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Research Paper

Flood Control Efforts Through Conservation-Based Boezem In Welang River, Rejoso Sub-District, Pasuruan East Java

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***ABSTRACT**: Welang River is located in Rejoso Sub-district which has the largest Catchment area of 518 Km and river length of 36 Km, river width of 35 M and every year experiences flooding during high rainfall so that it often experiences flooding due to river overflows with water levels ranging from 10-120 cm. This causes community losses, damage to roads which disrupts the local economy and affects the quality of clean water and public health.*
Based on the results of the analysis obtained, the 50-year return period rational method design flood discharge, Q : 221,8330, V : 1,1440km/h, I: 8.48 mm/hour, t: 27.2734 hours. And through flood tracking, the max storage capacity is obtained at 47973.89 M3 so that the planned Boezem volume is A: 57568.668 M3, Δt : 0.9 seconds, Td: 4 hours with a guard height of 0.30M, max water elevation: ± 2.55, and along the watershed conservation is carried out by vegetative methods, they are planting trees in deforested forests around the watershed so that the trees are able to store water reserves, planting open land with cover crops, planting in a contour manner, providing infiltration wells in the community environment, and community empowerment involving stakeholders around the watershed by means of community service to care for the environment for river cleaning. Thus, it can seek to control flooding in the Welang river and reduce the level of road damage around the Rejoso sub-district road.
***KEYWORDS**: Flood, Conservation, Boezem*

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I. INTRODUCTION

Flooding is the occurrence of large rains in the upper reaches of rivers that are unable to accommodate the capacity of river discharge due to the shrinking of the watershed and the changing function of water storage sites. Currently, many sites have become settlements on the banks of the river and the amount of garbage that pollutes river water. From these conditions, of course, the availability of Green Open Space (RTH) on the banks of the river is greatly reduced because many trees are cut down illegally to build settlements on the banks of the river, resulting in a lack of water catchment areas. Based on the results of surveys and direct observations of the Welang River, the Welang River has the Rejoso Watershed (DAS), the Welang Watershed with the largest catchment area of 518 Km, with a river length of 36 Km, river width of 35 M. The morphological condition of the Welang River has a watershed area of 518 km. The morphological condition of the Welang River has a meandering flow (meander) and is a type of river that often changes river flow due to changes in hydraulic factors. The morphology of the Welang river in the upstream part often experiences riverbed degradation, river cliff scouring dueto, with a narrow river cross section, high river cliffs with steep riverbed slopes and large river flow velocities, this is physically there are several large rocks in the upper reaches of the river.

High rainfall intensity resulted in water discharge in the Rejoso Watershed, and the Welang Watershed experienced maximum discharge resulting in greater flooding due to overflowing river water, and the widening river section gradually caused siltation at several points of the river channel. Flood conditions also greatly affected settlements on the banks of the Welang River and its surroundings due to reduced water catchment areas, as well as flooding on the roads of Pasuruan Regency. As a result of flooding, the quality of the environment has changed significantly, and damage to roads has disrupted the economy of the community in

Rejoso Sub- district. Therefore, it is necessary to restore the basic function of the river itself from the siltation of the river and can seek flood control with the construction of Boezem and watershed conservation as environmental conservation efforts based on the role and function of each watershed and includes aspects of protection, maintenance and sustainable use of ecosystems.

II. LITERATURE REVIEW

Average Rainfall Analysis

To determine the amount of average rainfall in a watershed, there are three methods commonly used, namely the Arithmetic method, the Polygon Thiessen method, and the Ishoyet method. To analyse the average rainfall in this study, the Polygon Thiessen method is used. (Sri Harto, 1993)

Thiessen polygon

This method incorporates the influence factor of the area represented by the rain gauging station which is referred to as the weighting factor (*w e i ghi ng f a c t or*) or also known as the Thiessen Coefficient. The amount of the weighting factor depends on the area of influence represented by the station bounded by polygons that intersect perpendicularly at the centre of the line connecting two stations. Thus each station will lie within a closed polygon. The area of the rainfall area is considered to be represented by one of the stations concerned is the area bounded by the polygon. (Sri Harto, 1993)

$$\overline{P} = \frac{A_1.P_1 + A_2.P_2 + ... + A_n.P_n}{A_{total}}$$

$$\overline{P} = \frac{A_1.P_1 + A_2.P_2 + A_3.P_3 + ... + A_n.P_n}{A_1 + A_2 + A_3 + ... + A_n} \quad (1)$$

Description:

P : Recorded rainfall (mm)

$P_{1..,}$ P_n: Rainfall at the measuring station (mm)

A_n : Area of influence of each station

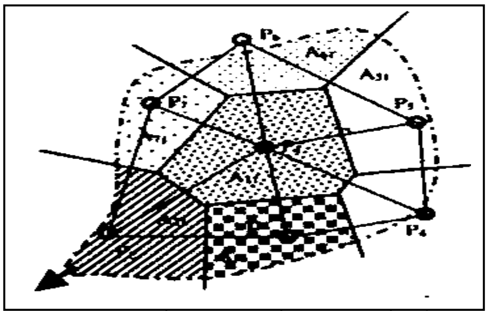

Figure. 2.1. Thiessen Polygon Method

Plan Maximum Rainfall Analysis

The data generated using the annual maximum rainfall data method. Maximum rainfall is important data to know because it is one of the characteristics of factors that can cause maximum flooding in a watershed. Maximum rainfall data can also be used to determine the plan of rain control buildings in Welang sunga Rejoso Pasuruan District. Berikur formula rain analysis plan with Gumbel method, namely

- Calculate the standard deviation of the rainfall data recorded at the local rainfall station with the formula :

$$S = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}} \quad (2)$$

S : Standard Deviation

Xi : Variant

X : Average

N : number of data

- Calculate the value of the frequency factor (K) from the rainfall data recorded at the localrainfall station with the formula :

$$K = \frac{Yt - Yn}{Sn} \quad (3)$$

Description:

K : Frequency Factor
Yn : Average price reduce variate
Sr : Reduced standard deviation
Yt : Reduced variated

- Calculate the Yt value with the following formula

$$Yt = -\ln(-\ln \frac{Tr-1}{Tr}) \quad (4)$$

Description:

Yt : Reduced variated
-In : Natural Logarithm $\frac{1}{(-x)}$
Tr : Rainfall plan period time

- Calculate rainfall using the annual return period plan with the following formula.

$$Xt = Xr + (K.\,Sx) \quad (5)$$

Description:

Xt : Annual rainfall plan
Xr : Average maximum rainfall
K : Frequency Factor
Sx : Standard Deviation

Design Flood Discharge

Design flood discharge is the maximum planned discharge in a river or natural channel with a certain return period that can be flowed without endangering the surrounding environment and river stability. Analysis of design flood discharge can be done by making direct observations and measurements at the river location or by analysing maximum rainfall data at rain measurement stations located in the river basin. There are several methods for calculating the design flood discharge, including the Rational method, Empirical method, HSS (Synthetic Unit Hydrograph) method which consists of HSS Snyder, HSS SCS, HSS Gama I, and HSS Nakayasu. An area under review with hydrological data is not available to reduce to the unit hydrograph, then a synthetic unit hydrograph is made based on the physical characteristics of the watershed. According to Soemarto (1999) in Bambang Triatmodjo, the Nakayasu synthetic unit hydrograph method was developed based on several rivers in Japan. The calculation of design flood discharge with Nakayasu synthetic unit hydrograph method requires the calculationof hourly effective rainfall distribution. This is necessary to estimate the amount of flow or maximum discharge that is closer to the reality conditions that occur in the field based on hourly rainfall or centralised rainfall. (Sri Harto, 1993)

The conveyance coefficient is the ratio between the water flowing on the land surface and the rainwater falling, the conveyance coefficient (RunOff) depends on the type of land surface and land use of the watershed. For watersheds where the use varies, the coefficient is a combination of the values of the conveyance coefficient. The comprehensive flow coefficient can be calculated by the equation :

$$C = \sum(\frac{C_i . A_i}{A_i}) \quad (6)$$

C : Coefficient of comprehensive flowd
Ci : Base flow coefficient
Ai : Area for each category

Plan flood discharge

Flooding is caused by high rainfall that causes river water to overflow from its flow, and overflow into the area around the channel or river, causing disturbance and damage to the surrounding environment. In the hydrological view, flooding occurs in a river or channel if the discharge flowing in the channel exceeds the average discharge capacity of the river / channel. The amount of plan discharge can be planned by analysing the height of the plan rain, and the maximum daily rain analysis produces plan rain in a certain period. Furthermore, the height of the rain plan is used to calculate the discharge plan with a return period in accordance with the calculation of rain plan. The planned flood discharge is the largest discharge that may occur in the planned return period. Analysis of the planned flood discharge is carried out based on the maximum daily rainfall that occurs in a certain period. This is done because the amount of river flow is determined by the amount of rain, rain intensity, area, length of time of rain, area of river basin and characteristics of the flow area. The method considered in the plan flood discharge analysis is the Nakayasu Synthetic Unit Hydrograph Method, with the equation: (Triatmojo, Bambang, 1996)

$$Qp = \frac{C.A.Ro}{3{,}6\ (0{,}3\ Tp + T0{,}3)} \qquad (7)$$

Qp : Peak flood discharge (m3 /second)
Ro : Rainfall units (mm)
T0,3 : Time required for discharge from TP to 30% of peak (hours)
Tp : Time required from the start of rainfall to the peak flood time (hours)
A : Watershed area (km)2
C : Watershed conveyance coefficient

Hydraulics Analysis

Hydraulics analysis is needed to plan rivers that can function optimally, so a calculation is needed to determine the appropriate dimensions in this study, namely river capacity calculated based on flood discharge with a return period of 15 years. The carrying capacity of this hydrological analysis also requires a morphological survey of the Welang river so that it can laterbe analysed for the river's carrying capacity, water discharge during maximum rainfall, and river cross-sectional dimensions (Bambang Triatmodjo, 2022). The average velocity formula in calculating the dimensions of the river cross section with the equation:

$$Q = \frac{1}{n} . R^{2/3} . I^{1/2} . A \qquad (8)$$

Q : River discharge (m^3 /second)
A : Cross-sectional area of the river $(m)^2$
N : Manning roughness coefficient
R : Hydraulic radius
I : Slope of river channel bed with guard height (w) 5%-30%

River Conservation

According to Sosrodarsono, 1994 that watershed conservation is defined as environmental conservation efforts based on the role and function of each area within the watershed and includes aspects of protection, maintenance and sustainable use of ecosystems . Various science and information about various conservation efforts to save the ecosystem and the environment in the watershed has been widely developed and important to be disseminated to the wider community through various media Utilisation of the potential of natural resources in the watershed (including forests) for various interests and human needs has led to the degradation of land and forests. Uncontrolled changes in the use of natural resources will affect the function and balance of the environment including hydrological processes within the watershed area, resulting in an imbalance of water balance, sediment, nutrients and destruction of biodiversity habitat. The goal of watershed management is to control the reciprocal relationship between natural resources and the watershed environment with human activities for the preservation of environmental functions and public welfare (Thioritz, 2009). In its application, the conception requires efforts that are not simple. It requires integrated management by various sectors/multi parties from upstream to downstream by considering various interests, biophysical and socio-economic conditions that exist in a watershed.

III. RESEARCH METHODOLOGY

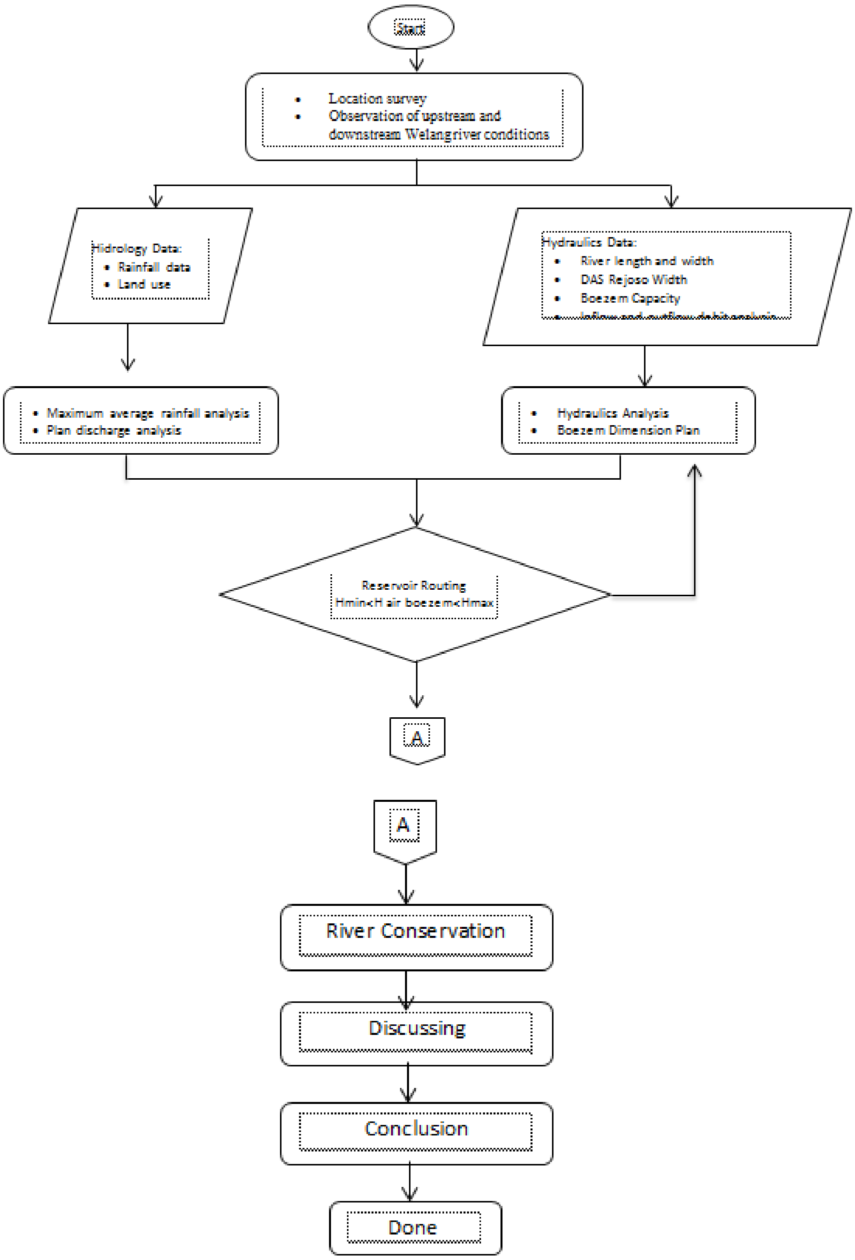

Figure 1. Flowchart of Research Methodology

Existing Condition of Welang River, Rejoso Sub-district

Welang River has the largest Catchment area of 518 km and the river length is 36 km, river width 35 M. The following are the results of observations of the Welang river carried out in the upstream, middle and downstream sections.

Figure 2. Upper Welang River

Figure 3. Middle Welang River

Figure 4. Lower Welang River

Based on information from the Jawa Pos Radar Bromo media on 13 February 2023, there was an overflow of the Welang river which caused flooding around Rejoso Village, affecting residential communities in Rejoso Village and flooding on roads which disrupted traffic vehicles, and affected the community's economy.

Picture 4.6. The overflowing Welang River flooded the houses in Rejoso Lor Village.

III. RESEARCH RESULTS

Plan Flood Discharge

Results Table Analysis Results Log Pearson III Value Analysis Results Design rainfall value

No.	Tahun	Tinggi Hujan (R)	log X	(Log X - Log $X_{rerata})^2$	(Log X - Log $X_{rerata})^3$
1	2007	80.0	1.903	0.009370329	-0.00090705
2	2008	109.7	2.040	0.001614770	0.00006489
3	2009	69.0	1.839	0.025934318	-0.00417650
4	2010	127.0	2.104	0.010797969	0.00112205
5	2011	81.0	1.908	0.008354952	-0.00076369
6	2012	109.7	2.040	0.001614770	0.00006489
7	2013	93.0	1.968	0.000986431	-0.00003098
8	2014	97.7	1.990	0.000102902	-0.00000104
9	2015	129.3	2.112	0.012503718	0.00139817
10	2016	124.3	2.095	0.008967547	0.00084920
Jumlah			19.9989	0.080247705	-0.00238007
Rerata			1.9999		
Standart Deviasi		0.0944			
Cs		-0.39262			

No	Birthday	Log Peaarson III
1	10	116,88
2	20	115,92
3	50	128,49
4	100	132,48

Source: Analysis Result

Table 1. Results of the Rational Method Design Flood Discharge Analysis

No.	Period Repeat	A	R	L	H	C	V	t	I	Q
	year	km2	mm	km	km		km/h	hours	mm/ho	
1	10	499,8	168,344	31,2	0,310	0,	1,1440	27,273	6,4412	178,994
2	20	499,8	191,656	31,2	0,310	0,	1,1440	27,273	7,3332	203,781
3	50	499,8	221,833	31,2	0,310	0,	1,1440	27,273	8,4878	235,866
4	100	499,8	244,445	31,2	0,310	0,	1,1440	27,273	9,3530	259,910

Source: Analysis Result

A : Watershed Area

R : Rational Rainfall Value

L : Largest River Length

H : Height Difference of Upstream and Downstream of River

C : Flow Coefficient

V : Flow Velocity

t : Time

I : Rainfall Intensity

Q : Design Flood Discharge

Hydraulics Analysis

Table 2. Channel Capacity Analysis Results

STA	Channel Plan					C Combined	I	A	Q capacity	Q plan	note.
	L	H	A	P	S						
	m	m	m2	m			mm	m2	m3/secon	m3/secon	
0+000	1,00	1,00	1,00	3,00	0,003	0,417	366,27	12,80	1,755450	0,000544	Ok
0+100	1,00	1,00	1,00	3,00	0,003	0,417	349,53	13,20	1,602500	0,000535	Ok
0+200	1,00	1,00	1,00	3,00	0,003	0,417	349,53	135,00	1,602500	0,005477	Ok
0+300	1,00	1,00	1,00	3,00	0,002	0,417	330,07	139,00	1,433319	0,005325	Ok
0+400	1,00	1,00	1,00	3,00	0,001	0,417	276,27	143,00	1,013510	0,004585	Ok
0+500	1,00	1,00	1,00	3,00	5E-04	0,417	231,25	146,00	0,358330	0,003919	Ok
0+600	1,00	1,00	1,00	3,00	5E-04	0,417	231,25	684,00	0,716660	0,018358	Ok
0+700	1,00	1,00	1,00	3,00	0,01	0,417	498,89	251,00	2,670833	0,014534	Ok
0+800	1,00	1,00	1,00	3,00	0,001	0,417	276,27	90,00	1,013510	0,002886	Ok
0+900	1,00	1,00	1,00	3,00	0,003	0,417	366,27	117,50	0,877725	0,004995	Ok
1+000	1,00	1,00	1,00	3,00	0,012	0,417	522,79	131,70	3,510901	0,007991	Ok
1+100	1,00	1,00	1,00	3,00	0,002	0,417	330,07	155,90	1,433319	0,005972	Ok
1+200	1,00	1,00	1,00	3,00	0,003	0,417	366,27	176,50	0,658294	0,007503	Ok
1+300	1,00	1,00	1,00	3,00	0,003	0,417	366,27	174,00	0,658294	0,007397	Ok
1+400	1,00	1,00	1,00	3,00	0,002	0,417	330,07	173,00	0,537495	0,006627	Ok
1+500	1,00	1,00	1,00	3,00	0,005	0,417	417,58	262,60	0,849854	0,012727	Ok
1+600	1,00	1,00	1,00	3,00	0,006	0,417	437,59	175,00	0,930968	0,008888	Ok
1+700	1,00	1,00	1,00	3,00	1E-03	0,417	276,27	181,00	0,380066	0,005804	Ok
1+800	1,00	1,00	1,00	3,00	5E-04	0,417	231,25	182,90	0,268747	0,004909	Ok
1+900	1,00	1,00	1,00	3,00	1E-04	0,417	152,99	183,90	0,120187	0,003266	Ok
2+000	1,00	1,00	1,00	3,00	0,002	0,417	311,70	185,80	0,480750	0,006722	Ok
2+100	1,00	1,00	1,00	3,00	0,001	0,417	276,27	187,10	0,380066	0,005999	Ok
2+200	1,00	1,00	1,00	3,00	4E-04	0,417	218,38	181,10	0,240375	0,00459	Ok
2+300	1,00	1,00	1,00	3,00	3E-04	0,417	202,83	186,10	0,208171	0,004381	Ok
2+400	1,00	1,00	1,00	3,00	3E-04	0,417	202,83	187,00	0,208171	0,004402	Ok
2+500	1,00	1,00	1,00	3,00	6E-04	0,417	242,33	243,40	0,294398	0,006846	Ok
2+600	1,00	1,00	1,00	3,00	1E-04	0,417	152,99	184,20	0,120187	0,003271	Ok
2+700	1,00	1,00	1,00	3,00	3E-04	0,417	202,83	181,10	0,208171	0,004263	Ok
2+800	1,00	1,00	1,00	3,00	0,003	0,417	366,27	190,00	0,658294	0,008077	Ok

L : Channel width

H : Channel length

A : Channel area

P : Wet perimeter of the channel

C combined: Combined flow coefficient value

I : Rainfall intensity

A : Area at a given point

Qcapacity: Channel capacity discharge

Qplan: Plan discharge passing through the channel

From the results of the flood tracing analysis, namely with a maximum storage capacity of 47973.89 M^3 so that the Boezem dimensions can be planned, namely by knowing the cumulative Boezem volume of the Boezem cumulative volume added 20% for the safety number, so that the Boezem storage volume can be calculate:

V = Cumulative volume + 20% Cumulative volume
V = 47973.89 m3 + (20% x 47973.89 m3)
V = 47973.89 m3 + 9,594.778
= 57568.668 m3

Boezem Volume = Area x Depth
57568.668 m3 = A x (4.71 - 3 m)
57568.668 m3 = A x (1.71)
A = 57568.668 m3 / 1.71
A = 33665.89 m2

Flood Routing Analysis

To analyse Flood Routing, the relationship between elevation, water level and planned Boezemstorage must be calculated.

Δt = 15 minutes x 60 seconds = 900/1000 = 0.9 seconds
Td = 4 hours = 240 minutes.

Table 3. Boezem Inflow Discharge

Channel P4		Channel T11	
T (minutes)	Q (M3/sec)	T (minutes)	Q (M3/sec)
0	0	0	0
57,84	2,88	31,01	0,79
297,84	2,88	27,01	0,79
355,69	0	302,01	0

Source: Analysis Result

Table 4. Inflow Results Td = 4 hours

Superposition			
T (hour)	Q (M3/second)	T (hour)	Q (M3/second)
0,00	0,00	3,21	3,67
0,25	1,13	3,46	3,67
0,52	2,34	3,71	3,67
0,50	2,29	3,96	3,67
0,75	3,03	4,21	3,67
0,96	3,67	4,46	3,67
1,21	3,67	4,71	3,37
1,46	3,67	4,96	2,98
1,71	3,67	5,21	2,13
1,96	3,67	5,46	1,39
2,21	3,67	5,71	0,64
2,46	3,67	5,75	0,53
2,71	3,67	5,93	0,00
2,96	3,67	6,00	0,00

Source: Analysis Result

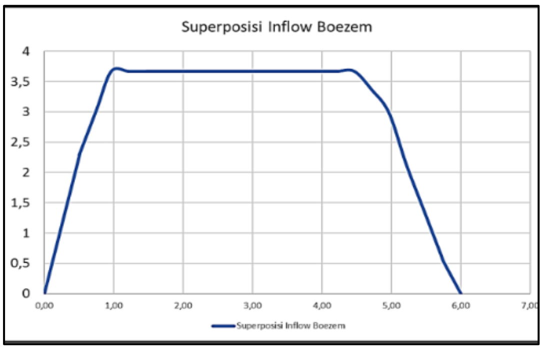

Figure 5. Superposition of Boezem Inflow

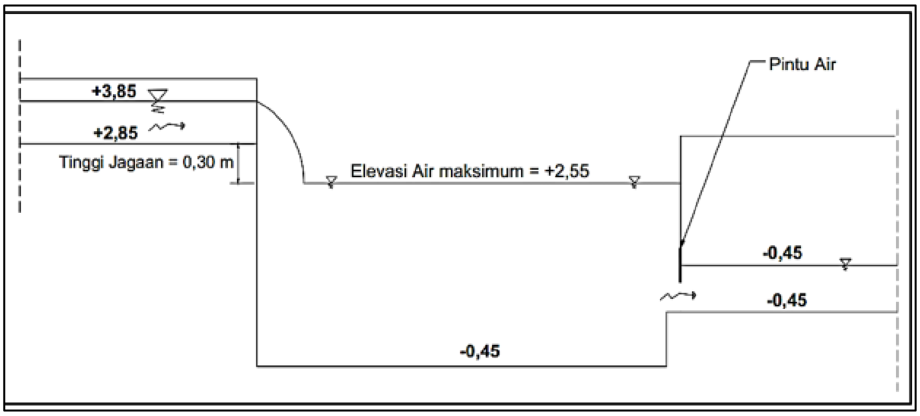

Figure 6. Cross Section of Boezem Inflow and Out Flow

Operation of Boezem

The Boezem operating system is based on whether the downstream elevation at the outflow to the Welang River is higher or lower. If the downstream elevation is lower than the Boezem elevation, the water is diluted by the gravity method using a sluice gate with a maximum water level elevation of + 2.55 m with a 0.30 m guard height.

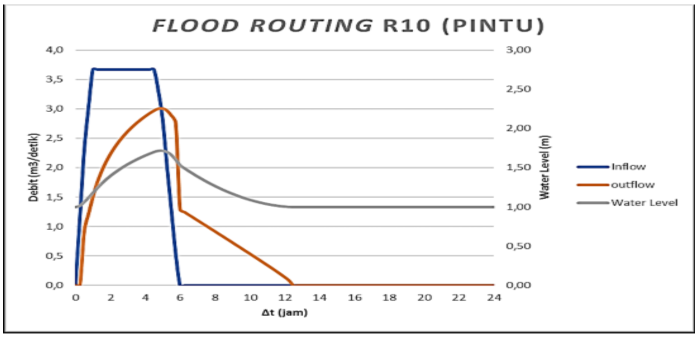

Figure 7. Flood Routing Boezem with Door as Outflow

Table 5. Operation of Boezem with Pump

No.	Water Elevation			Number of active pumps
1	+0,05	-	+0,79	0
2	+0,79	-	+1,17	2
3	+1,17	1	+0,57	1
4	< +0,55			

Source: Analysis Result

Table 6. Operation of Boezem with Sluice Gate

No.	Water Elevation			Number of active pumps
1	+0,05	-	+0,62	0
2	+0,62	-	+1,16	2
3	+1,16	1	+0,55	1
4	< +0,55			0

Source: Analysis Result

Conservation

Considering the function of the watershed is useful for people's lives, the watershed plays an important role in protecting the environment and can control the occurrence of flooding and provide clean water needs for the community and reduce the flow of soil masses from upstream to downstream. In order to maintain the condition of the watershed, conservation is needed, they are:

1. Land utilisation with vegetative methods, which is planting trees in deforested forests around the watershed so that the trees can store water reserves,
2. Afforestation of open land with steep slopes by planting trees and grasses.
3. Planting open land with cover crops
4. Planting by travelling along elevation lines (contours)
5. empowering communities around the watershed to strive for the protection and maintenance of the river through environmental care by cleaning up rubbish in the river with the involvement of stakeholders and the community, and making infiltration wells to reduce flooding on roads in Rejoso Sub-district.

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