# Study of Polder System for Flood Control In Kembang Residential Area, Bondowoso Regency, Indonesia

*by* Noor Salim

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# Study of Polder System for Flood Control In Kembang Residential Area, Bondowoso Regency, Indonesia

**Noor Salim**[1]
Lecture[1]
Departement of Civil Engineering
Muhammadiyah University of Jember
Jember, Jawa Timur
Indonesia

## ABSTRACT

*The rainy season is a season that is often complained by people in various cities because floods often occur. Especially in the Kembang Residential Area on Bondowoso Regency, when there is rain the drainage is unable to accommodate the existing water discharge so that the water overflows and inundates the road surface and settlements around the road. This can be caused by the high intensity of rain, land use that is not regulated properly. And to overcome these problems it is necessary to conduct water management through flood control dams, a system that is made to deal with the problem of excess water, excess water above the ground can be evaluated with a drainage system.*

*In evaluating this drainage system, first we look for field data such as land use, existing drainage conditions, rainfall data for the past 10 years, then its hydrological analysis which includes maximum rainfall, frequency and distribution of rainfall, planned flood discharge. Then the hydrolysis analysis which includes the basic slope of the channel, geometric elements, and the channel planning itself. From the analysis of the drainage system in the Kembang residential area of Bondowoso Regency it was found that the smallest discharge from the drainage system is located on channel 7C which is 0.049 $m^3$ / second with square cross section, while the largest discharge is in channel 4A which is 1.984 $m^3$ / second with trapezoidal cross section. Land use greatly influences flood discharge and land use changes which were previously water catchment areas later became residential areas. Land use also affects the adequacy of drainage. In this study, land uses that influences the flow of drainage channels are residential area and rice fields.*

*The drainage system in the area of the Kembang residential area has unequal flow direction between one channel and another. On average, channels that experience changes in existing dimensions to the dimensions of the new channel experience an increase in width or a water level of 15-25%. With the construction of the polder, it can accommodate water capacity of 617.63 $m^3$ with a building area of 484 $m^2$, and a depth of 1.3 m. Thus the channel in the downstream polder does not need to be widened, because the water that flows into the downstream channel has been controlled by the polder door.*

***Keywords :*** Flood, Drainage, Polder

## 1. INTRODUCTION

The increasing population and the need for settlements in an urban area and its surroundings will result in increased land use and green areas / open areas that temporarily hold back and absorb rainwater into the soil decreases. The imbalance between the land cut and fill, the construction of roads for transportation routes and the number of pavement which causes the portion of seepage and resistance to decrease and thus the portion of rainwater runoff increases and flood is happened.

Surface runoff or surface flow is part of rainfall that flows above the soil surface and transports soil particles. Runoff occurs because the intensity of the rain that falls in an area exceeds the infiltration capacity, and after the infiltration rate is fulfilled the water will fill the basins at the surface of the soil.

Therefore, the role of the community in maintaining water channels and supporting buildings can maintain drainage capacity, some of the things that cause inundation are inadequate capacity of the channel, illegal buildings that exist along the flood plain, sedimentation and existing water fructuations. Refer to Salim, Noor (2015), the overflow of water is caused by the amount of waste and deflection in the channel.

One of the residential area where floods often occur is Kembang residential area on Bondowoso regency. In the event of rain, the area is often flooded due to the discharge of water that is not accommodated by the existing channel, so that water overflows into the highway and forms a puddle that is very disturbing to road users which results in decreased road serviceability.

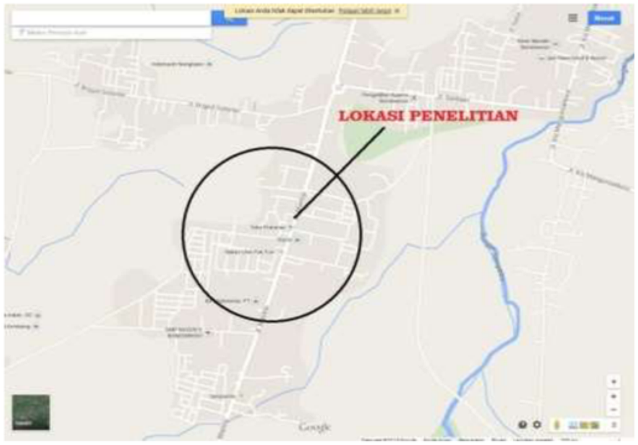


**Figure 1. Location of Study**

To overcome the problem of rainwater runoff that caused flooding in the Bondowoso's Kembang residential area, the flood discharge that occurred due to rainfall, land use, direction of the water flow and the conditions and dimensions of the channel in the location must be studied. Channel dimensions and conditions are determinants of when a flood occurs because the channel is used to accommodate the existing water discharge. If the existing channel capacity cannot cover flood water discharge, it is necessary to enlarge the dimensions of the channel or study other drainage systems, one of which is the construction of a water reservoir or polder.

The Polder System is a way of handling floods with the completeness of the physical facilities of the drainage channel and the reservoir which are controlled as a whole. With a polder system, the location of flood-prone areas will be clearly limited, so that the water level, the volume of water that will be released from the system can be controlled Controlled In the planning of the reservoir, the sluice gate is used, namely the Romijn Gate because the dam weir is needed to divide the river flow so that the reservoir can function according to the channel capacity at that location. The maximum discharge that enters the reservoir is used to determine the required width of flood divider building and dimensions of the door.

## 2. RESEARCH METHODOLOGY

The study was conducted in the city of Bondowoso, located in the Kembang residential area of Bondowoso Regency with a three-month research duration The data collection is divided into 2, namely primary data and secondary data collection Primary data collection is data collection obtained directly, while secondary data is the data sourced from publications of government agencies. Secondary data needed are rainfall data and land use data. while the primary data needed are the dimensions, slope and condition of the existing channel, as well as the measurement of the elevation difference in the location of the Kembang residential area.

Chronology of the research is as follows:

- Determine the drainage system, to find out the drainage sub-section.
- Determine watershed zones (DAS) per channel area, to determine the watershed area per channel.
- Calculating the maximum rainfall using the thiessen polygon method will get better data than using the algebraic method.
- Calculating rainfall design using several distributions according to CS value, with log normal method, log person III or gumbel to determine the maximum rainfall with a certain return period.
- Testing using frequency distribution with the Smirnov Kolmogorov test and Chi-Square test to determine whether the distribution used is acceptable or not. Calculate the average rainfall intensity, in order to find out how much rainfall intensity in each channel which is reviewed in several period.
- Calculate the planned debit to find out how much the rain debit by adding the debit according to the known direction of the flow in the Kembang residential area.
- Determine the dimensions of the channel and calculate how much the debit can accommodate, if the debit is greater than or equal to the debit plan then change the dimensions.



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- Calculate polders or water storage ponds and downstream channel capacity and the width of the sluice requirements, in order to determine the discharge coming out at the research location.

## 3. ANALYSIS RESULTS AND DISCUSSION

### 3.1 Hidrology Analysis

Hydrological analysis is needed to determine the amount of design rainfall and the design flood in a certain return period. In the drainage system in the Kembang residential area, Bondowoso we planned design rainfall with a 10-year return period (R10) and flood discharge with a 10-year return period (Q10). Supirin (2004), the actual method done to get the maximum average rain is by determining the maximum rain obtained by using the Thiessen polygon method.

From the results of the calculation of the maximum daily rainfall, the polygon thieseen formula is considered more accurate because it uses weighing areas using three rain-measuring stations, namely Pengairan rain station, Ancar Rain Station and Grujugan lor Rain Station in 2005 - 2014..

### 3.2 Land Use Coefficient

According to land use, the coefficient of land use on channel 6A is as follows:

- Farm field 0,7, with an area of 11.512,135 $m^2$
- Residential area 0,65, with an area of 9.275 $m^2$
- Vacant land 0,15, with an area of 0 $m^2$

Using C DAS formula as follows :

$$C\ DAS = \frac{11.512,135\ x 0,7 + 9.275\ x 0,65 + 0 x 0,15}{11.512,135 + 9.275 + 0}$$

$$= 0,678$$

For CDAS calculation, other channels can be seen in the land use coefficient table, on the next page. Maps of land use are shown in Figure 2.

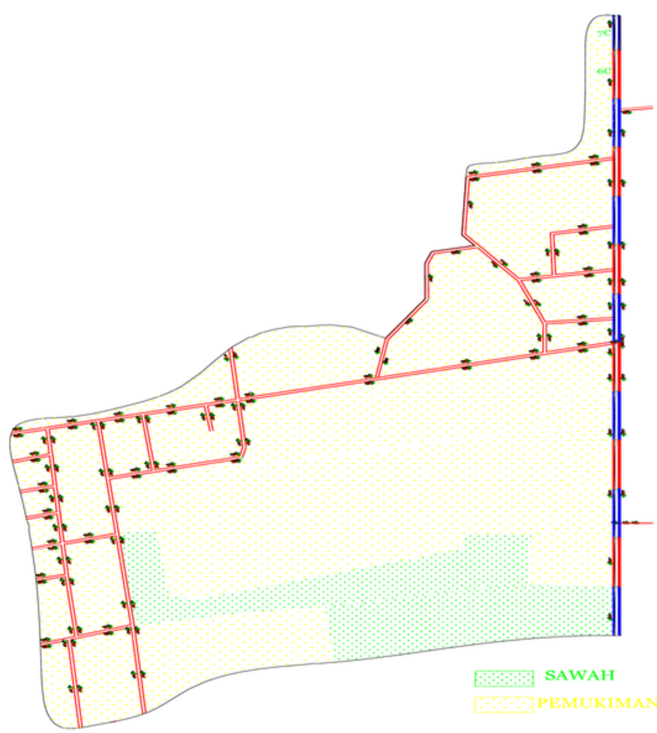


**Figure 2. Land use mapping**



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### 3.3 Design Flood Discharge

Rational Method Equation with example calculation on channel 6A as follows :

Q = Maximum flood discharge ($m^3/s$)

C = drain coefficient /land use runoff coefficient =0,678

I = average rainfall intensity (mm/hour)

Ten-year design rainfall intensity = 252,282 mm/hour = drain area ($km^2$) = area of the 6A channel watershed = 0,021 $km^2$

Q = 0,2778 . C . I . A

= 0,2778 . 0,678 . 252,282 . 0,021

= 0,987307291 $m^3/s$

### 3.4 Hydrolics Analysis

The channel network pattern in the Kembang residential area, Bondowoso can be shown in Figure 3

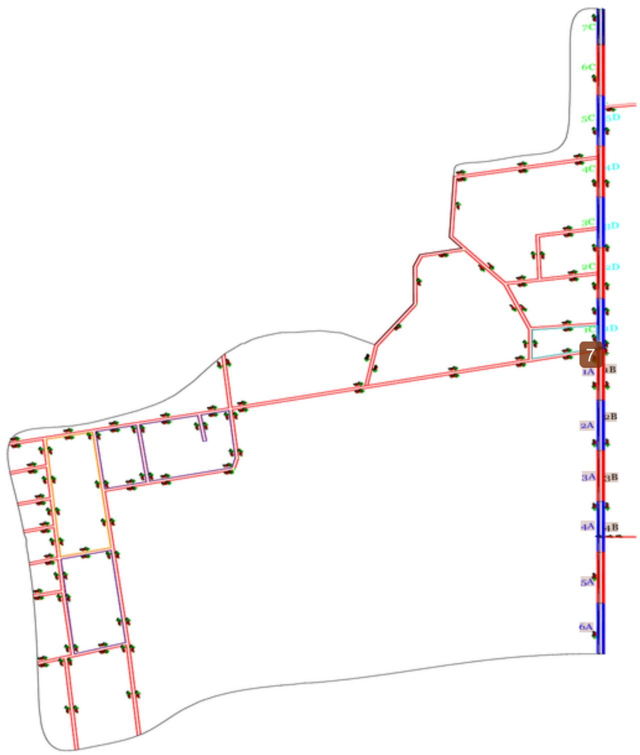

**Figure 3. Channel network mapping**

#### 3.4.1 Base Slope of the Channel

The ratio of the difference in height between the farthest place (ΔH) and the place of observation of the length of the channel (L), namely ΔH / L. Determination of the base slope of the channel is attempted to follow the slope of the land contour surface in the planned area. Example calculations on channel 6A with the data as follows:

L = 50 m ,

ΔH = 0,117 m

S $= \frac{\Delta H}{L}$

$= \frac{0,117}{50} = 0,00234$



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### 3.4.2 Designing Square and Trapezoidal Channel Dimensions

In evaluating the network and the dimensions of the drainage channel, you must first know the maximum design discharge with a certain return period and plan a maximum discharge for 10 years. The results of the calculation of the channel dimension planning are shown in table 1 and table 2.

**Table 1. Designing Existing Square Channel Dimensions**

| No | Channel name | b (m) | y (m) | Q.channel $m^3/s$ | Qrec $m^3/s$ | Action |
|---|---|---|---|---|---|---|
| 1 | Channel 1B | 1,5 | 1 | 3,15 | 1,72 | Fixed dimension |
| 2 | Channel 2B | 1,5 | 1 | 2,26 | 1,45 | Fixed dimension |
| 3 | Channel 3B | 1,5 | 1 | 1,14 | 1,02 | Fixed dimension |
| 4 | Channel 4B | 1,5 | 1 | 2,22 | 1,43 | Fixed dimension |
| 5 | Channel 1C | 0,35 | 0,2 | 0,04 | 0,73 | Changed dimension |
| 6 | Channel 2C | 1,1 | 0,7 | 0,69 | 0,81 | Changed dimension |
| 7 | Channel 3C | 1,1 | 0,7 | 0,95 | 1,10 | Changed dimension |
| 8 | Channel 4C | 1,2 | 0,6 | 0,93 | 1,44 | Changed dimension |
| 9 | Channel 5C | 1,2 | 0,6 | 0,79 | 1,49 | Changed dimension |
| 10 | Channel 6C | 1,2 | 0,6 | 1,56 | 1,57 | Changed dimension |
| 11 | Channel 7C | 1,2 | 0,6 | 1,13 | 1,62 | Changed dimension |
| 12 | Channel 1D | 1,5 | 1 | 2,34 | 1,47 | Fixed dimension |
| 13 | Channel 2D | 1,5 | 1 | 1,67 | 1,24 | Fixed dimension |
| 14 | Channel 3D | 1,5 | 1 | 2,32 | 1,47 | Fixed dimension |
| 15 | Channel 4D | 1,5 | 1 | 2,44 | 0,28 | Fixed dimension |
| 16 | Channel 5D | 1,5 | 1 | 2,49 | 1,52 | Fixed dimension |

**Table 2. Designing Existing Trapezoidal Channel Dimensions**

| No | Channel name | b (m) | y (m) | Qchannel $m^3/s$ | qrec $m^3/s$ | Action |
|---|---|---|---|---|---|---|
| 1 | Channel 1A | 0,35 | 0,20 | 0,06 | 0,10 | Changed dimension |
| 2 | Channel 2A | 0,35 | 0,20 | 0,05 | 0,23 | Changed dimension |
| 3 | Channel 3A | 2,00 | 0,80 | 1,77 | 0,30 | Fixed dimension |
| 4 | Channel 4A | 2,00 | 0,80 | 3,27 | 2,28 | Fixed dimension |
| 5 | Channel 5A | 1,10 | 0,6 | 1,08 | 0,82 | Fixed dimension |
| 6 | Channel 6A | 2,00 | 0,8 | 2,36 | 1,81 | Fixed dimension |

From the results of the calculations above, the channel that has changed the existing dimensions to the dimensions of the new channel has an increase in width and water level of 15-25% in average. It is noted that across the road on Kembang residential area is rice field area. According to Salim, Noor (2013) it is stated that the geomeric condition of the road in the three study locations was relatively flat, the left and right of the road were paddy fields where the surface position was almost the same causing inundation easily and lack of flow of water on the road causing flood as a result of rainfall that exceeds normal.

The addition of widening channel dimensions to both width and height will be minimized or completely eliminated when there is a storage or polder. Using the polder, some of the flood water will enter it, so that the rest can be discharged into the existing channel. Discharge settings from polder to existing channels are used with the Romijn sluice.

### 3.4.3 Polder Design

#### 3.4.3.1 Calculation of Channel Capacity Analysis in The Downstream

The capacity of the channel calculated is the downstream channel capacity from the location of the reservoir, in this case the cross-sectional capacity of the channel. The use of the downstream flood height design as a benchmark of the highest point expected so that the height in the upstream part will also be higher, so that the polder design can be maximized.



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Channels that are used as a downstream benchmark are channels that are directly connected to the gate of the housing entrance or the edge channel around the Kembang residential area. And the edge channel is on the edge of the road which is often used by water when it rains. The results of the channel capacity calculation are shown in table 3.

**Table 3. Capacity Calculation Result**

| No | Channel name | b (m) | y (m) | Q.channel $m^3/s$ | Qrec $m^3/s$ |
|---|---|---|---|---|---|
| 1 | Channel 1b | 1,5 | 1 | 3,15 | 1,72 |
| 2 | Channel 2b | 1,5 | 1 | 2,26 | 1,45 |
| 3 | Channel 3b | 1,5 | 1 | 1,14 | 1,02 |
| 4 | Channel 4b | 1,5 | 1 | 2,22 | 1,43 |
| 5 | Channel 1c | 0,35 | 0,2 | 0,04 | 0,73 |
| 6 | Channel 2c | 1,1 | 0,7 | 0,69 | 0,81 |
| 7 | Channel 3c | 1,1 | 0,7 | 0,95 | 1,10 |
| 8 | Channel 4c | 1,2 | 0,6 | 0,93 | 1,44 |
| 9 | Channel 5c | 1,2 | 0,6 | 0,79 | 1,49 |
| 10 | Channel 6c | 1,2 | 0,6 | 1,56 | 1,57 |
| 11 | Channel 7c | 1,2 | 0,6 | 1,13 | 1,62 |
| 12 | Channel 1d | 1,5 | 1 | 2,34 | 1,47 |
| 13 | Channel 2d | 1,5 | 1 | 1,67 | 1,24 |
| 14 | Channel 3d | 1,5 | 1 | 2,32 | 1,47 |
| 15 | Channel 4d | 1,5 | 1 | 2,44 | 0,28 |
| 16 | Channel 5d | 1,5 | 1 | 2,49 | 1,52 |

From table 3 it can be seen that the maximum Q capacity with downstream water level is 1.13 $m^3/s$.

### 3.4.3.2 Calculation of Volume of Storage Pond

To find out the volume of water that needs to be accommodated in a storage pond, it is necessary to compare the flowrate with the channel capacity: Q capacity design - Q channel capacity = 1.62 $m^3/s$ – 1.13 $m^3/s$ = 0,49 $m^3/s$.

The design capacity used is the Q design at the time the Q channel is the most minimal compared to the others, so that the best results of reservoir or polder design are obtained. Therefore, it is expected that the existing flood water runoff can be included in the polder design. To save on routine expenses in the event of a flood, a pond storage or polder is made without a pump. And this can be more practical and efficient in terms of financing. The results of the calculation of the pool reservoir are presented in table 4.

**Table 4. Calculation of Pond Storage Volume**

| t (hour) | Q ($m^3/s$) | Volume ($m^3$) |
|---|---|---|
| 1 | 0,49 | 29,630 |
| 2 | 0,49 | 58,800 |
| 3 | 0,49 | 88,200 |
| 4 | 0,49 | 117,600 |
| 5 | 0,49 | 147,000 |
| 6 | 0,49 | 176,400 |
| Total | | 617,630 |

With the storage pond designed without a pump, the maximum water level of the reservoir is the same as the maximum water level in the channel, so that the depth of the reservoir (H) is 1.3 m. The pool storage area is adjusted to the needs of the storage volume.

The dimensions of the reservoir with a sloping wall of 1: 2, the designed storage area is predicted by plotting the land on the location plan. Placement of the reservoir location is shown in Figure 4.



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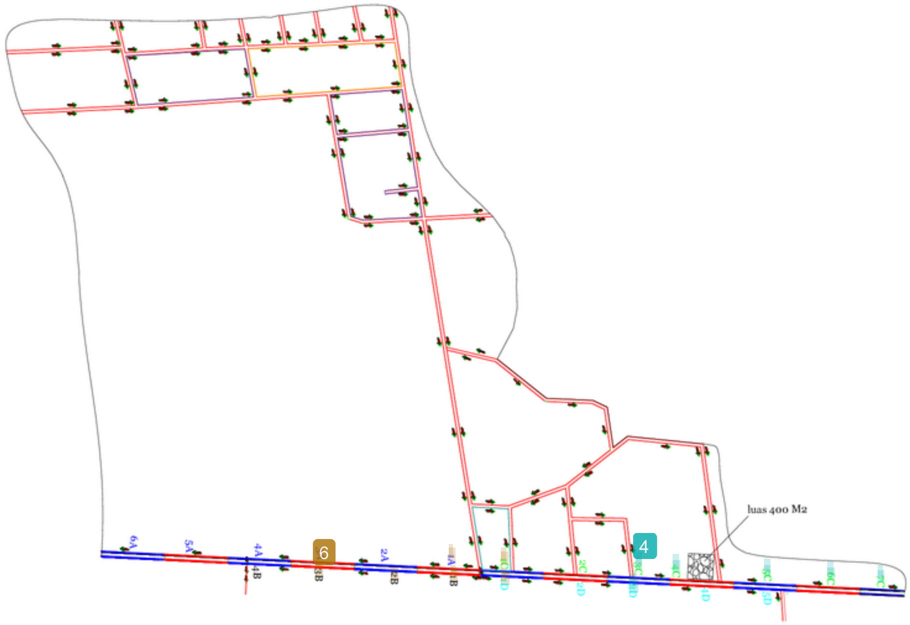


**Figure 4. Placement Location of the Storage Pond**

The designed storage capacity can be known by comparing the relationship between water level (H) and cumulative reservoir (cumulative S), which can be seen in table 5.

**Table 5 Calculation of H Relationships with Volume**

| H (m) | Area ($m^2$) | Volume ($m^3$) | Cumulative S ($m^3$) |
|---|---|---|---|
| 0,1 | 484 | 48,4 | 48,4 |
| 0,2 | 484 | 96,8 | 145,2 |
| 0,3 | 484 | 145,2 | 290,4 |
| 0,4 | 484 | 193,6 | 484 |
| 0,5 | 484 | 242 | 726 |
| 0,6 | 484 | 290,4 | 1016,4 |
| 0,7 | 484 | 338,8 | 1355,2 |
| 0,8 | 484 | 387,2 | 1742,4 |
| 0,9 | 484 | 435,6 | 2178 |
| 1 | 484 | 484 | 2662 |
| 1,1 | 484 | 532,4 | 3194,4 |
| 1,2 | 484 | 580,8 | 3775,2 |
| 1,3 | 484 | 629,2 | 4404,4 |
| 1,4 | 484 | 677,6 | 5082 |
| 1,5 | 484 | 726 | 5808 |
| 1,6 | 484 | 774,4 | 6582,4 |
| 1,7 | 484 | 822,8 | 7405,2 |
| 1,8 | 484 | 871,2 | 8276,4 |
| 1,9 | 484 | 919,6 | 9196 |
| 2 | 484 | 968 | 10164 |
| 2,1 | 484 | 1016,4 | 11180,4 |
| 2,2 | 484 | 1064,8 | 12245,2 |
| 2,3 | 484 | 1113,2 | 13358,4 |
| 2,4 | 484 | 1161,6 | 14520 |
| 2,5 | 484 | 1210 | 15730 |
| 2,6 | 484 | 1258,4 | 16988,4 |



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### 3.4.3.3 Sluice Width Requirement Analysis

In the planning of the reservoir the sluice gate is used, namely the Romijn Gate because the dam weir is needed to divide the flow of the river so that the reservoir can function according to the channel capacity at that location. Sluice dimensions needed:

- **Effective Width of Romijn Gate**

Using formula (Kriteria Perencanaan 04,1986 ) :

Q = Cd * Cv * 2/3* √ ( 2/3 * 2.g ) * B * h1^1,5

With :

Q = flood discharge m3/s
Cd = Discharge coefficient = 0,93 + 0,1 * H1/L with L=Hmax
Cv = Initial Speed Coefficient = Cd * A'/A1
A' = Wet cross section area on the Romijn table
A1 = Wet cross section area of sluice gate channel.
= Cd *b*h1/B*(h1*0,5) =Cd*h1/(h1+0,5)
B = Effective Width of Romijn gate (m)
H1 = Energy Height on the Table (m)
h1 = Upstream Energy Height on the Table (m)
g = Gravity acceleration = 9,81 m/s2
H1 = V12 /2g, with the downstream speed

**Table 6. Effective Sluice Width Calculation**

| V | V^2/(2*g) | H1 | h1 | Cd | Cv | Be | Q |
|---|---|---|---|---|---|---|---|
| 1,74 | 0,154 | 1,3 | 1,146 | 0,98 | 0,703 | 0,78 | 1,13 |

- **Romijn Gate Width**

It is planned that a Romijn gate will be required.

The designed Romijn gate width:

Bp = Be + Ka * Hmax
= 0,78 + ( 0,1 * 1,3 ) = 0,91 m
bp = Romijn gate width
Be = effective Romijn gate width
Ka = abutment coefficient = 0,1
Hmax = flood water level above 1,3

## 4. CONCLUSION

Based on the results of the field survey and calculation analysis, conclusions can be made as follows.

1. The smallest discharge from the drainage system is located on channel 7C which is 0.049 $m^3$ / second in square shape, while the largest discharge is in channel 4A which is 1.984 $m^3$ / second in trapezoidal shape.
2. Land use greatly influences flood discharge as land use change, which previously used as water catchment land then become a residential area. Land use also affects the adequacy of drainage channels. In this study, land use that influences the flow of drainage channels is residential area and rice fields.
3. The drainage system in the area of the Kembang housing has an unequal flow direction between one channel and another.
4. The channel that undergoes changes in existing dimensions to the dimensions of the new channel experiences an increase in width or a water level of 15-25% on average.
5. With the construction of the polder, it can accommodate water capacity of 617.63 $m^3$ with a building area of 484 $m^2$, and a depth of 1.3 m. So that the channel in the downstream polder, the channel that does not need to be expanded, because the water that flows into the downstream channel has been regulated by the polder sluice gate.
6. The changes in the dimensions of the channel and the making of polders that are useful to overcome the water overflow that occurs with calculations as contained in the study can be done in this case, and no less important is the routine maintenance of each channel for the next 10 years, so that the channel can function as it should be.

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