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ORIGINAL ARTICLES

Analysis of Design Flood Due to Rainfall Station Distribution

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ABSTRACT

This paper studied the analysis of design flood based on the distribution of rainfall station. Location of study was at Amprong sub-watershed, East Java-Indonesia. The methodology was consisted of observing the distribution of rainfall station using Kagan-Rodda, analysis of existing and modified design rainfall and design flood. Result could be used as consideration to move the uninfluenced rainfall station to the other location which needed it.

Key words: design flood, desgin rainfall, Kagan-Rodda

Introduction

Nowadays, amidst global climatic change, extended periods of drought, heightened demand of water and increased urbanization, the development and application of scientific knowledge and integrated water resources management policies for sustainable management of aquatic resources of paramount importance was not only to national governments but also to transnational networks (Christodoulou, E. Symeon, 2011). Such scientific knowledge and policies should cover a myriad of issues related to water, ranging from water scarcity and conservancy, climate change and their effects on water, drought, and flood to water quality, water cycling, water loss, wastewater treatment, com-modification of water, water pricing (Christodoulou, E. Symeon, 2011).

Floods are natural disasters that can cause economic damage, and loss of life and livelihoods. Estimation of discharge is vital and hence it has been a focus of research for decades. Researchers have developed several methods for this purpose including the regression-based and the soft computing methods (Taylur, Gokmen, 2011). Channel geometry equations which relate discharge to channel width or channel cross section are considered to be the most reliable.

Modeling river runoff hydrograph is a classical hydrological problem. The numerous hydrological models developed for its solution are commonly divided into conceptual and physically based, or lumped parameter and distributed-parameter models (Nasonova, O.N., 2010). Each type of models has its advantages and short comings, and the choice of the model to be applied is determined by specific problem. A large number of recent publications describe simulating river runoff hydrographs with the use of models of heat and water exchange between land surface and the atmosphere (Nasonova, O.N., 2010).

The primary objective of frequency analysis is to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions (Chow, V.T., 1988). The preciseness of hydrologic frequency analysis depends on the type of statistical distributions and parameter estimation techniques (Hassanzadeh, 2011). A lot of models have been developed to describe the distribution of hydrological data. However, the choice of a suitable model is still one of the major problems in frequency analysis.

Materials and Methods

This study was carried out at Amprong sub-watershed. Amprong river was consisted of some others rivers namely Pakis river, Jilu river, Amprong river, Nang Nung river, Lanjjir river, Tulus river, Cokro river, and Lanjing river. Number area of Amprong sub-watershed was 609.25 km^2. The study area was falls between south latitude 7^{o}54’ and 8^{p}10’ and east longitude 112^{o}37.5’ and 112^{o}56’. Map of location was as Figure 1.

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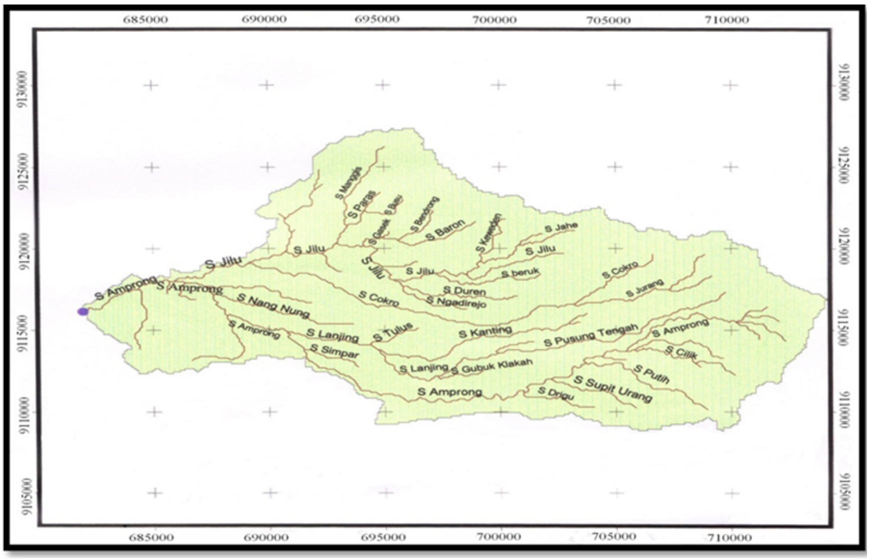

Fig. 1: Map of Amprong sub-watershed.

Data using in this study was yearly rainfall 91994-2008), daily rainfall (1994-2008), and some data of rainfall station such as the position of rainfall station and polygon of Thiessen, the distance among stations, and the number area of influenced area based on polygon of Thiessen.

Formula of Polygon Thiessen method: (Montarcih, Lily, 2010)

$$P = \frac{P_1A_1 + P_2A_2 + ... + P_nA_n}{A_1 + A_2 + ... + A_n} = \frac{\sum_{i=1}^{n} P_iA_i}{\sum_{i=1}^{n} A_i} \quad (1)$$

Note: P_1, P_2, …, P_n was rainfall at thw rainfall station of 1, 2, ….., n. A_1, A_2, …., An was number area of polygon; 1, 2, …, n. n was the number of rainfall station (Figure 2).

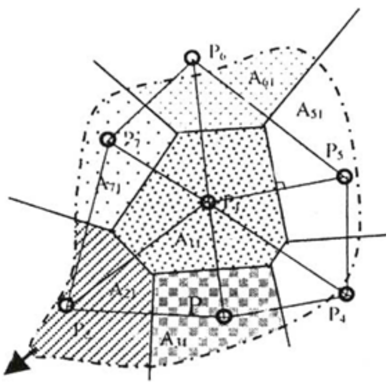

Fig. 2: Polygon Thiessen.

Formula of Design Rainfall:

The probability equation of density function was as follow (Harto Br, Sri, 1998)

$$P(X) = \frac{1}{(a)\,\Gamma\,(b)} \left[\frac{X - C}{a}\right]^{b-1} e^{-\left[\frac{X-C}{a}\right]} \quad (2)$$

Note:
P(X) = probability *X* variate

Kagan-Rodda Method:

The characteristics of Kagan-Rodda were: 1} the procedure and analysis was so simple; 2) the need of data which was supplied by available rainfall stations could be sufficed; 3) it could give phenomena pattern of rainfall stations distribution with the certain error. This method was based on statistical analysis which related density of rainfall stations with interpolation error and interpolation error averaging tool. The formula used in this method was as follow (Harto Br, Sri, 1998):

$$r_{(d)} = r_{(0)} . e^{\left(\frac{-d}{d_0}\right)} \quad (3)$$

$$Z_1 = Cv . \sqrt{\frac{\left[1 - r_{(0)} + \left(\frac{0,23 . \sqrt{A}}{d_{(0)} \sqrt{n}}\right)\right]}{n}} \quad (4)$$

$$Z_2 = Cv \sqrt{\frac{1}{3}(1 - r_0) + \frac{0,52 r_0 \sqrt{\frac{A}{n}}}{d_0}} \quad (5)$$

$$L = 1,07 \sqrt{\frac{A}{n}} \quad (6)$$

Note
$r_{(d)}$ = coefficient of correlation for the distance of stations (d)
$r_{(0)}$ = coefficient of correlation for the shortest distance of stations (d)
d = the distance inter stations (km)
$d_{(o)}$ = radius of correlation
Cv = coefficient of variation
A = number area of watershed (km^2)
N = number of stations
Z_1 = error of tool (%)
Z_2 = interpolation error (%)
L = distance of inter station (km)

Results and Discussion

Pattern of rainfall station distribution was arranged by Kagan-Rodda method. Distribution of rainfall station was described as Table 1 for existing condition) and Table 2 based on Kagan-Rodda. Design rainfall based on polygon of Thiessen was performance as Table 3 for existing condition and Table 4 based on Kagan-Rodda. Design flood for existing condition was described as Table 5 and Table 6 was based on Kagan-Rodda.

Table 1: Distribution of rainfall station (existing).

No	Name of station	Location of rainfall station	
		LS	BT
1	Jabung	7°57'16"	112°45'9"
2	Karang Ploso	7°92'43"	112°36'33"
3	Kedung Kandang	7°59'35"	112°39'20"
4	Lowokwaru	7°95'19"	112°63'59"
5	Pendem	7°91'9"	112°59'3"
6	Poncokusumo	8°2'27"	112°48'5"
7	Singosari	7°53'39"	112°39'40"
8	Tumpang	7°59'57"	112°45'38"

Table 2: Distribution of rainfall station (based on Kagan Rodda).

No	Name of station	Location of rainfall station	
		LS	BT
1	Station-1	7°84'18"	112°49'5"
2	Station-2	7°69'67"	112°57'45"
3	Station-3	7°35'81"	112°20'47"
4	Statiun04	8°91'14"	112°70'43"

Table 3: Analysis of Design rainfall (existing condition).

No	Tr (year)	R average (Log)	SD (log)	Skewness (Cs)	Probability (%)	G	Design rainfall	
							Log	mm
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	1	1,950	0,056	-1,791	99	-3,494	1,755	56,925
2	2	1,950	0,056	-1,791	50	0,281	1,966	92,432
3	5	1,950	0,056	-1,791	20	0,800	1,995	98,803
4	10	1,950	0,056	-1,791	10	0,947	2,003	100,691
5	20	1,950	0,056	-1,791	5	1,008	2,006	101,481
6	25	1,950	0,056	-1,791	4	1,039	2,008	101,879
7	50	1,950	0,056	-1,791	2	1,073	2,010	102,332
8	100	1,950	0,056	-1,791	1	1,092	2,011	102,576
9	200	1,950	0,056	-1,791	0,5	1,102	2,012	102,714
10	1000	1,950	0,056	-1,791	0,1	1,186	2,016	103,822

Note:
1 = Number
2 = Return period
3 = (SlogXi)/n
4 = ((S(LogXi-$\overline{LogX}$))/(n-1)) ^{0,5}
5 = (n.S(LogXi-$\overline{LogX}$) ^{3})/((n-1)(n-2)(SLogX) ^{3})
6 = (1/Tr)*100
7 = based on log person III table (due to skewness and return period
8 = $\overline{LogX}$ + K.SLogX
9 = antilog X

Table 4: Analysis of Design rainfall (based on rainfall station distribution using Kagan-Rodda).

No	Tr (year)	R average (Log)	SD (log)	Skewness (Cs)	Probability (%)	G	Design Rainfall	
							Log	mm
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	1	1.941	0.081	-1.032	99	-3.043	1.694	54.214
2	2	1.941	0.081	-1.032	50	0.169	1.955	90.162
3	5	1.941	0.081	-1.032	20	0.851	2.011	102.449
4	10	1.941	0.081	-1.032	10	1.108	2.031	102.140
5	20	1.941	0.081	-1.032	5	1.271	2.045	103.210
6	25	1.941	0.081	-1.032	4	1.353	2.051	106.287
7	50	1.941	0.081	-1.032	2	1.474	2.061	107.074
8	100	1.941	0.081	-1.032	1	1.566	2.069	107.184
9	200	1.941	0.081	-1.032	0.5	1.638	2.075	107.140
10	1000	1.941	0.081	-1.032	0.1	2.212	2.121	108.545

Note :
1 = Number
2 = Return period
3 = (SlogXi)/n
4 = ((S(LogXi-$\overline{LogX}$))/(n-1)) ^{0,5}
5 = (n.S(LogXi-$\overline{LogX}$) ^{3})/((n-1)(n-2)(SLogX) ^{3})
6 = (1/Tr)*100
7 = based on log person III table (due to skewness and return period
8 = $\overline{LogX}$ + K.SLogX
9 = antilog X

Table 5: Analysis of design rainfall based on polygon of Thiessen.

Return period (year)	Design rainfall	
	existing	Based on Kagan-Rodda
1	56.92	54.21
2	92.43	90.16
5	98.80	102.45
10	100.69	102.14
20	101.48	101.21
25	101.88	106.29
50	102.33	107.07
100	102.58	107.18
200	102.71	107.14
1000	103.85	108.55

Conclusion:

Based on Kagan-Rodda method, that was needed only 4 rainfall stations, but there were 8 existing rainfall stations before. The difference of design rainfall between existing and modified condition was 4.76% and the difference for design flood was 4.68%.

Table 6: Analysis of design flood.

Return period (year)	Design flood	
	existing	Based on Kagan-Rodda
1	955.83	911.14
2	1541.25	1503.81
5	1646.28	1706.39
10	1677.41	1701.30
20	1690.44	1718.94
25	1696.99	1769.67
50	1704.47	1782.65
100	1708.49	1784.46
200	1710.76	1783.74
1000	1729.03	1806.90

References

Christodoulou, E. Symeon, 2011. Water Resources Conservancy and Risk Reduction Under Climatic Instability. Journal of Water Resource Manage, 25: 1059-1062

Chow, V.T., D.R. Maidment, L.W. May, 1988. Applied Hydrology. Mc. Graw-Hill, New York.

Hassanzadeh, Yousef, Abdi, Amin, Talatahari, Siamak and Singh, P. Vijay, 2011. Meta-Heuristic Algorithms for Hydrologic Frequency Analysis. Journal of Water Resource Manage, 25: 1855-1879.

Harto Br, Sri, 1998. Optimasi Kerapatan Jaringan Stasiun Hidrologi. PAU Ilmu Teknik UGM, Yogyakarta.

Montarcih, Lily, 2010. Hidrologi Praktis. CV Lubuk Agung. 322 pages.

Nasonova, O.N., F.M. Gusev. F.E. Kovalev, 2010. Application of a Land Surface Model for Simulating Rainfall Streamflow Hydrograph: 1. Model Calibration. Journal of Water Resources, 38(2): 155-168.

Taylur, Gokmen and Singh, P. Vijay, 2011. Predicting Mean and Bankfull Discharge from Channel Cross-Sectional Area by Expert and Regression Methods. Journal of Water Resource Manage, 25: 1253-1267.