The effect of land use change to surface runoff discharge in the POMPONG watershed at Bangka regency

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Abstract. Changes in land use cause a reduction in water infiltration, and can cause environmental damage such as floods and inundation. Flood inundation occurred frequently every year. In addition, other environment damage is a change in morphological characteristics around the river. This happened in the Pompong watershed with an area of 7,701.192 hectares located in Bangka Regency. The purpose of this study was to determine the effect of runoff coefficient (C) and total surface runoff discharge (Qp). The method used in this study is the Nakayasu HSS method with a return period of 50 years. Land use changes were analyzed from 2009 to 2018. The result of the analysis showed that the amount of surface runoff discharge (Qp) in the Pompong watershed was strongly influenced by land use changes. The change occurred from 2012-2013 with a decrease in C value of 0.001 resulting in a Qp value of 0.943 m$^3$/second, a C value in 2014-2015 decreased by 0.007 resulting in a Qp value of 5.395 m$^3$/second, in 2015-2018 there was an increase a C value of 0.116 results in a Qp values of 100.512 m$^3$/second.

1. Introduction
The increasing number of people is directly proportional to the need for land for shelter and activities. Based on information from relevant agencies [1] the Pompong watershed in 2009-2018 underwent a change in land use from agricultural to residential and mining areas. Land use changes other than the Pompong watershed also occur in other watersheds such as the Kantung watershed where the area that was originally a forest became a residential and agricultural area which has an impact on increasing the runoff coefficient value [2].

The Pompong watershed is located in the Sungailiat City, Bangka Regency with an area of 7,701.192 hectares [3]. Sungailiat City as a centre of education and tourism with a fixed area and followed by an increase in population every year, it will have an impact on increasing land needs. Demands for land requirements such as residential areas, offices, trade and industry. The need for new land requires an expansion of the existing area, so that it will have an impact on the land use change.

The impact of land use changes in the Pompong watershed can cause a reduction in water catchment areas, an increase in runoff coefficient values, resulting in an increase in runoff discharge
which causes environmental damage that is flooding and inundation that always occurs in around the river.

Changes in the behaviour and function of surface water can lead to a reduction in base flow and infiltration as well as an increase in surface runoff. In addition, river capacity is also affected by surface runoff in a river flow. Increased surface runoff in river flow can cause flooding and inundation in downstream areas during the rainy season [4].

Several studies related to land use changes have been conducted by several researchers before. The study obtained factors that influence the occurrence of an increase in runoff coefficient and the amount of surface runoff, including: land use change [5],[6],[7], land use or land use change [8],[9],[10], and land use [11].

From the problems above, it is necessary to conduct research to determine the effect of runoff coefficient (C) and the amount of surface runoff discharge (Qp) in the Pompong watershed in Bangka Regency.

2. Research Method
This study uses the Nakayasu method to analyse the synthesis unit hydrograph (HSS) modelling. For HSS modelling, watershed data is needed [1],[3], including rainfall data, watershed area (A), flow coefficient (C) [12], rain depth unit (Ro) is set at 1 mm [13], time from flood start to peak hydrograph (tp), time from flood peak to 0.3 times peak discharge (t0.3) [13]. This study uses maximum annual daily rainfall data obtained from relevant agencies [1] for the last 10 years, namely the 2009-2018 period. Furthermore, this data is used to determine design rain. There are three stages to calculating design rain, namely:

- Daily rainfall data obtained from related agencies [14], then processed into annual maximum daily rainfall data.
- After that the maximum annual daily rainfall data is analyzed for the determination of design rainfall. The data needed is then analyzed the distribution of maximum rainfall frequency using probability distribution methods i.e. the Gumbel, Normal, Log Normal, and Log Pearson III.
  - If the values of each of the above distribution have obtained, a frequency distribution conformity test is performed by conducting the Chi-Square Test (χ²) and the Smirnov-Kolmogorov Test
  - If it fulfills what is required, then it can be followed by determining the design rain.

The amount of surface flow is calculated using the Nakayasu synthetic unit hydrograph method. The same method was also used by previous researchers [15], [16]. The amount of surface runoff discharge (Qp) is influenced by one factor, namely land use which is related to the value of the flow coefficient (C).

The delay time (td) is obtained from 0.4 plus 0.058 times the river length (L), while to get the duration of rain (T) obtained by multiplying 0.5 times the delay time (td). After obtaining the value of the time delay (td) and duration of rain (T) can be calculated the time from the beginning of the flood to the peak of the hydrograph (tp). For the time value from the beginning of the flood to the top of the hydrograph (tp) obtained from the time of delay (td) plus 0.8 times the duration of rain (T).

To get the time from the peak of the flood to 0.3 times the peak discharge (t0.3), it takes the values of the characteristic coefficient of the watershed (α) and the delay time (td), while the α value is obtained from 0.47 times the area of the watershed (A) times the length of river (L) power 0.25 divided by the time delay (td). For t0.3 is obtained by multiplying the values of α and td.
3. Result
From the results of the research that has been done, the results obtained as presented in Table 1 to Table 5 below. Recapitulation of the flow coefficient (C) from 2009-2018 can be seen in Table 1 below.

The Pompong watershed area (A) is 77.012 km², rain depth unit (R_o) is set at 1 mm, peak time (t_p) is 2.222 hours and \( t_{0.3} \) is 2.961 hours. The peak discharge values can be seen in Table 2. The design rainfall value (\( R_{24} \)) uses the Gumbell probability distribution with a return period of 50 years which is 232.564 mm. The effective rain value can be seen in Table 3. After effective rainfall is obtained then effective rainfall is counted for hours for 3 hours. For the results of the effective rain hours calculation can be seen in Table 4. Calculation of flood hydrograph from 2009-2018 is needed to find out the total direct hydrograph due to effective rain hourly. Surface runoff discharge values can be seen in Table 5.

### Table 1. Recapitulation of C value in 2009 to 2018

| No. | Year | Runoff Coefficient (C) |
|-----|------|------------------------|
| 1.  | 2009 | 0.390                  |
| 2.  | 2010 | 0.390                  |
| 3.  | 2011 | 0.390                  |
| 4.  | 2012 | 0.390                  |
| 5.  | 2013 | 0.388                  |
| 6.  | 2014 | 0.388                  |
| 7.  | 2015 | 0.381                  |
| 8.  | 2016 | 0.497                  |
| 9.  | 2017 | 0.497                  |
| 10. | 2018 | 0.497                  |

*Source: Research result, 2019*

### Table 2. Peak discharge in the Pompong watershed from 2009-2018

| No. | Year | Peak Discharge (m³/second) |
|-----|------|---------------------------|
| 1.  | 2009 | 2.298                     |
| 2.  | 2010 | 2.298                     |
| 3.  | 2011 | 2.298                     |
| 4.  | 2012 | 2.298                     |
| 5.  | 2013 | 2.291                     |
| 6.  | 2014 | 2.291                     |
| 7.  | 2015 | 2.249                     |
| 8.  | 2016 | 2.933                     |
| 9.  | 2017 | 2.933                     |
| 10. | 2018 | 2.933                     |

*Source: Research result, 2019*
Table 3. The effective rainfall value from 2009-2018

| No. | Year | Design rainfall ($R_{24}$) (mm) | Runoff coefficient ($C$) | Effective rainfall (mm) |
|-----|------|----------------------------------|--------------------------|-------------------------|
| 1.  | 2009 | 232.564                          | 0.390                    | 90.629                  |
| 2.  | 2010 | 232.564                          | 0.390                    | 90.629                  |
| 3.  | 2011 | 232.564                          | 0.390                    | 90.629                  |
| 4.  | 2012 | 232.564                          | 0.390                    | 90.629                  |
| 5.  | 2013 | 232.564                          | 0.388                    | 90.343                  |
| 6.  | 2014 | 232.564                          | 0.388                    | 90.343                  |
| 7.  | 2015 | 232.564                          | 0.381                    | 88.689                  |
| 8.  | 2016 | 232.564                          | 0.497                    | 115.680                 |
| 9.  | 2017 | 232.564                          | 0.497                    | 115.680                 |
| 10. | 2018 | 232.564                          | 0.497                    | 115.681                 |

Source: Research result, 2019

Table 4. Effective rain hours from 2009-2018

| No. | Year | Effective rainfall (mm) | $\Delta X$ | Effective rain hours (mm) |
|-----|------|-------------------------|------------|---------------------------|
|     |      |                         | $X_1 = 58.480\%$ | $X_2 = 15.200\%$ | $X_3 = 10.663\%$ |
|     |      |                         | $[4] = X_1[3]$ | $[5] = X_2[3]$ | $[6] = X_3[3]$ |
| 1.  | 2009 | 90.629                  | 53.000      | 13.776                    | 9.663         |
| 2.  | 2010 | 90.629                  | 53.000      | 13.776                    | 9.663         |
| 3.  | 2011 | 90.629                  | 53.000      | 13.776                    | 9.663         |
| 4.  | 2012 | 90.629                  | 53.000      | 13.776                    | 9.663         |
| 5.  | 2013 | 90.343                  | 52.833      | 13.732                    | 9.633         |
| 6.  | 2014 | 90.343                  | 52.833      | 13.732                    | 9.633         |
| 7.  | 2015 | 88.689                  | 51.865      | 13.481                    | 9.457         |
| 8.  | 2016 | 115.680                 | 67.650      | 17.584                    | 12.335        |
| 9.  | 2017 | 115.680                 | 67.650      | 17.584                    | 12.335        |
| 10. | 2018 | 115.681                 | 67.651      | 17.584                    | 12.335        |

Source: Research result, 2019
Table 5. Surface runoff discharge ($Q_p$) by using Nakayasu HSS method

| No. | Year | $Q_p$ (m$^3$/second) |
|-----|------|----------------------|
| 1.  | 2009 | 149.660              |
| 2.  | 2010 | 149.660              |
| 3.  | 2011 | 149.660              |
| 4.  | 2012 | 149.660              |
| 5.  | 2013 | 148.717              |
| 6.  | 2014 | 148.717              |
| 7.  | 2015 | 143.322              |
| 8.  | 2016 | 243.833              |
| 9.  | 2017 | 243.833              |
| 10. | 2018 | 243.837              |

Source: Research result, 2019

The relationship of runoff coefficient ($C$) to surface runoff discharge ($Q_p$), it appears that if the runoff coefficient ($C$) is getting higher, then the surface runoff discharge ($Q_p$) produced will be even greater. Land use is one of the factors that influence the runoff coefficient. A good land use will make the runoff coefficient value low, whereas unfavourable land use will cause a high runoff coefficient value. The graph of the correlation coefficient of runoff ($C$) to surface runoff discharge ($Q_p$) can be seen in Figure 1.

![Figure 1. Relationship of runoff coefficient with surface runoff discharge](source: research result, 2019)

4. Conclusion
Changes in land use in the Pompong watershed from 2009 to 2018 affect the value of $C$ which in turn affects the amount of surface runoff discharge. The change occurred from 2012-2013 with a decrease
in $c$ value of 0.001 resulting in a $Qp$ value of 0.943 m$^3$/second. The C value in 2014-2015 decreased by 0.007 resulting in a $Qp$ value of 5.395 m$^3$/second. In 2015-2018, an increase in C value of 0.116 produces a $Qp$ value of 100.512 m$^3$/second.

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Acknowledgement
We gratefully acknowledge the funding from Universitas Bangka Belitung through the RKAKL FT for the publication of this paper.