ANALYSIS OF DRAINAGE CHANNEL CAPACITY AT SINDANG STREET IN SINDANG HOUSE PUMP AREA

Mohammad Imamuddin¹, Dwi Cahyanto²

¹Lecturer in the Department of Civil Engineering, Universitas Muhammadiyah Jakarta, INDONESIA
²Student in the Department of Civil Engineering, Universitas Muhammadiyah Jakarta, INDONESIA

E-mail: imamuddin0001@gmail.com

ABSTRACT

Sindang street, which is located in North Rawabadak Sub-district, Koja District, is one of the areas in North Jakarta Administrative City which is an area that is prone to flooding. Even though a working pump house is available, there are still puddles in several places. One of the problems that occur is the channel that drains water into the storage pool narrowing due to sedimentation in the channel. By analyzing the channel using the Log Pearson III distribution method using data obtained from the STA Tanjung Priok Rainfall Station, the rainfall intensity that occurs in a 5 year cycle is 170.748 mm, the Mononobe equation is used to find the intensity of rain per hour that occurs. Then it can be searched for the planned rain discharge using a Rational Method so that it is known that there are 2 channels, namely (P and Q) unable to accommodate the rainfall that occurs.

Key word: puddle; channel; drainage; pump area; rainfall.

INTRODUCTION

Sindang Pump House is one of the pump houses located at 6° 6'56.70" south latitude and 106° 53'45.57" east longitude. To the west of the Sindang Pump House is the Rawa Badak Market, to the south there is a residential area and an industrial area, while to the east there is the Sunter River which empties into Jakarta Bay. The north side of the Sindang Pump House is a busy shopping center. Although there is a Sindang Pump House that is prepared to deal with flooding, puddles still occur when there is rain with high rainfall intensity. However, this condition does not last long, if the rain stops, the puddles will disappear over time. Another problem is natural factors in the form of sedimentation and dry leaves in the channel along Jl. Sindang which blocks the flow of water to the Sindang Pump House. The channel around Rawa Badak Utara Park has a closed channel which makes it difficult to clean up sedimentation and trash in the channel. Where the channel also has deep sedimentation, the channel also has a pungent odor that is not good because the water does not flow into the reservoir of the Sindang Pump House. In the western part of the Sindang Pump House there is also a shopping center and Rawa Badak Market, the problem that occurs in this area is that the drainage channel in front of the market is misused by local traders for selling places. From the above conditions, the writer wants to analyze the problems of the channel around the Sindang Pump House area which can be an evaluation of citizens and the government in order to handle carefully the problems surrounding frequent flooding.

The rain that comes every day will cause the volume of water to increase on the surface, this volume of water will affect the water reservoir to overflow. This water overflow will cause flooding so that the performance of the pump house always works optimally (Iban S, 2017); (Siti NF et al, 2016); (Muslim PA, Muhamad L, 2016).

Research purposes

The aim of this research is:
a. Knowing the rain discharge that enters the channel.

b. Knowing the channel's ability to accommodate rain discharge.

**Frequency and Probability Analysis**

In statistics, there are several parameters related to data analysis which include the average value ($\bar{X}$), standard deviation (s), coefficient of variation (Cv), coefficient of skewness (Cs), and coefficient of kurtosis (Ck).

\[ \bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \]  \hspace{1cm} (1)

\[ s = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}} \]  \hspace{1cm} (2)

\[ Cv = \frac{s}{\bar{X}} \]  \hspace{1cm} (3)

\[ Cs = \frac{n \times \sum_{i=1}^{n} (X_i - \bar{X})^3}{(n-1) x (n-2) x s^3} \]  \hspace{1cm} (4)

\[ Ck = \frac{n^2 x \sum_{i=1}^{n} (X_i - \bar{X})^4}{(n-1) x (n-2) x (n-3) x s^4} \]  \hspace{1cm} (5)

Explanation:

- $\bar{X}$ = Average value
- $X_i$ = Value of variant
- $n$ = Amount of data
- $s$ = Standard deviation
- $Cv$ = Coefficient of variation
- $Cs$ = Coefficient of skewness
- $Ck$ = Coefficient of kurtosis

**Normal Distribution**

Normal distribution is also called the Gauss distribution, the normal distribution equation:

\[ X_t = X + K_t \cdot S_x \]  \hspace{1cm} (6)

Explanation:

- $X_t$ = Rainfall plan return period T year (mm)
- $X$ = Rainfall average value (mm)
- $K_t$ = Frequency factor (Gauss variable value)
- $S_x$ = Standard deviation

**Gumbel distribution**

The following is the formula for the Gumbel Method:

\[ X = \bar{Y} + \left( \frac{Y_t - \bar{Y}}{s_Y} \right) \cdot S_x \]  \hspace{1cm} (7)

Explanation:
\( X_t \) = Rainfall plan return period T year (mm)
\( \bar{X} \) = Rainfall average value (mm)
\( Y_t \) = Reduced variate of Gumbel parameter for period T years
\( Y_n \) = Reduced mean is a function of the amount of data
\( S_n \) = Reduced standard deviation
\( S_x \) = Standard deviation

**Log-normal distribution**

The normal log distribution is the result of a transformation from another distribution, namely the normal distribution, where by changing the variate \( X \) into a logarithmatic value of the \( X \) value, the following is a mathematical model with a normal log distribution:

\[
Y = \bar{Y} + K \cdot S_d
\]

Explanation:
\( Y \) = logarithmatic value of \( x \) or \( \ln x \) value
\( \bar{Y} \) = The calculated average value of the data
\( K \) = Characteristics of the log-normal probability distribution
\( S_d \) = Standard deviation

**Pearson III Log Distribution**

Karl Pearson developed several kinds of empirical equations from a distribution, one of which is the Pearson III log distribution, the following is the log Pearson type III probability distribution formula as follows:

\[
\log X_t = \log X + G \cdot S_x
\]

Explanation:
\( \log X_t \) = Rainfall plan return period T year (mm)
\( \log X \) = Rainfall average value (mm)
\( G \) = Standard variable for \( X_t \)
\( S_x \) = Standard deviation

**Rainfall Intensity**

If the only available rainfall data is daily rainfall, dr. Mononobe formulates its rainfall intensity as follows:

\[
I = \frac{R_{24}}{t} \left[ \frac{24}{t} \right]^{2/3}
\]

Explanation:
\( R_{24} \) = Maximum rainfall in 24 hours (mm)
\( t \) = Duration of rainfall (hour)
\( I \) = Rainfall intensity (mm/hour)
Peak Runoff Rates
To calculate the Peak Runoff Rates at a drainage, the following Rational Method calculations are used:

\[ Q = 0.278 \cdot C \cdot I \cdot A \]  

(11)

Explanation:
- **Q** = Surface runoff peak discharge (m³/sec)
- **C** = Runoff coefficient
- **I** = Rainfall intensity (mm/hour)
- **A** = Area of drainage area (km²)

Time of Rain Intensity Concentration (Tc)
To find the concentration time (Tc), it can be calculated using the Kirpich formula as follows:

\[ T_c = \frac{0.0145 + 16.77}{50.385} \]  

(12)

Explanation:
- **T_c** = Concentration time (minutes)
- **L** = The length of the water's path from the farthest point to the point under review (m)
- **S** = Slope of the channel

Average Flow Speed (V)
To find the average flow velocity (V), use the following formula:

\[ V = \frac{1}{n} \cdot R^{7/2} \cdot S^{1/2} \]  

(13)

Explanation:
- **V** = Average flow velocity (m/sec)
- **n** = Manning's roughness coefficient
- **R** = Hydraulic radius (m)
- **S** = Channel slope

Calculating the Discharge of Existing Channels
The purpose of examining the existing channel is to find out the amount of water flow that can be accommodated by the channel with its current state. Analysis of the capacity of the drainage channel is carried out to determine the ability of the existing drainage channels to the calculated discharge plan.

Channel Discharge
The following is the channel discharge formula as follows:

\[ Q = A \cdot V \]  

(14)

Explanation:
- **Q** = Flow rate (m³/sec)
- **A** = Wet cross-sectional area (m)
- **V** = Average flow velocity (m/sec)
The slope of the channel is obtained from the slope of the contour map in Google Earth. Here is the formula for finding the slope of the channel:

\[ S = \frac{\Delta H}{L} \]  \hspace{1cm} (15)

**Explanation:**
- \( S \) = The slope of the channel
- \( \Delta H \) = The difference between the height of the farthest point and the drainage area
- \( L \) = Channel length (m)

**Wet cross-sectional area**
The following is the formula for finding the wet cross-sectional area of the channel:

\[ A = b \cdot h \]  \hspace{1cm} (16)

**Explanation:**
- \( A \) = Wet section of the channel (m²)
- \( b \) = Channel width (m)
- \( h \) = Water height (m)

**Hydraulic Radius**
Here is the formula for finding the Hydraulic Radius on the channel:

\[ R = \frac{A}{P} \]  \hspace{1cm} (17)

**Explanation:**
- \( R \) = Hydraulic Radius (m)
- \( A \) = Wet cross-sectional area (m²)
- \( P \) = Wet circumference (m)

**RESEARCH METHODOLOGY**

**Data collection**
Data collection techniques in this study are primary data collection which is data obtained directly from direct observation in the field, namely in the form of dimensional data on drainage channels around the pump house area and secondary data collection which is data that already exists and obtained from other parties related to this research. Secondary data includes rainfall data and maps from google earth. Secondary data were obtained from STA Tanjung Priok and agencies related to research.

![Figure 1. Research location](image-url)
Analysis of the frequency of rainfall data

The calculation of the frequency analysis of the rainfall data is carried out in order to obtain the value of the planned rainfall using several probability distribution analyzes including Gumbel, Normal, Normal Log and Person III Log. By using a 5-year rainfall cycle.

Analysis of channel capacity

Calculation of channel drainage capacity analysis at the study location points using the equations contained in the literature review related to channel drainage capacity calculations.

RESULTS AND CONCLUSION

Rainfall Data Analysis

Maximum daily rainfall data is obtained from badan Meteorologi, Klimatologi, dan Geofisika (BMKG). The observation location of Tanjung Priok Maritime Meteorology Station for 15-years.

| Table 1. Maximum rainfall data |
|-------------------------------|
| Year | Maximum Rainfall |
| 2005 | 109,9 |
| 2006 | 90,3 |
| 2007 | 182,2 |
| 2008 | 87,9 |
| 2009 | 148,9 |
| 2010 | 88,3 |
| 2011 | 78,5 |
| 2012 | 75,1 |
| 2013 | 117,8 |
| 2014 | 284 |
| 2015 | 247 |
| 2016 | 112,7 |
| 2017 | 148,6 |
| 2018 | 129,6 |
| 2019 | 130,3 |

| No | Xi  | (Xi – X) | (Xi – X)² | (Xi – X)³ | (Xi – X)⁴ |
|----|-----|----------|-----------|-----------|-----------|
| 1  | 109,9 | -25,51   | 650,59    | -16594,38 | 423267,41 |
| 2  | 90,3  | -45,11   | 2034,61   | -91774,54 | 4139643,46 |
| 3  | 182,2 | 46,79    | 2189,62   | 102459,43 | 4794418,42 |
| 4  | 87,9  | -47,51   | 2256,88   | -107217,01| 5093522,58 |
| 5  | 148,9 | 13,49    | 182,07    | 2456,73   | 33149,50  |
| 6  | 88,3  | -47,11   | 2219,04   | -104531,49| 4924129,84 |
| 7  | 78,5  | -56,91   | 3238,37   | -184284,77| 10487031,91|
From the table above we can find out the values which include the average value ($\bar{X}$), standard deviation ($s$), coefficient of variation (Cv), coefficient of skewness (Cs), and coefficient of kurtosis (Ck):

1. Average value ($\bar{X}$) = 135.40
2. Standard deviation ($s_d$) = 60.94
3. The coefficient of variation (Cv) = 0.45
4. The coefficient of skewness (Cs) = 1.46
5. The coefficient of kurtosis (Ck) = 5.12

**Table 3.** The results of the calculation of the distribution method and the terms of the distribution method

| No | Distribution  | Requirements | Result      | Explanation       |
|----|---------------|--------------|-------------|-------------------|
| 1  | Gumbel        | Cs < 1.14    | Cs = 1.4696 | not eligible      |
|    |               | Ck < 5.4     | Ck = 5.1235 | eligible          |
| 2  | Normal        | Cs = 0      | Cs = 1.4696 | not eligible      |
|    |               | Ck = 3      | Ck = 5.1235 | not eligible      |
| 3  | Log Normal    | Cs = 1.441  | Cs = 1.4696 | not eligible      |
| 4  | Log Pearson III | Ck = 6.908 | Ck = 5.1235 | not eligible      |

Rainfall Plan Pearson Log Method III

After calculating the rainfall, the standard deviation, the slope coefficient, and the sharpness coefficient. Next, calculate the return period according to the method that meets the requirements, namely the Log-Pearson III method.

**Table 4.** Rainfall plan log Pearson III method

| No | Tahun | Xi    | Log Xi | $(\log Xi - \log X)^2$ | $(\log Xi - \log X)^3$ |
|----|-------|-------|--------|------------------------|------------------------|
| 1  | 2005  | 109.9 | 2.0410 | 0.0032                 | -0.0002                |
| 2  | 2006  | 90.3  | 1.9557 | 0.0200                 | -0.0028                |
| 3  | 2007  | 182.2 | 2.2605 | 0.0267                 | 0.0044                 |
From the table above we can find out the values which include the Log average value \( \bar{X} \), standard deviation Log x (Sd) and skewness coefficient of Log x (Cs):

1. Log average value \( \bar{X} \) Log x = 2,0972
2. Standard deviation \( S_d \) Log x = 0,1721
3. Skewness coefficient \( Cs \) log x = 0,7549

| Location | Area (Km) | Run off coefficient |
|----------|-----------|---------------------|
| A        | 0,009102  | 0,616710613         |
| B        | 0,0000628 | 0,15                |
| C        | 0,025433  | 0,579328038         |

Calculate the Run off Coefficient
Based on the existing condition of the channel which has different dimensions and the location of the channel between the residential area and the main road, the catchment area is divided into 17 sections.

| Year cycle (T) | (average value of Log X) | Nilai (G) | Sd log X | Log X tahun | Rain plain (mm) |
|----------------|---------------------------|------------|----------|-------------|-----------------|
| 2              | 2,0973                    | -0,125     | 0,17217  | 2,076       | 119,069         |
| 5              | 2,0973                    | 0,785      | 0,17217  | 2,232       | 170,746         |
| 10             | 2,0973                    | 1,335      | 0,17217  | 2,327       | 212,357         |
| 25             | 2,0973                    | 1,981      | 0,17217  | 2,438       | 274,408         |
| 50             | 2,0973                    | 2,432      | 0,17217  | 2,516       | 328,127         |
| 100            | 2,0973                    | 2,861      | 0,17217  | 2,590       | 388,886         |
| 200            | 2,0973                    | 3,272      | 0,17217  | 2,661       | 457,718         |
Calculating Rainfall Intensity
Before looking for channel rainfall intensity, first calculate the time of rain intensity concentration that occurs using the Kirpich formula.

| Location | L  | S          | Tc minute | Tc hour |
|----------|----|------------|-----------|---------|
| A        | 263| 0,003802   | 12,1642   | 0,202737|
| B        | 6,33| 0,020537   | 0,360402  | 0,006007|
| C        | 253| 0,003953   | 11,63158  | 0,19386 |
| D        | 245| 0,004082   | 11,20783  | 0,186797|
| E        | 242| 0,004132   | 11,04947  | 0,184158|
| F        | 218| 0,004587   | 9,793814  | 0,16323 |
| G        | 280| 0,010714   | 8,566639  | 0,142777|
| H        | 797| 0,003764   | 28,67658  | 0,477943|
| I        | 285| 0,007018   | 10,22078  | 0,170346|
| J        | 175| 0,005714   | 7,598775  | 0,126646|
| K        | 1220| 0,001639  | 54,81301  | 0,91355 |
| L        | 312| 0,00641    | 11,34715  | 0,189119|
| M        | 73 | 0,013699   | 2,768041  | 0,046134|
| N        | 209| 0,009569   | 7,143434  | 0,119057|
| O        | 124| 0,008065   | 5,104305  | 0,085072|
| P        | 287| 0,003484   | 13,45514  | 0,224252|
| Q        | 84,8| 0,011792 | 3,29103   | 0,05485 |

Table 7. Calculating Time of Channel Concentration (Tc)

| Location | Year cycle (T) | Rain plain | Rainfall intensity (I) |
|----------|----------------|------------|------------------------|
| A        | 0,039096       | 0,576074279|
| E        | 0,044537       | 0,578205762|
| F        | 0,046903       | 0,577645353|
| G        | 0,032986       | 0,838151337|
| H        | 0,165          | 0,814666667|
| I        | 0,023266       | 0,857040316|
| J        | 0,005255       | 0,899838249|
| K        | 0,1086         | 0,83035221 |
| L        | 0,004487       | 0,95       |
| M        | 0,009971       | 0,861854378|
| N        | 0,010916       | 0,858299743|
| O        | 0,004747       | 0,866305035|
| P        | 0,025905       | 0,856438911|
| Q        | 0,001401       | 0,871413276|

Table 8. Rainfall Intensity
Plan Rain Discharge ($Q_T$)
The calculation of the planned rainfall discharge uses a rational method.

| Location | Year cycle | Run off coefficient (C) | Rainfall intensity (I) | Catchment Area (A) | Peak Runoff Rates ($Q_t$) |
|----------|------------|-------------------------|------------------------|---------------------|--------------------------|
| A        | 5          | 0.017                   | 171,469                | 0.009               | 0.268                    |
| B        | 5          | 0.150                   | 1790.394               | 0.000               | 0.272                    |
| C        | 5          | 0.579                   | 176,664                | 0.025               | 0.996                    |
| D        | 5          | 0.576                   | 181,089                | 0.039               | 2.130                    |
| E        | 5          | 0.578                   | 182,815                | 0.045               | 3.438                    |
| F        | 5          | 0.578                   | 198,123                | 0.047               | 4.931                    |
| G        | 5          | 0.838                   | 216,617                | 0.033               | 1.665                    |
| H        | 5          | 0.815                   | 96,809                 | 0.165               | 3.618                    |
| I        | 5          | 0.857                   | 192,567                | 0.023               | 4.685                    |
| J        | 5          | 0.900                   | 234,639                | 0.005               | 11.589                   |
| K        | 5          | 0.830                   | 62,858                 | 0.109               | 1.576                    |
| L        | 5          | 0.950                   | 179,604                | 0.004               | 1.789                    |
| M        | 5          | 0.862                   | 459,993                | 0.010               | 2.888                    |
| N        | 5          | 0.858                   | 244,506                | 0.011               | 3.524                    |
| O        | 5          | 0.866                   | 305,909                | 0.005               | 3.874                    |
Based on the peak runoff rates and the existing channel capacity, it can be compared to determine whether the channel capacity is able or not to accommodate the rain discharge.

Table 11. Comparison of channel discharge capacity with rain discharge

| Area | Discharge | Explanation | Discharge | Explanation |
|------|-----------|-------------|-----------|-------------|
| A    | 0.268     | 1,396       | Eligible  | 2,280       | Eligible     |
| B    | 0.272     | 3,686       | Eligible  | 5,300       | Eligible     |
| C    | 0.996     | 7,552       | Eligible  | 9,454       | Eligible     |
| D    | 2,130     | 6,161       | Eligible  | 9,607       | Eligible     |
| E    | 3,438     | 6,837       | Eligible  | 9,666       | Eligible     |
| F    | 4,931     | 7,215       | Eligible  | 10,184      | Eligible     |
| G    | 1,665     | 1,905       | Eligible  | 2,214       | Eligible     |
| H    | 3,618     | 6,504       | Eligible  | 9,226       | Eligible     |
CONCLUSION
Analysis of the planned flood in the Sindang Pump House area with rainfall data using daily rainfall data for STA Tanjung Periok, it was obtained that the planned rainfall discharge with a 5-year return period with Log Pearson III analysis was 170.748 mm, then the P channel with the ability to accommodate rain discharge of 0.175 m³/sec <0.989 m³/sec and the Q channel with a discharge of 3,220 m³/sec <4.093 m³/sec cannot accommodate the rainfall that occurs, by making changes to the dimensions of the channel, the ideal channel discharge obtained for channels P and Q is 5,913 m³/sec and 16.329 m³/sec.

REFERENCE
Anonim. (1997). Drainase perkotaan. Jakarta: Gunadarma. (Indonesian).

Anonim. (2012). Tata cara penyusunan rencana induk sistem drainase perkotaan. Jakarta: Bina Marga. (Indonesian).

Asdak, Chay. (2002). Hidrologi Dan Pengelolaan Daerah Aliran Sungai, Jakarta: Gadjah Mada University Press. (Indonesian).

Buttler D., Davies W.J., (2004). Urban drainage. London: Spoon Press

Hardiharjaja. (1997). Irigasi dan Bangunan Air. Jakarta: Gunadarma. (Indonesian).

Pemerintah Indonesia. (2014). Permen. PU No. 12 Tentang Penyelenggaraan Sistem Drainase Perkotaan. (Indonesian).

Tahun 2014. Jakarta: Kementerian Pekerjaan Umum. (Indonesian).

Pudyawati P.P.S., Dewi R.K. (2018). Perencanaan Sistem Drainase Kawasan Indonesia Power, Tambaklorok-Semarang. Jurnal karya teknik sipil, Vol 7, No 1,76-88. (Indonesian).

https://ejournal3.undip.ac.id/index.php/jkts/article/view/19367

Rahmawati, E., Wahyu, A.R. (2017). Pengembangan Drainase Sistem Polder Sungai Sringin Kota Semarang. Jurnal karya teknik sipil, Vol 6, No 1,282-290. (Indonesian).

https://ejournal3.undip.ac.id/index.php/jkts/article/view/15868

Suripin. (2004). Sistem Drainase Yang Berkelanjutan. Yogyakarta: Andi. (Indonesian).

Soemarto, C.D. (1987). Hidrologi Teknik. Surabaya: Usaha Nasional. (Indonesian).

Triatmodjo, B. (2008). Hidrologi Terapan. Yogyakarta: Beta Offset. (Indonesian).

White F.M. (2009). Fluid mechanic. New York: McGraw-Hill.
Mohammad Imamuddin, Dwi Cahyanto
Analysis of Drainage Channel Capacity at Sindang Street in Sindang House Pump Area

Iban Satriadi, 2017. ANALISIS HIDROGRAF BANJIR SALURAN IRIGASI CIBALOK BOGOR. ASTONJADRO Jurnal Rekayasa Sipil, 6(1), pp.49-59. (Indonesian). http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO/article/view/2261/1435

Siti Nurfatimatul Farodhiyah, Nurul Chayati, feril Hariati, 2016. NILAI KERUGIAN BANGUNAN RUMAH TINGGAL AKIBAT BANJIR PASANG DI MUARA BARU (Studi kasus: Kelurahan Penjaringan, Kota Jakarta Utara). ASTONJADRO Jurnal Rekayasa Sipil, 5(2), pp.24-34. (Indonesian). http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO/article/view/837/676

Muslim Pati Alam, Muhamad Lutfi, 2016. ANALISIS TREND HIDROGRAF TERHADAP SIMULATOR HUJAN SATU MODEL DAS DENGAN METODE HSS GAMA I. ASTONJADRO Jurnal Rekayasa Sipil, 5(2), pp.58-66. (Indonesian). http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO/article/view/840/679