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The Choice of Storage Pool and Pump Combination from Optimum Polder System

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Abstract— *Banger river often overflows and floods around Banger Region. Polder concept identified as the most appropriate solution to resolve the problem of flooding in Banger River. Polder is an area surrounded by flood protective structures (dikes and dams) separating the water inside and outside the polder. The water in the polder is controlled by the structures of the building (sluice and pump) and the storage pool as a flood drainage. Effective use of the pump and the storage pond becomes very important to be used as a study. The results of flood routing for the pump capacity is 3,0 m^3/s requires 528.597 m^3 of storage volume or 11,128 Ha for a depth of 4,75 m. Meanwhile, an extensive on site limited to 10,100 Ha due to land acquisition, so that the pump capacity 3,0 m^3/s or less are not used to research alternative. In this study, there are four alternative combinations of pumps and pond reservoirs, namely: (1) Pump with a capacity of 4,5 m^3/s and the storage pool volume 476.190 m^3, or an area of 10,025 Ha to a depth of 4,75 m. (2) The pump with a capacity of 6,0 m^3/s and the storage pool volume 439.146 m^3 or 9,245 Ha area for pool depth of 4,75 m. (3) The pump with a capacity of 7,5 m^3/s and the storage pool volume 402.876 m^3 or area of 8,482 Ha to 4,75 m depth of the pool. (4) Pump with a capacity of 9,0 m^3/s and the storage pool volume 388.260 m^3 or area of 8,174 Ha to 4,75 m depth of pool. Four alternatives above were obtained the costs as follows, Alternative (1) Rp 85.842.808.000,00, alternative (2) Rp 80.859.892.000,00, alternative (3) Rp 76.653.524.000,00 and alternative (4) Rp 76.903.429.000,00. Third alternative is selected with the smallest cost, is about Rp 76.653.524.000,00.*

Keywords— *Floods, pumps, pond reservoirs, flood routing.*

I. INTRODUCTION

Banger river polder is a small polder system covering the area which is about 600 hectares. This polder area is flood-prone area which is caused by high tide and land subsidence. Based on previous study, this area has a problem of land subsidence with the drop rate is about 9 to 15 cm in a year (Wahyudi, S. Imam et al., 2012A). The development of sea level rise and the increasing of rainfall intensity is one of the causes of climate changed, therefore it needs to be anticipated in the future.

Banger Polder area which is covered in embankments will protect the area from flooding which is caused by high tide which through Banger river and eastern flood canal. The flooding protection consists of east embankment for protection of eastern flood canal and north embankment for protection toward Java Sea. Then, there is a dam in banger river which covers banger river form the ocean flow. Therefore, pump station is needed for water disposal from banger polder area to the sea through eastern flooding canal (Witteven, B., 2004).

Banger river polder system is one of the solutions expected which is able to reduce the puddle as a result of tides of sea level effect and flood in east Semarang area and make the area more protected. Polder system is a way of flood mitigation with the completeness of physical means covering drainage area system, retention pool, embankments around the area, pump and sluice as a unity of water system development which is not separated.

Based on the description above, it needs an analysis about the choice of pump capacity and storage pool area. The wider a pool, the bigger investment costs for land acquisition and construction. Otherwise, the bigger pump capacity, the greater procurement of pumps cost and operation and its maintenance. This analysis used the method which combine several combination alternatives among the pump capacity, storage pool and the most minimum cost.

The location which will be analysed in this research is in banger watershed which lies in East Semarang District area with the area covered includes Jl.Brigjen Sudiarto, Jl.MT Haryono, Jl. Kaligawe Raya, eastern Flood canal, etc. for more detail, it is presented in the map bellow.

The boundaries of Banger polder are as follow:

- North : Jl. Kaligawe Raya
- South : Jl. Brigjen Sudiarto
- West : Jl. MT Haryono
- East : Kali Banjir Kanal Timur

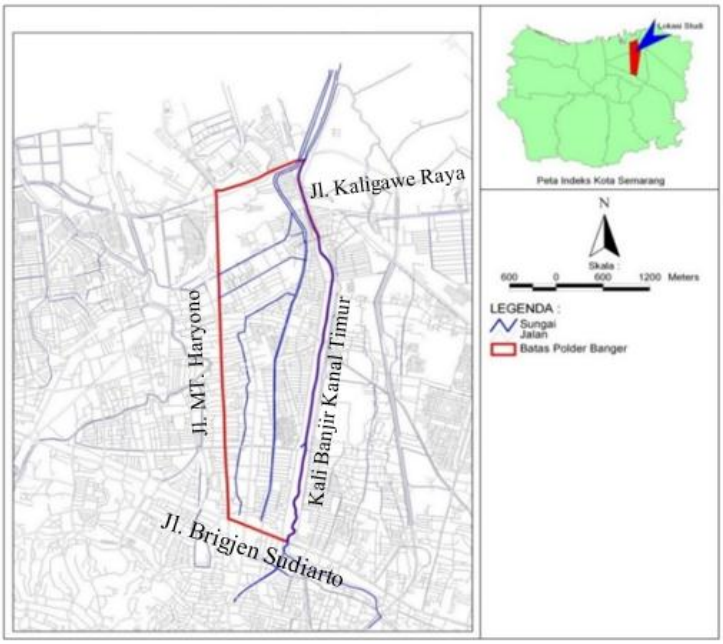

Figure 1. Map Location of Banger Polder (Witteven, B., 2004)

II. Research Method

A. Technique of Data Collection

The technique of data collection was conducted by the method of data observation. The data needed for this research "analysis of the combination of storage pool and pump of optimum polder system" are as follow:

1) Data of Rainfall

Data of rainfall needed in this research are daily rain data with the duration or the length of rainfall data for each rain station is minimal 15 years. Besides that, it is also needed hourly rain data in order to analyse the rain intensity. The rainfall data is taken from three rain stations which are around the watershed, such as Simongan station, maritime station, and Karangroto station. Rainfall data is obtained from several sources such as Meteorology Climatology and Geophysics Council of Semarang, Great Hall River Area of Pemali Juana, and Public Works Department of Water Resources and Spatial Planning of Central Java Province.

2) Topographic Maps

Topographic map is needed to calculate the storage pool area. This map is obtained from the plan (*Witteven, B., 2004*).

3) Planning Data and Pump Operation

Planning data and pump operation is used to analyse the budget cost of pump from package of River Channel Normalization Planning Activities in 2011 by PT. Agung Pertiwi.

4) Data of Construction Planning of Storage Pool

The data of construction planning of storage pool is used to analyse the estimation cost of storage pool construction from the package of River Channel Normalization Planning Activities in 2011 by PT. Agung Pertiwi.

B. Technique of Data Analysis

Analysis of Rainfall data

The steps in hydrology analysis are as follow:

1. Determining the water catchment area as well as its immensity.
2. Determining the daily maximum rainfall of the average of water catchment area from the rainfall data which has been existed
3. Determining the immensity effect of rain stations area
4. Analysing the planning rainfall with reset period of T year.
5. Calculating the flood discharge of planning based on the immensity of planning rainfall on the reset period of T year.
6. Combining between available water discharge with the capacity of existing channels

Water Catchment Area

This water catchment area is used to determine the maximum discharge plan on the system of flood control in East Semarang District area with the detention pool and pump station in polder system, besides that, to limit the area which will be served by the construction on Banger Polder system.

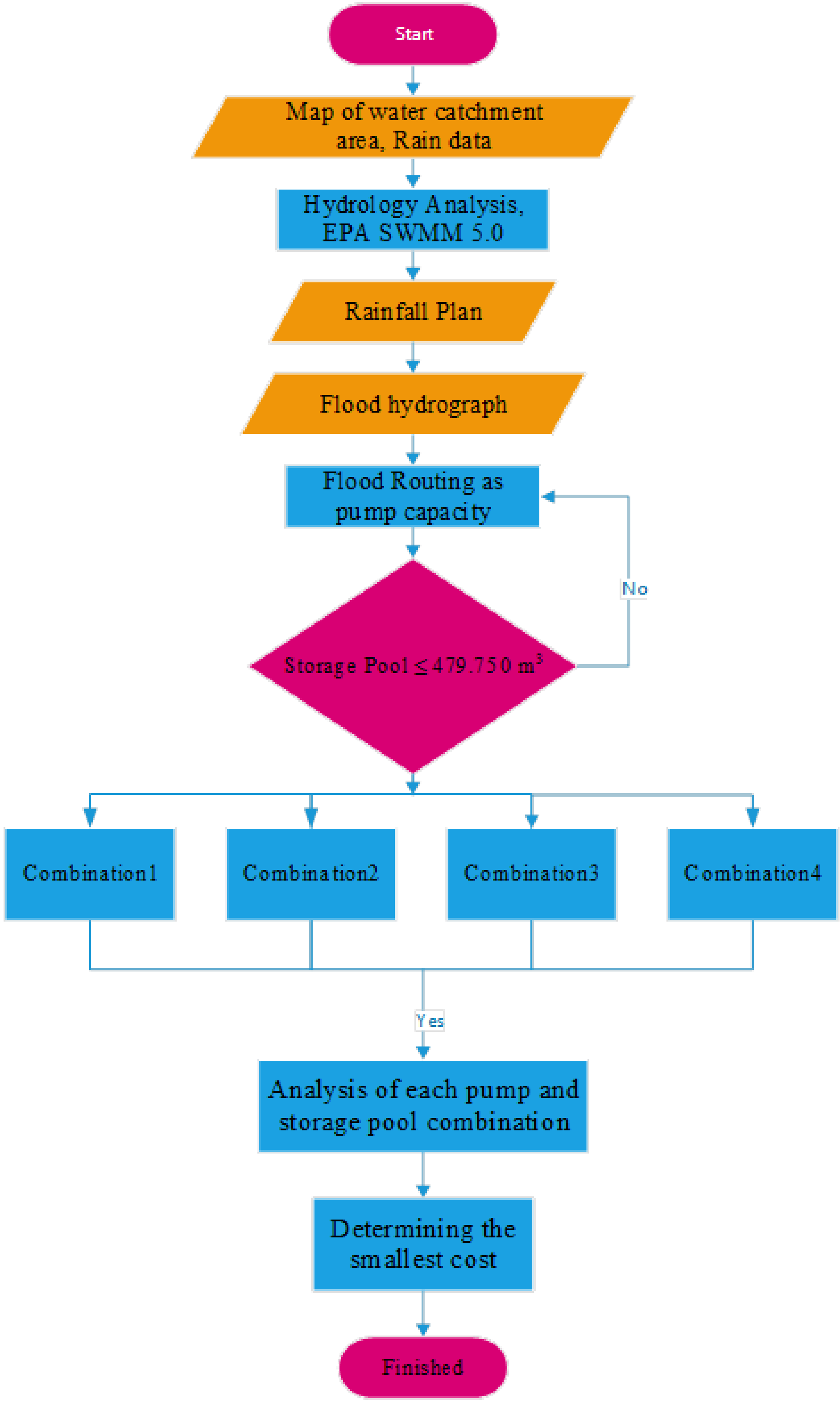

Figure 2. Flow Chart of Research Implementation

The determination of water catchment area was conducted based on the earth map. The way that can be used to determine water catchment area by using AutoCad program or plotting on the map then the measurement used Planimeter equipment. The determination of water catchment area in this research drafting used AutoCad program.

The determination area of water catchment area station effect for this drainase plan used three rain station such as Simongan station (42a), Karangroto station (94), Maritim station (Tanjung Mas). Based on topography map of Banger river flow area has the area 5,051 km^2.

Analysis of Daily Rainfall Data of Maximum Average

The amount of daily maximum rainfall, the average of water catchment is calculated by Thiessen method. However, because of Karangroto station have no influence area in the area observed in this case is Banger river water catchment area, the maximum rainfall data from Karangroto station was not used in this analysis of maximum average of daily rainfall data. Therefore, it used only rainfall data from Simongan station and maritime station (Tanjung Mas).

The average of maximum daily rain was obtained by determining the maximum rain in each year.

Analysis of Rainfall Plan Frequency

The data used in analysis of rainfall plan is the intensity of maximum daily rainfall average of Banger river water catchment area based on time concentration (t_c).

Determination of Distribution

Not all the value of hydrology variable lies or same with its average value, however it is possible there is a greater or smaller value of its average value. The number of dispersions was conducted by dispersion measurement, i.e. through statistical parameter calculation for untuk (X_i–Xrt). $(X_i–Xrt)^2$. $(X_i–Xrt)^3$. $(X_i–Xrt)^4$ first.

Where:
X_i = The Amount of rainfall of water catchment area (mm)
Xrt= The Average of maximum rainfall area (mm)

Analysis of the Frequency of Plan Rainfall

The data used in this plan rainfall analysis is the intensity of maximum daily rainfall average of Banger river water catchment area based on the time concentration (t_c).

Calibration of Compatibility of Selected rainfall Distribution

The examination of this compatibility calibration is intended to give the certainty truth of a hypothesis (in this case is the compatibility of rain distribution which is selected) by noticing the population of each sample used in this frequency analysis. To know the truth of hypothesis, it is needed to test on the hypothesis, where the result is could be accepted or rejected.

Probability Value of Rainfall to be Plotted on Statistical paper

From the data of maximum rain that has been the most maximum calculated in each year, then it is sorted from the smallest order to biggest order first, and calculating the probability value.

Analysis of Rainfall Plan

The working steps of hydrology analysis can be explained as follow:

a) Sorting the rainfall value from the biggest to the smallest or can be or it also can be from the smallest to the biggest value.
b) Calculating the probability value for each data sorted.
c) The probability values are plotted into statistical paper by horizontal way is the percentage value of probability (q, % → in this research the plotted is the value of q because the data is sorted from the smallest to the biggest and vertical direction of rainfall value (mm)
d) Taking two distribution points from the result of rain distribution calculation, then drawing a straight line that link of both points.
e) From the drawing line can be known the value of rainfall in each time repeated with the way of noticing the probability number at the bottom of paper in horizontal direction, drawing vertical line cutting the straight line linked of two points. From the intersection, drawing horizontal line toward the data value of rainfall area, therefore the rainfall value in time repeated has been obtained.

Analysis of Existing Flood Discharge

Analysis of existing flood discharge used EPA SWMM program 5.0. This research used the rainfall for time repeated 10 years (T= 10 years)

Analysis of flood routing

Analysis of flood routing used Muskingum method, where the principle is the continuity of inflow and outflow.

$$I - O = S/t, \text{ become}$$

$$(I1+I2)/2 + (O1+O2)/2 = (S2-S1)/\Delta t,$$

Where,
I = inflow (m^3/second)
O = outflow (m^3/second)
S = volume of storage (m^3)
t = time (second)

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III. Result And Discussion

The result of Run EPA SWMM 5.0

Output of flood hydrograph of EPA SWMM 5.0 is presented graphically as follow:

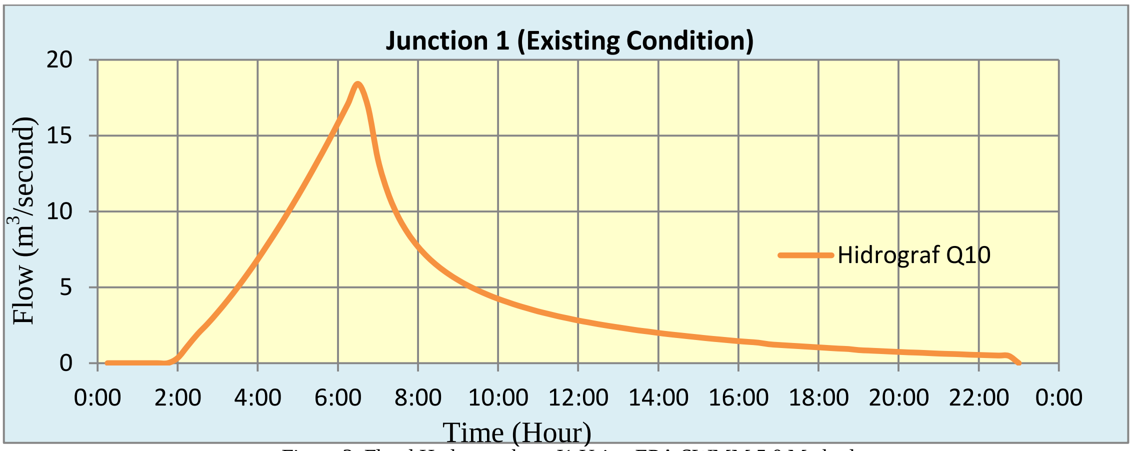

Figure 3. Flood Hydrograph on J1 Using EPA SWMM 5.0 Method

From the result of flood hydrograph above, then conducted the flood routing toward the different pump capacity so that obtained different volume of storage also. From the volume of storage, it is obtained the storage pool area.

1. *The discussion of flood routing*

Flood routing used in this research used Q10 annual.

a. The assumption of using pump capacity which is 1.5 m^3/s. the volume or the capacity of pool needed is 445.400 $m^{3.}$ If the depth of pool is 4.75 m, to reach the volume 445.400 m^3 needed 9.38 Ha of pool area.

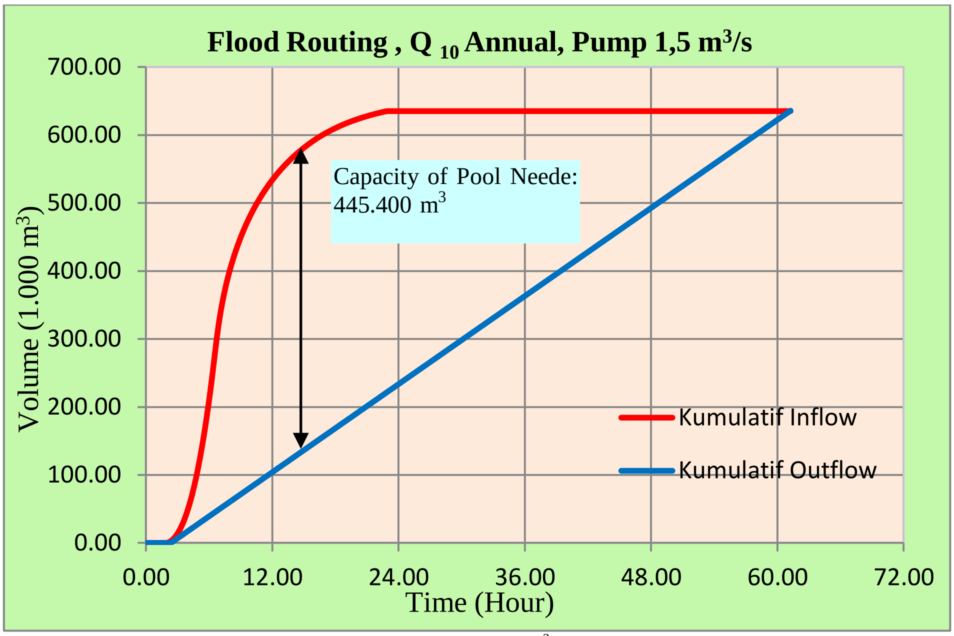

Figure 4. Flood Routing with 1.5 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-Pump) is at the hour of 3.705 minutes or 61 hours 45 minutes from the beginning inflow.

b. The assumption of using pump capacity which is 3.0 m^3/s. the volume of pool or the capacity of pool needed is 336.900 m^3. If the depth of pool is 4.75 m, to reach the volume 336.900 $m^{3,}$ it is needed 7.09 Ha of pool area.

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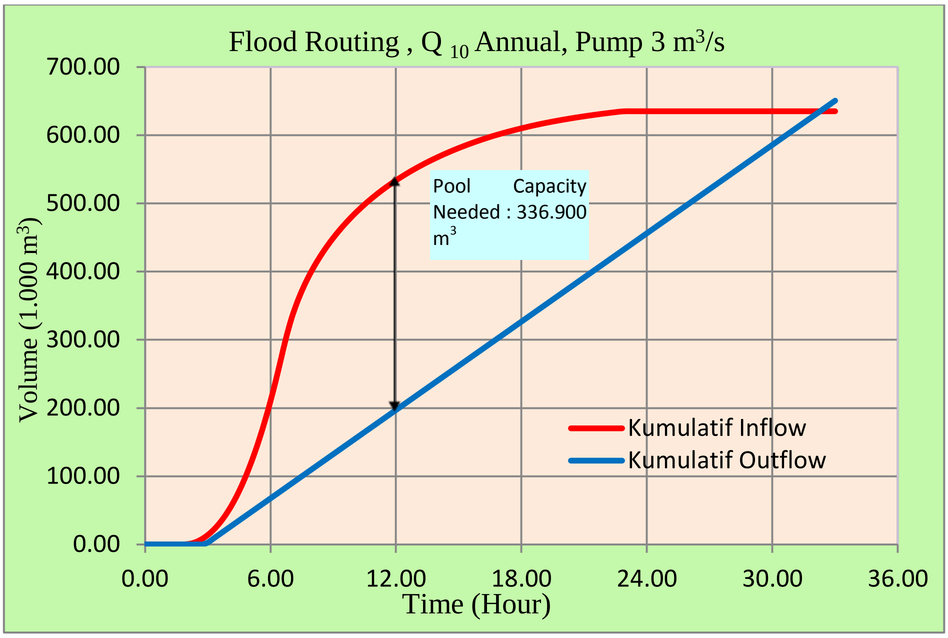

Figure 5. Flood Routing with 3 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-Pump) is at the hour of 33 from the beginning of inflow.

c. The assumption of using 4,5 m^3/**s** pump capacity. The volume or pool capacity needed is 338.490 m^3. If the depth of pool is 4.75 m, to reach the volume 338.490 m^3 it is needed 7.13 ha of pool area.

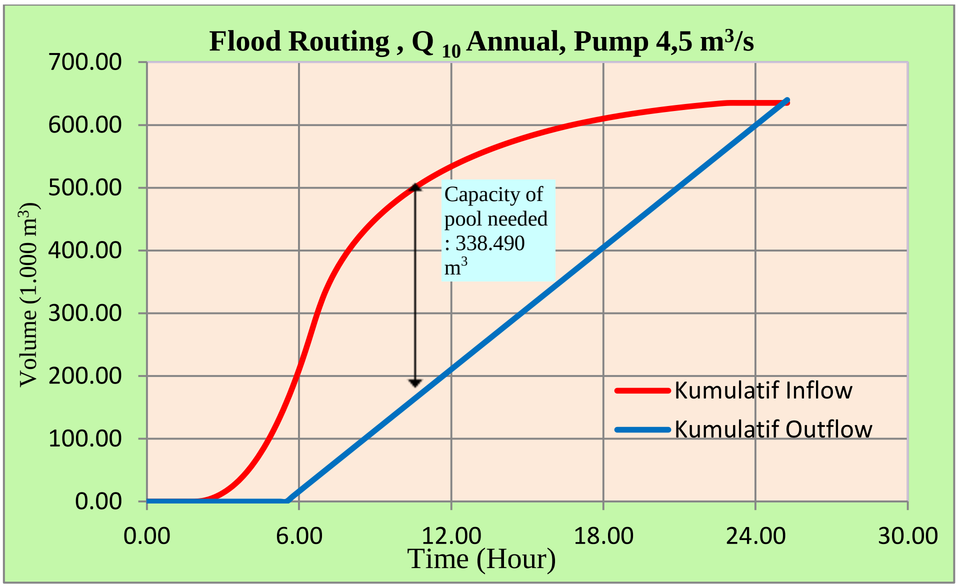

Figure 6. Flood Routing with 4,5 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-Pump) is at the hour 25 over 15 minutes from the beginning of inflow.

d. The assumption of using 6,0 m^3/s pump capacity. The volume or pool capacity needed is 228.550 m^3. If the depth of pool is 4.75 m, to reach the volume 228.550 m^3 it is needed 4.81 Ha pool area.

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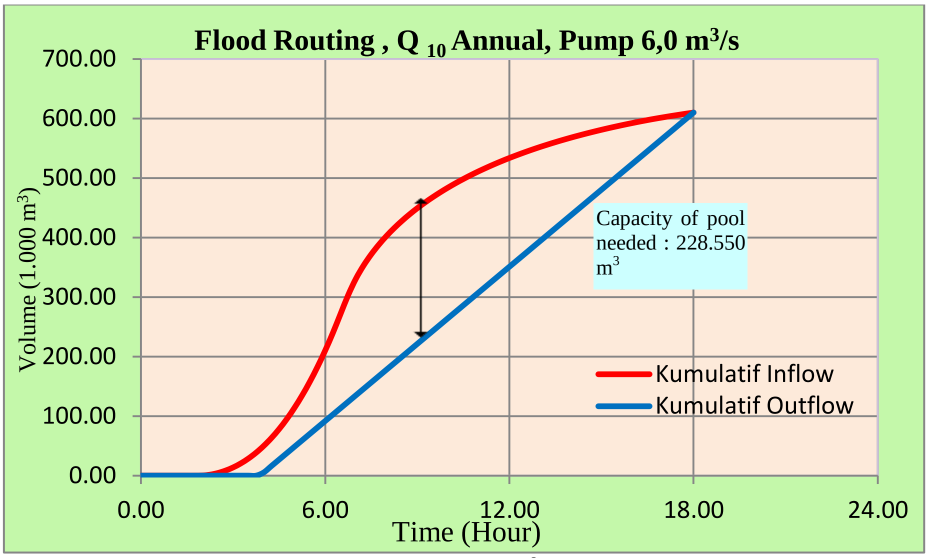

Figure 7. Flood Routing with 6,0 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-pump) is at the hour 18 from the beginning of inflow.

e. The assumption of using 7,5 m^3/s pump capacity. The volume or pool capacity needed is 193.630 m^3. If the depth of pool is 4.75 m, to reach the volume 193.630 m^3 it is needed 4.08 Ha pool area.

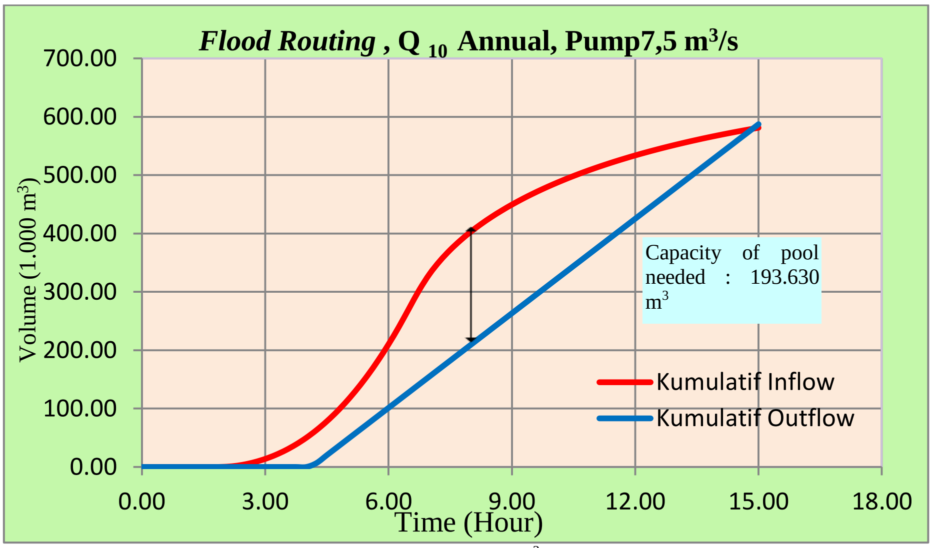

Figure 8. Flood Routing with 7,5 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-pump) is at the hour 15 from the beginning of inflow.

f. The assumption of using 9.0 m^3/s pump capacity. The volume or pool capacity needed is 185.760 m^3. If the depth of pool is 4.75 m, to reach the volume 185.760 m^3 it is needed 3.91 Ha pool area

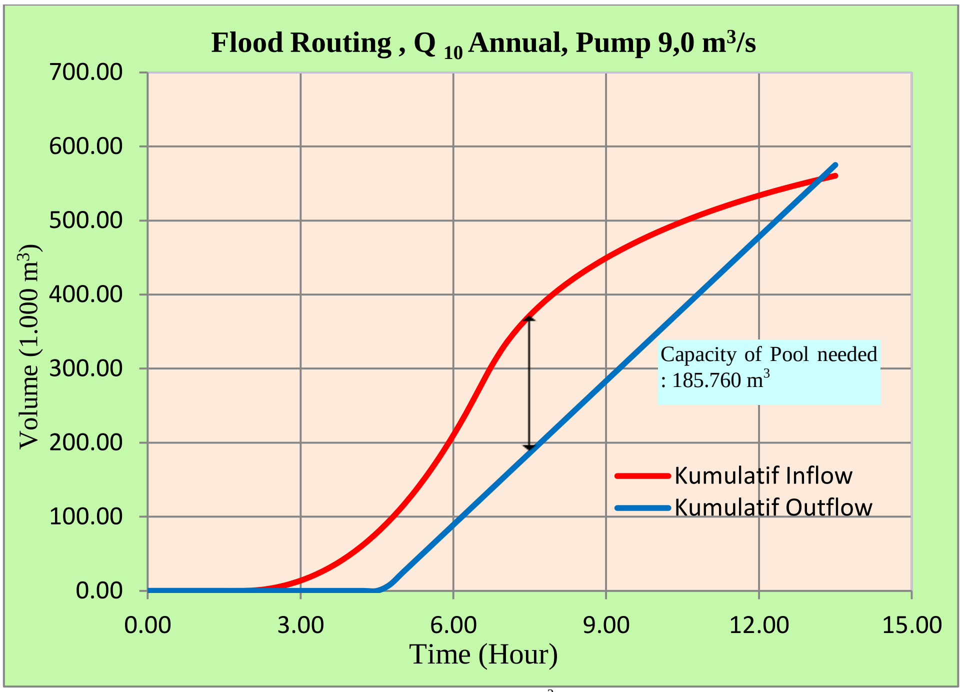

Figure 9. *Flood Routing* with 9,0 m^3/s of pump capacity

The time needed to be back into original position between Q-inflow and Q-outflow (Q-pump) is at the hour 13 over 30 minutes from the beginning of inflow.

The result of flood routing :

By flood routing ways, it is obtained the result as follow:

1. If it used the pump in the capacity 4.5 m^3/s, the result of flood routing is obtained the volume 476.190 m^3 or 10.025 Ha for 4.75 m of pool depth. (Alternative 1)
2. If it used the pump in the capacity 6.0 m^3/s, the result of flood routing is obtained the volume 439.146 m^3 or 9.245 Ha for 4.75 m of pool depth. (Alternative 2)
3. If it used the pump in the capacity 7.5 m^3/s, the result of flood routing is obtained the volume 402.876 m^3 or 8.482 Ha for 4.75 m of pool depth. (Alternative 3)
4. If it used the pump in the capacity 9.0 m^3/s, the result of flood routing is obtained the volume 388.260 m^3 or 8.174 Ha for 4.75 m of pool depth. (Alternative 4)

The Choice of Pool and Pump Combination

From each alternative, it can be calculated the cost as follow:

1. Alternative 1, pump capacity 4,5 m^3/s and storage pool area 10,025 Ha.
   The cost obtained is Rp 85.842.808.000,00
2. Alternative 2, pump capacity 6,0 m^3/s and storage pool area 9,245 Ha.
   The cost obtained is Rp 80.859.892.000,00
3. Alternative 3, pump capacity 7,5 m^3/s and storage pool area 8,482 Ha.
   The cost obtained is Rp 76.653.524.000,00
4. Alternative 4, pump capacity 9,0 m^3/s and storage pool area 8,174 Ha.
   The cost obtained is Rp 76.903.429.000,00

From the fourth alternatives, the smallest cost obtained is on alternative 3 which is Rp 76.653.524.000,00

Economical Technique

Economic analysis needed in Banger river Polder construction covers the modal cost and benefit cost.

Modal Cost

The modal cost in Banger river polder system construction is divided into two, such as direct cost, indirect cost, and operational cost and maintenance. The calculation of direct cost, indirect cost and operational cost and maintenance are as follow:

1. Direct Cost

Direct cost consists of land acquisition cost and construction cost. The cost of land acquisition in Banger river polder system of construction area is Rp 6.000.000.000/Ha. The simulation result of the fourth alternatives of cost calculation, 3 alternatives was selected for the implementation of Banger river Polder system construction with the pump capacity 7,5 m^3/s and storage pool area 8.48 Ha. It is obtained the direct cost value which is Rp. 48.669.524.000,00, with the detail as follow:

Land Acquisition Cost (Rp. 6.000.000.000,00 × 4,08 Ha) = Rp. 25.440.000.000,00
Construction Cost = Rp. 18.805.022.216,00 +
Sum = Rp. 44.245.022.216,00
Sum (+ PPN 10%) = Rp. 48.669.524.438,00
Integration = Rp. 48.669.524.000,00

2. Indirect Cost
Indirect cost in the construction system of Banger river polder is a technical cost which is estimated 15 percent of construction cost. The technical cost needed for Banger river polder system construction is:

Technical cost (15% x Rp. 20.685.524.000,00 = Rp. 3.102.828.600,00
Sum (+ PPN 10%) = Rp. 3.413.111.460,00 +
Integration = Rp. 3.413.111.000,00

3. Operational Cost and Maintenance.
Operational cost consists of operator cost, fuel and lubricants consumption cost as well as grocery shopping cost and work equipment. The calculation of operational cost and maintenance based on the calculation of Budget plan for a year is Rp. 3.144.900.000,00 (+ Value-added tax 10%).

Benefit Cost

1. Direct Benefit
Direct benefit of Banger river polder system construction is expected can be solve the flood and rob of East Semarang. In the land research conducted by Ifan R Suhelmi, et al. (2013), obtained the economical value of land use as on the table below.

Table 1. The Value of Land Use in Semarang Area

Land Use	**The value of land use (Rupiah /Hectare)**
Settlement	7.080.295.000
Building/ Industrial Area	9.179.524.000
Embankment	811.971.000
Open field	12.263.000
Road	10.875.000.000

(Source : Ifan R Suhelmi, et al.2013)

Based on the calculation of cost of lost caused by flood and Rob in water catchment in Banger, it is obtained the number estimation of flood losses and rob is Rp 202.143.064.200

Table 2. The Lost Cost Caused By Flood And Rob In Water Catchment Area Of Banger

Land Use	**Puddle Area (Hectare)**	**The Value of Land Use (Rupiah/Hectare)**	**The Lost Cost Caused By Flood And Rob In Water Catchment Area Of Banger (Rupiah)**
Settlement	20,5	7.080.295.000	145.146.047.500
Building/ Industrial Area	6,2	9.179.524.000	56.913.048.800
Open field	3,3	12.263.000	40.467.900
Road	4	10.875.000	43.500.000
Sum	**34**		**202.143.064.200**

2. Indirect benefit
Indirect benefit is a new benefit which is able to be felt after several times of the project has been finished to be constructed. Indirect benefit of Banger river polder system construction is as follow:

– As tourism spot
– Creating an employment when activity implementation and post-construction of Banger river polder system

The Parameter of Economy

The costs needed for work implementation are as follow:

- Land acquisition cost (L) = Rp. 55.896.000.000,00
  Construction cost for five years (K) = Rp. 20.685.524.000,00
  Annual construction costs = Rp. 4.137.105.000,00
- Technical cost for seven years = Rp. 3.102.828.000,00
  Annual technical cost (T) = Rp. 443.261.000,00
- Operational cost and maintenance (O&P) = Rp. 3.144.900.000,00

Benefit costs estimated of the Banger river polder system construction are as follow:

- The benefit of flood and roc control for ten years is Rp. 202.143.064.200
- The benefit cost of flood and roc control in a year is Rp. 20.214.306.420

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1. Calculating NPV
Calculating NPV used Discount Factor (DF) = 15%. The detail of calculation suitable for the project age (ten years) can be viewed on the table below:

Table 3. The Calculation of NPV (DF = 15%)

(dalam juta rupiah)

Tahun	Cost (C)					Benefit (B)	DF	PV		
	LARAP	Teknik	Konstruksi	O&P	Jumlah	Banjir dan Rob	15%	PV Cost		PV Benefit
1	2	3	4	5	6 = 2+3+4+5	7	8	9 = 6	10 = 5 x 8	11 = 7 x 8
2016		488			488			488		
2017		488			488			488		
2018	55.968	488	4.137		60.593			60.593		
2019		488	4.137		4.625			4.625		
2020		488	4.137		4.625			4.625		
2021		488	4.137		4.625			4.625		
2022		488	4.137		4.625			4.625		
2023				1.430	1.430	10.107	0,87		1.243	8.789
2024				1.430	1.430	20.214	0,76		1.081	15.285
2025				1.430	1.430	20.214	0,66		940	13.291
2026				1.430	1.430	20.214	0,57		817	11.558
2027				1.430	1.430	20.214	0,50		711	10.050
2028				1.430	1.430	20.214	0,43		618	8.739
2029				1.430	1.430	20.214	0,38		537	7.599
2030				1.430	1.430	20.214	0,33		467	6.608
2031				1.430	1.430	20.214	0,28		406	5.746
2032				1.430	1.430	20.214	0,25		353	4.997
Jumlah									87.241	92.662
NPV (PV Benefit - PV Cost)										5.421

From the calculation result, obtained that the value of NPV is more than zero which is Rp 5.421.000.000, therefore, it can be concluded that the project of Banger river polder system is reliable to be constructed from the technical economy side.

2. IRR

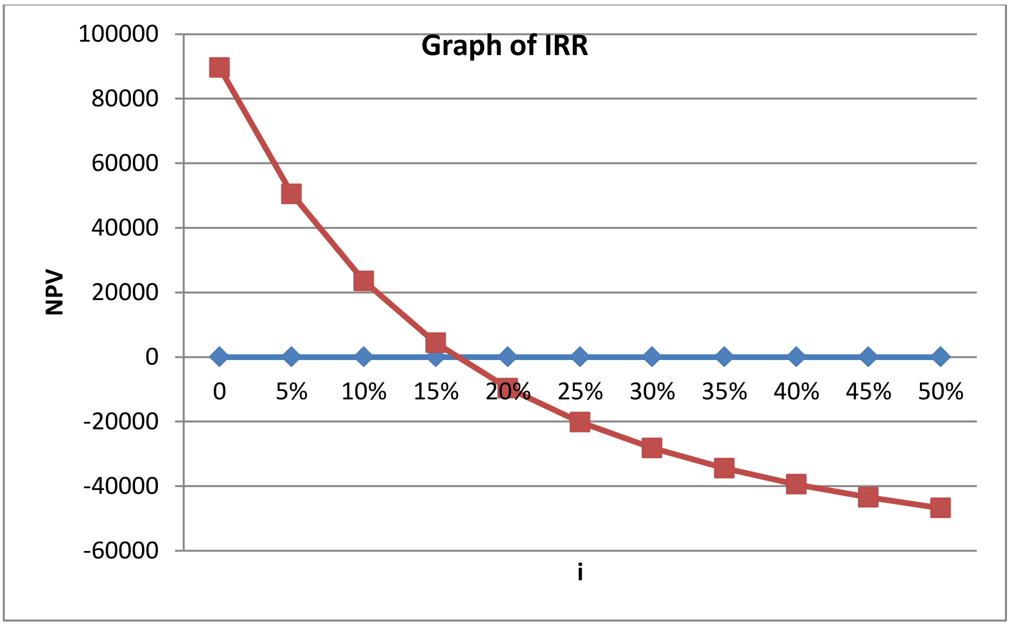

Figure 10. Graph of EIRR of the Polder system project in Water catchment area of Banger

From the calculation result, it can be noticed on the figure 10, the value of EIRR of the Polder system project in Water catchment area of Banger is 16.69 percent. It means that the project will have the benefit as long as the applicable interest rate is less than 16.69 percent. Meanwhile, if the value of interest rate is more than 16.69 percent, the project wil have the lost.

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IV. CONCLUSION AND SUGGESTION

The result of this research show that the volume needs of storage pool and pump capacity is influenced by the maximum flood flow and flood duration. The combination of optimal storage pool capacity and pump is the capacity of storage pool which is 8.48 Ha and pump capacity is 7.5 m^3/s. combination of pool and pump capacity are also influenced by the cost of pump and operational cost of pump as well as land compensation cost. This research did not calculate social factor and others to limit the scope of research. From the calculation result of NPV and BCR that the project of Banger river Polder system is reliable to be constructed from technical economy side. Further research is needed to be conducted in more detail and deep for social analysis toward the land compensation cost and operational cost of pump in detail. Regarding the number of overall costs of the project, the implementation is conducted in step by step, by observing the priority scale and the benefit of each component in a system.

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