Assessment of existing urban drainage system under contemporary rainfall in Tangerang, Indonesia

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Assessment of existing urban drainage system under contemporary rainfall in Tangerang, Indonesia

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Abstract. Flood has been dealing a devastating damage to human civilization yet it even could be exacerbated by climate change which increases the amount of precipitation. The investigation on an area within Tangerang Regency reveals the recent rainfall data set has higher mean and maximum value than the older one. The newly estimated design rainfall is 1.43 times the old design rainfall. Hence the expansion of the drainage channels is required for the existing system can no longer drain the escalated rainfall. Several studies also support the revision of existing drainage systems in order to adapt the new hydrological regime due to climate changes.

1. Introduction

Flood is a perpetual and universal disaster which is yet to be contained. Policy makers, engineers, academicians, and other stakeholders have been putting great effort to handle this issue for flood is capable to inflict heavy damage. Some examples of financial damage caused by flood were:

- Lestari has reported the devastating loss of IDR 6.7 trillion for the flood in Jakarta in 2012 [1];
- Kompas newsportal estimated the loss of IDR 1 trillion for the most recent Jakarta flood in January 2020 [2];
- Another study estimated Jakarta suffered about USD 321 million (about IDR 4.7 trillion using USD 1 = IDR 14,654 conversion rate in May 2020) annually because of flooding [3];
- Wu appraised the economic loss of RMB 6.98 million (IDR 14.33 trillion using 1 RMB = 2053 IDR) for the flood in Lizhong Town in 2006 and RMB 2.2 million (IDR 4.52 trillion) for the flood in Houbai Town in 2015 [4]; and
- Huang reported the economic damage of USD 8.93 million (IDR 130 trillion) due to the flood in Hunan Province in 2008 [5].

Flood keeps recurring although most settlements already have drainage systems designed. Inadequate and erronous existing design is one of major reason, but recent researches reveal the significance of climate change and urbanization (which results in land use change) [6] [7] as the major contributors. It is important to accurately identify the problem so stakeholders can precisely formulate solutions in order to prevent flood in future.

This study aims to assess if the existing drainage system in a local area is still sufficient to anticipate flood. The objective is achieved by comparing the rainfall data set used to design the existing drainage system with the more recent rainfall data set. Afterwards, both design rainfall and channels dimension are calculated and compared.

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2. Case study

The location of the case study is at Pasar Kemis, West Tangerang, Indonesia. The coordinate of the area is 106°31'17.28"E and 6°12'24.26"S and the study focuses around the main street i.e. Otonom Pasar Kemis Street. The street is a very vital for it provides access for people and cargo to move from and to Pasar Kemis subdistrict where more than 200,000 people live [8]. Unfortunately, flood regularly strikes the area hence damaging many residential houses and infrastructures and putting the economic activities to halt.

Figure 1, **Figure 2**, and **Table 1** display the characteristics of the drainage system in the assessed area. **Figure 1** depicts the map of the drainage network and it shows the drainage channels are positioned at both sides of streets and the general flow direction is northward. **Figure 2** depicts the catchment area for each channel. The number labels in the figure are for **Table 1** where the table presents the design discharge as well as their dimensions.

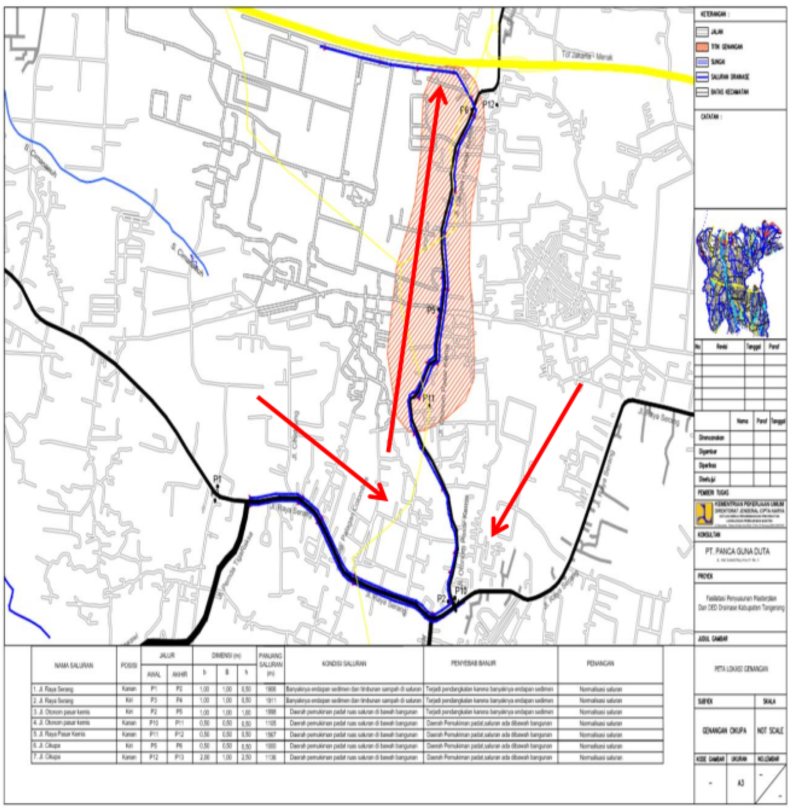

Figure 1. The plan view of the drainage network of Otonom Pasar Kemis Street (with slight modification from original figure) [9]

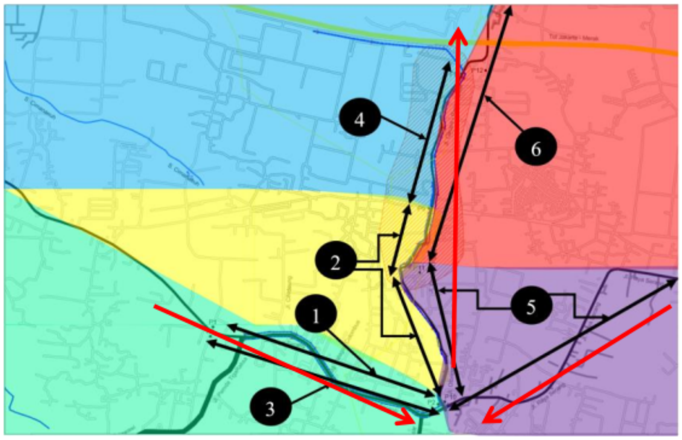

Figure 2. The sketch of catchment area of each drainage channel (based on **Figure 1**)

Table 1. The design discharge and the dimension of the channels [9]

Num	Channel (location)	Q_{desugn} $(10^{-3}\ m^3/s)$	b_{design} (m)	h_{design} (m)
1	P1-P2 (Jl. Raya Serang)	89.7	1.0	0.5
2	P2-P5 (Jl. Otonom Pasar Kemis)	179.2	1.0	1.0
3	P3-P4 (Jl. Raya Serang)	89.5	1.0	0.5
4	P5-P6 (Jl. Cikupa)	455.2	0.5	0.5
5	P10-P11 (Jl. Otonom Pasar Kemis)	40.6	0.5	0.5
6	P11-P12 (Jl. Raya Pasar Kemis)	32.2	0.5	0.5

Table 2. The comparison of rainfall used for the existing design and for the design review

Year	Rainfall for the existing design (mm)	Rainfall for the design review (mm)
1982	98.88	
1983	65.49	
1984	76.86	
1985	57.12	
1986	75.93	
1987	92.61	
1988	65.83	
1989	71.44	
1990	68.61	
1991	53.90	
1992	93.23	
1993	94.78	
1994	64.01	
1995	115.68	
1996	131.50	
1997	58.50	
1998	72.50	
1999	93.75	
2000	112.75	
2001	73.50	

Year	Rainfall for the existing design (mm)	Rainfall for the design review (mm)
2002	57.50	
2003	65.00	
2004	86.75	96.00
2005	89.25	87.70
2006	63.00	68.10
2007	79.00	227.50
2008	76.25	82.00
2009	82.00	106.00
2010	100.27	83.40
2011	80.96	83.40
2012		120.00
2013		103.40
2014		112.50
2015		152.50
2016		103.50
2017		162.60
2018		78.00

The precipitation (rainfall) for the existing design were derived from the regional averaged value of rainfall station of Cinangka, Kalen Petung, Petir, and Cadas Sari which were averaged arithmatically. Unfortunately, the whereabouts and other information about the stations are no longer available.The rainfall data used for the design review is derived from Budiarto Curug meteorology station which is positioned at 106°33'50" E and 6°17'12"S at +46 m MSL. The station is located at the southeast of Pasar Kemis. Both data for the existing design and for the design review are presented on **Table 2**.

3. Result and analysis

Firstly, the statistical parameters of rainfall for the existing design and the design review are analyzed. The recent rainfall (2004-2018) are higher in maximum, average, and standard deviation (see **Table 3**). Consequently, the newer design rainfall will be higher than the previous one. Their probability of occurences are also analyzed by plotting of non-exceedance probability for both rainfall data ($P = i / (n + 1)$; P = non-exceedance probability, i = series, n = population size). **Figure 3** shows the plotting and it clearly points out the trend shift towards heavier rain in the current condition rather than the past.

This finding is consistent with other studies which found the similarly increasing trend of maximum or extreme precipitation such as in Poland [10] or in Denmark [11]. However, this finding must be interpreted with caveat that the trend could differ from one place to others [12] hence further researches must be conducted to determine if the trend of escalating precipitation applies to its surrounding areas. Furthermore, it is very difficult to tell if the trend comes from nature, humans, or sampling variability [13].

Table 3. The comparison of statistical parameters between older and recent rainfall data

Parameter	Rainfall for the existing design (1982-2011)	Rainfall for the design review (2004-2018)
Maximum	131.50	227.50
Average	80.56	111.11
Standard deviation	18.87	41.61
Design rainfall	94.20	134.38

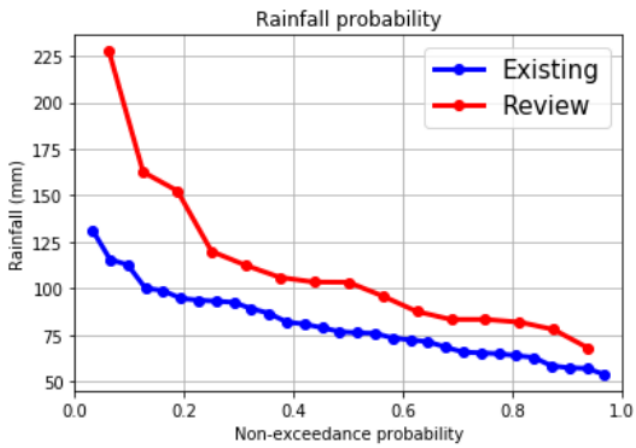

Figure 3. The probability of old and new rainfall data for existing and reviewed drainage system

The approach to obtain the channels' dimension for both design are referred to Indonesia national standard [14]. Firstly, the design rainfall is calculated by frequency analysis. By the regulation of the Public Work Ministry [15], the return period used is 5 years by taking into account the population of the city. The result is presented at the bottom line of **Table 3** which outlines the growth of the design rainfall by 43 % (from 94.20 mm to 134.38 mm).

The consequence of escalating rainfall is the necessity of larger drainage channels' capacity. Manning formula is employed to calculate the required channel's dimension in order to sufficiently drain the incoming flood. The design parameters for the design review are similar to the existing design except for the rainfall data. The results are presented on **Table 4** which indicates the increasing design discharge for the drainage network. It directly translates into the need to increase the dimension of the channels so that they can prevent incoming flood.

Table 4. The difference in the channels' specification between using the older rainfall data and the more recent data

Num	Channel	Existing design			Design review		
		Q_{desugn} (10^{-3} m^3/s)	b_{design} (m)	h_{design} (m)	Q_{review} (10^{-3} m^3/s)	b_{review} (m)	h_{review} (m)
1	P1-P2	89.7	1.0	0.5	128.0	1.0	0.6
2	P2-P5	276.0	1.0	1.0	393.7	1.0	1.3
3	P3-P4	89.5	1.0	0.5	127.7	1.0	0.6
4	P5-P6	43.4	0.5	0.5	61.9	0.5	0.6
5	P10-P11	40.6	0.5	0.5	57.9	0.5	0.6
6	P11-P12	32.2	0.5	0.5	45.9	0.5	0.6

4. Conclusion

The existing drainage system in Pasar Kemis (Tangerang) is no longer sufficient to drain the incoming flood under the new hydrological regime. It increases the maximum or extreme rainfall which results in the need to expand the existing drainage channels' dimension. Furthermore, the effect of urbanization has not been taken into account thus the required expansion could be possibly even larger.

It is still technically difficult for certain to attribute the trend of the escalating maximum rainfall to climate changes and more researches are required to confirm this. Many studies around the world have already been performed which indicate the need to increase the capacity of the current urban drainage system due to climate changes [16] [17] [18]. However, there are still so many uncertainities about the relation between climate changes and precipitation characteristics. Climate changes could increase extreme or mean precipitation such as in this paper, but it also could change its duration and temporal distribution throughout a year and it could change other things yet to be hitherto revealed. Although the relation between them is still vague at best, incorporating the effect of climate change in designing drainage system is very important to protect people from flood.

References

[1] Lestari S 2002 *J. Sains & Teknologi Cuaca* **3** 159
[2] Money.Kompas.com, 2020.
[3] Budiono Y, Arts J, Brinkman J, Marfai M A and Ward P 2015 *Nat. Hazards*. **75**. 413
[4] Wu X, Zhou L, Gao G, Guo J and Ji Z 2016 *Nat. Hazards* **82** 2000
[5] Huang X et al 2008 *Nat. Hazards*, **47** 73.
[6] Willems P, Arnbjerg-Nielsen K, Olsson J and Nguyen V 2011 Atmosp. Res **103** 118.
[7] Jung M, Kim H, Mallar K J B, Pak G and Yoon J 2015 *Water Sci. Tech.* **71** 660
[8] Simanungkalit D D C, Sutandi A and Kurniawan V 2020 *J. Mitra Teknik Sipil* **3** 454.
[9] Bappeda Kabupaten Tangerang 2014 Fasilitasi Penyusunan Masterplan dan DED Drainase Kabupaten Tangerang
[10] Kaźmierczak B and Kotowski A 2013 *Theor. and Appl. Climatology* **118** 296
[11] Arnbjerg-Nielsen K 2012 *Urban Water J* **9** 65
[12] Pińskwar I, Choryński A, Graczyk D and Kundzewicz Z W 2019 *Theor. and Appl. Climat*. **135** 787
[13] Willems P, Arnbjerg-Nielsen K, Olsson J and Nguyen V 2012 *Atmosp. Res*. **103** 118
[14] Badan Standardisasi Nasional 2016 SNI 2415:2016 Tata cara perhitungan debit banjir rencana
[15] Kementerian Pekerjaan Umum and Perumahan Rakyat 2014 Peraturan Menteri Nomor 12 Tahun 2014 tentang Penyelenggaraan Sistem Drainase Perkotaan
[16] Mailhot A and Duchesne S 2010 *J. Water Res. Plan. and Manage.* **136** 208
[17] Willems P 2013 *J. Hydrology* **496** 177.
[18] Notaro V, Liuzzo L, Freni G and Loggia G L 2015 *Water* **7** 6945

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