4	21.81	87.24	7.98	7.99	14.30	22.67
5	4-5	18.80	94.00	6.76	6.77	7.99	12.67
6	5-6	16.64	99.84	5.84	5.85	5.85	9.27
Total				99.84	100	100	158.53

Table 7. Hyetograph of the Yusron Lubis method with a 2-year return period

Time (hrs)	Coefficient of rain (%)	Hyetograph (mm)
1	12	19.02
2	32	50.72

3	29	45.97
4	12	19.02
5	9	14.26
6	3	4.75
7	2	3.17
8	1	1.58

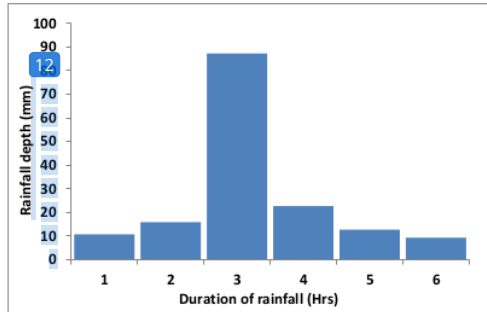


Figure 6. The hyetograph of ABM Method

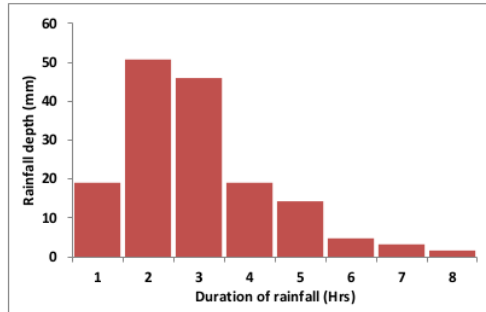


Figure 7. The hyetograph of Yusron Lubis

With all the data obtained above, the flood discharge plan can then be determined by the Nakayasu Synthetic Hydrograph Method. This plan flood discharge data is then used as a base flow or as an inflow in the river segment which is then reviewed for calculation in the Muskingum method.

Table 8. The flood unit hydrograph plans of Nakayasu method for a 2 year return period

Time (hrs)	Flow rate (m <sup>3</sup> /sec)	Hourly rainfall (mm/hrs)								Debit (Q) (m <sup>3</sup> /sec)
		1	2	3	4	5	6	7	8	
		19.02	50.72	45.97	19.02	14.26	4.75	3.17	1.58	
1	0.054	1.021	0.000							1.021
2	0.283	5.391	14.376	0.000						19.766
3	0.750	14.265	38.040	34.474	0.000					86.779
4	1.496	28.453	75.874	68.761	28.453	0.000				201.542
5	2.555	48.608	129.622	117.470	48.608	36.456	0.000			380.766
6	3.958	75.292	200.777	181.955	75.292	56.469	18.823	0.000		608.606
7	5.730	108.998	290.661	263.412	108.998	81.748	27.249	18.166	0.000	899.233
8	4.268	81.184	216.490	196.194	81.184	60.888	20.296	13.531	6.765	676.531
9	3.581	68.123	181.661	164.630	68.123	51.092	17.031	11.354	5.677	567.689
10	3.005	57.163	152.435	138.144	57.163	42.872	14.291	9.527	4.764	476.358
11	2.521	47.966	127.911	115.919	47.966	35.975	11.992	7.994	3.997	399.721
12	2.116	40.250	107.332	97.270	40.250	30.187	10.062	6.708	3.354	335.413
13	1.775	33.774	90.064	81.621	33.774	25.331	8.444	5.629	2.815	281.451
14	1.522	28.949	77.198	69.961	28.949	21.712	7.237	4.825	2.412	241.244
15	1.354	25.754	68.679	62.240	25.754	19.316	6.439	4.292	2.146	214.621
16	1.204	22.912	61.099	55.371	22.912	17.184	5.728	3.819	1.909	190.936
17	1.071	20.384	54.357	49.261	20.384	15.288	5.096	3.397	1.699	169.864
18	0.953	18.134	48.358	43.824	18.134	13.601	4.534	3.022	1.511	151.119
19	0.848	16.133	43.021	38.988	16.133	12.100	4.033	2.689	1.344	134.441
20	0.754	14.353	38.274	34.685	14.353	10.764	3.588	2.392	1.196	119.605
21	0.616	11.720	31.252	28.322	11.720	8.790	2.930	1.953	0.977	97.664
22	0.564	10.736	28.628	25.944	10.736	8.052	2.684	1.789	0.895	89.463

23	0.517	9.834	26.224	23.766	9.834	7.376	2.459	1.639	0.820	81.951
24	0.474	9.008	24.022	21.770	9.008	6.756	2.252	1.501	0.751	75.070

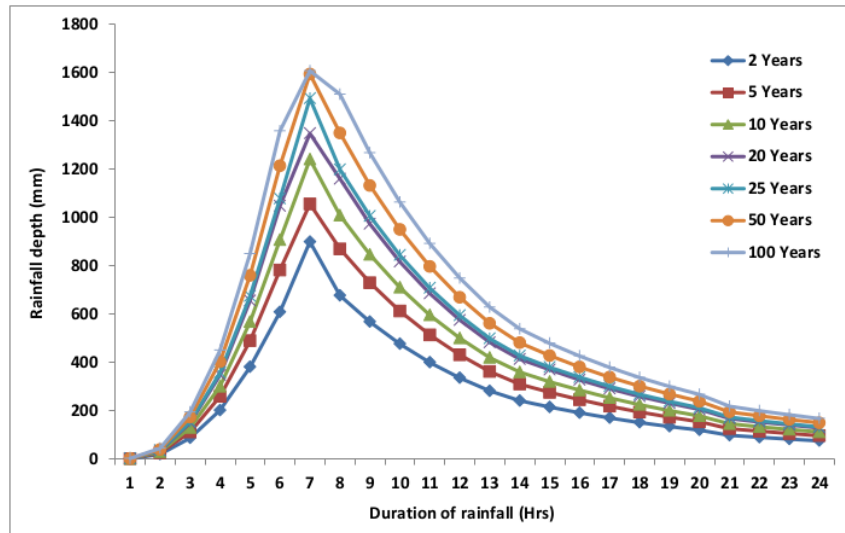


Figure 8. Details of the Nakayasu flood hydrograph of the Tallo River

### 3.3. Determination of routing constants

The basic principle of the completion of the flood calculation using the Muskingum method is the completeness of the discharge measurement data at the upstream and downstream rivers which are obtained at the same time. This measurement is very important to get the value of the reservoir that occurs at the cross section of the river being reviewed. This value will be used to determine the values of K and x. However, due to the lack of flow measurement data of downstream rivers, in this study, the values of x and K were not calculated according to existing formulas. By setting the range of the two coefficients, the values of x and K are determined through trial and error.

- I.  $I$  is the flow of discharge into a particular riverbed. Discharge data that will be used in this study is taken from the design flood hydrograph of the design flood based on rainfall around the upstream trough of the river.
- II.  $\Delta t$  is the routing period (seconds, hours, days). The routing period in this study is 1 hour.
- III. K is the price in units of time and is called the pool coefficient which is approximately the same as the time of the flood in the river section. To get the range of K values, this study used the formula for the arrival time of the flood in Bavaria in Germany[10], which is:  $t = L / W$  where,  $W = 20 (H / L)^{0.6}$

Where,

- T = flood arrival time (hour)
- W = speed of arrival from flood (m / sec)
- L = river length (km)
- H = difference in elevation (m)

So the value of  $t = K$ . All the above coefficients are known, except for the elevation (H) of the river watershed observed. As for the elevation value, the upstream and downstream sections are taken from Digital Elevation Model (DEM) data which is basic data or topographic (height) contours. The calculated K value of each segment are Segment 1 (K = 0.32), Segment 2 (K = 0.57), Segment 3 (K = 0.16), Segment 4 (K = 0.20), and Segment 5 (K = 0.22).

x is the value that indicates the river's slope. The steeper the slope, the greater the x value is. In general, the value of x ranges from 0.1 to 0.3 [10, 11]. The value of x will then be determined by trial and error based on the range.

3.4. Muskingum Method Calculation Results

After all the constants are known, the flood routing by the Muskingum Method can be calculated using the formulas Q1 to Q4. The length of the river under review was 20km and divided into 5 segments per 4km. The inflow value used is from the planned flood discharge data for segment 1, while for segment 2 the inflow value is obtained from the outflow value from before, and continuously until segment 5. Based on the calculation results of the inflow and outflow value with values x = 0.1 to x = 0.3, note that the largest value of discharge generated with the value x = 0.1. Therefore, the x value will be used in the calculation of the inflow and outflow values. The calculation result of inflow and outflow for return period of 2 years in segment 1-segment 5 are tabulated in Table 9.

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 O_1 \tag{Q1}$$

$$C_0 = \frac{-Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t} \tag{Q2}$$

$$C_1 = \frac{Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t} \tag{Q3}$$

$$C_2 = \frac{K - Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t} \tag{Q4}$$

11 Table 9. Summary of inflow and outflow for return period of 2 years in segment 1-segment 5

T (hrs)	13 Segment 1		Segment 2		Segment 3		Segment 4		Segment 5	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
0	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
1	19.77	12.14	12.14	5.85	5.85	4.64	4.64	3.56	3.56	2.75
2	86.78	61.55	61.55	33.47	33.47	27.22	27.22	20.99	20.99	15.78
3	201.54	161.60	161.60	104.46	104.46	90.11	90.11	74.26	74.26	59.51
4	380.77	318.53	318.53	228.66	228.66	205.43	205.43	178.41	178.41	151.53
5	608.61	532.55	532.55	409.77	409.77	377.16	377.16	338.50	338.50	298.99
6	899.23	801.33	801.33	646.95	646.95	605.44	605.44	555.32	555.32	503.14
7	676.53	793.35	793.35	795.00	795.00	780.70	780.70	751.70	751.70	711.44
8	567.69	580.72	580.72	701.07	701.07	732.45	732.45	760.27	760.27	774.73
9	476.36	510.03	510.03	552.27	552.27	572.32	572.32	607.15	607.15	649.74
10	399.72	421.89	421.89	472.56	472.56	481.52	481.52	492.44	492.44	510.79
11	335.41	355.65	355.65	394.08	394.08	408.82	408.82	425.42	425.42	438.93
12	281.45	297.99	297.99	331.33	331.33	338.96	338.96	352.08	352.08	369.67
13	241.24	253.18	253.18	279.16	279.16	288.04	288.04	297.13	297.13	307.12
14	214.62	222.26	222.26	240.24	240.24	245.11	245.11	253.69	253.69	263.26
15	190.94	198.53	198.53	212.29	212.29	216.62	216.62	221.13	221.13	227.42
16	169.86	176.41	176.41	189.18	189.18	192.60	192.60	197.66	197.66	202.46
17	151.12	157.00	157.00	168.22	168.22	171.59	171.59	175.51	175.51	180.52
18	134.44	139.66	139.66	149.68	149.68	152.47	152.47	156.36	156.36	160.31
19	119.61	124.25	124.25	133.15	133.15	135.76	135.76	138.94	138.94	142.79
20	97.66	105.35	105.35	116.21	116.21	119.02	119.02	122.54	122.54	126.11
21	89.46	90.74	90.74	99.21	99.21	101.92	101.92	105.39	105.39	109.32
22	81.95	84.67	84.67	88.26	88.26	89.52	89.52	91.61	91.61	94.32
23	75.07	77.14	77.14	81.47	81.47	82.48	82.48	83.61	83.61	85.00
24	68.77	70.78	70.78	74.46	74.46	75.66	75.66	77.17	77.17	78.63

3.5. Discussion of calculations using the Muskingum method

From the calculation results, the obtained outflow value is using the Muskingum method. For each segment, the resulting outflow value varies. For example, segment 1 (study area at a distance of 4km from the study's starting point). After finding the inflow which is the result of flood discharge calculation from Nakayasu SUH, then the x and K values are calculated. The values of x and K are entered with different numbers - so get an estimate of the discharges that occur in segments 1 to segment 5. Where the largest discharge value is in segment 1 which is inflow 899.233 m<sup>3</sup>/sec and outflow 801.330 m<sup>3</sup>/sec for the 2 years return period.

From the results of these calculations can also be made flood routing graphs that illustrate inflow and outflow. As examples, Figure 9-Figure 13 illustrate for a 2-year return period with x = 0.1 in segment 1 to segment 5. From the results of calculations and estimates of obtained x and K, the flood discharge from each station has decreased. Reduction of discharge at each station reviewed is due to the occurrence of storage at the previous station.

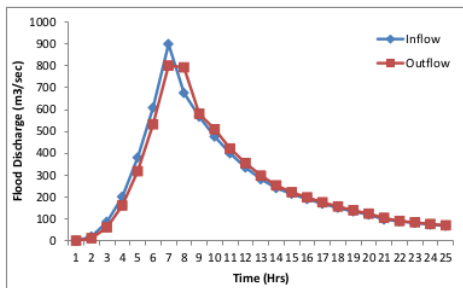


Figure 9. Flood routing for Segment 1

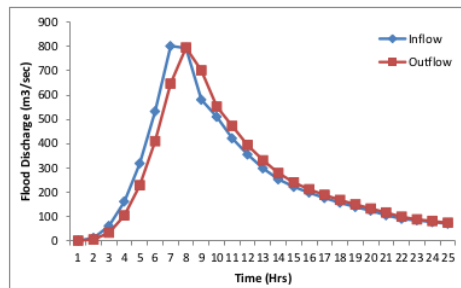


Figure 10. Flood routing for Segment 2

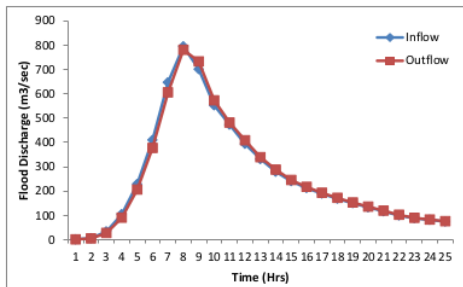


Figure 11. Flood routing for Segment 3

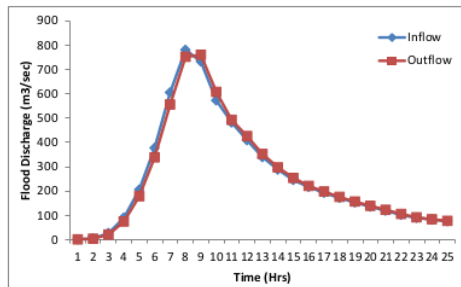


Figure 12. Flood routing for Segment 4

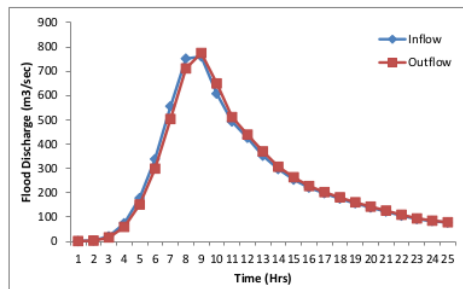


Figure 13. Flood routing for Segment 5

#### 4. Conclusion

As a conclusion, this study successfully demonstrated the implementation of mathematic model in Tallo River Flood Analysis. The values of  $x$  and  $K$  in the Tello River segment assessed are based on trial and error results in the range of 0.1 to 0.3 for the value of  $x$ . Whereas the value of  $K$  is obtained using the flood arrival time formula for each segment, namely: 1 (0.32) hour, Segment 2 (0.57) hours, Segment 3 (0.16) hours, Segment 4 (0.20) hours, and Segment 5 (0.22) hours. The results of the calculation of the Tallo River outflow using the Muskingum kinematic method have increased dynamically in the river segment. For example in the 2-year return period: Segment 1 (801.333 m<sup>3</sup>/sec), Segment 2 (794.995 m<sup>3</sup>/sec), Segment 3 (780.700 m<sup>3</sup>/sec), Segment 4 (760.273 m<sup>3</sup>/sec), and Segment 5 (774.776 m<sup>3</sup>/sec). Based on the obtained result, the value of the inflow compared to the value of the outflow is not too different. Where, this indicates that the existence of inflow of water from various sources that enter the river flow other than rainfall from downstream areas and the application of the concept of storage in flood routing.

The recommendation of this study is the parameters used to calculate the amount of outflow value need to be studied in more depth. For further research, it should involve several other parameters that affect runoff of a river so that the analysis can be done comprehensively. Lastly, the efforts to preserve the environment around the Tallo River Watershed need to be carried out so that there is no drastic flood runoff.

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