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Management of Flood Control in Sampean Lama-Muara Weir

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ABSTRACT

The highest flood in Sampean watershed was occurred in February 2008. It indicated that the watershed had a heavy degradation. The flood disaster and indication of higher critical level on watershed as the background of this research to study the management of flood control in Sampean watershed. In depth analysis, this study intended to anticipate and minimize harm due to the flood disaster. The methodologies consisted of hydrology and hydraulic analysis. Historical data indicated that the highest flood in Sampean Baru Weir was 2,012.96 m^3/s and it was due to the rainfall of 178 mm. Now the capacity of Kali Sampean was 1,435.82 m^3/s and it was based on the discharge with 2 years return period (Q_2). Alternative design was planned due to the discharge with 50 years return period of 2,468.78 m^3/s. In addition, it was also designed by considering height factor of tide-ebb (High Water Level – HWL) of 2.43 Design alternative I was carried out by building dyke with 1 trap double dimension and alternative II was building dyke wirh two traps double dimension. Free board design was 0.75 m from flood water level. Beside design of the dyke, flood handling was also carried out by improving and widening river section or capacity..

Keywords: flood, Sampean watershed, river

INTRODUCTION

A continuing case in hydrology is peak discharges estimation due to the design purposes on watersheds with only limited available data. One of the approaches to this case is to regionalize the flood frequency characteristics and analysis on a number of gauged watersheds, the other is to estimate the flood frequency distribution on the basis of more readily and available long rainfall records or intensity duration frequency rainfall statistics, and then to use a spesified design of storm or high flow. [1]. Almost the entire territory of the watershed belongs to insufficient moistering domain. It is due to the character of water regime with pronouncing flood and it is relatively stable on summer dry period. [2]. Hydraulic structures are the subject to uncertainties. Uncertainties are as the primary contributors to hydraulic structures failure. It is nacessary to recognize the uncertainties involving in hydrologic and hydraulic design and analysis. Numbering of uncertainties provides the information that is needed for risk-based design and reliability analysis [3]. For many years the hydrologists have been interested in the impacts of various uncertainties on the reliability and accuracy on the estimation of catchment hydrological variables such as peak discharge and volume. The estimation of rainfall uncertainty will give an impact on runoff simulation. However, with economic implementation and development of water resource system plannings and projects in the watersheds, human activities have altered the conditions for runoff generation. For example, the construction of dams, changes in land use, and river conduits diversion has made the runoff series nonstationary from time to time [4]. In addition, the optimal combination of flood protection options is determined to minimize the construction cost of flood control and damages along the river. The design flood values is very important for deciding the option especially when the lengths of recorded data were short and it may require the usage of various statistical distributions [5]

The highest flood in Sampean watershed was happened on February 2008. It indicated that the condition of Sampean watershed experienced the heavy degradation besides the natural factor like climate which caused high rainfall and long duration. Therefore, it was nacessary to carry out the flood management there. Population growth in Bondowoso and Situbondo Regency was followed by critical land use in these areas and it caused sedimentation in the Dam of Sampean Lama and Sampean Baru. Flood in rainy season and drought in dry season is as the phenomenon in the recent years, even on February 2008 there was happened flood disaster in Situbondo Regency and almost the whole Situbondo City was flooding due to the running over of Sampean River. Some reasons of the flood were more surface runoff due to the high rainfall intensity and duration, so the capacity of Sampean River could not store the water. In addition, there was shallowing or sedimentation on the river bed that decreased the flow capacity. Flood occurances in Sampean watershed during 1922 to 2008 were as follow [6][7][8]: 1) In 1922 with flood discharge of 2,200 m^3/s; 2) In 1933, water of Sampean River flow through Bondowoso City and running over the dyke due to rarefaction of the dyke. The flow discharge in the range of 900 to 1,000 m^3/s; 3) In 2002, there were two flood occurances in the downstream of Sampean

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watershed of Situbondo Regency such as on January 29 and February 4. The flow discharge was estimated as 2,000 m^3/s. The harm included water resources structure (general work) of 25 milyard rupiahs; non general work structure of 4.7 milyards rupiahs; and 35 persons have passed away; and 4) On February 8, 2008 there was happened flood in Sampean watershed which invloved Bondowoso and Situbondo Regency. The flow discharge was estimated as 2,400 m^3/s with the rainfall intensity between 115 mm until 181 mm which was more than normal rainfall of 100 mm.

The purpose of this study was to anticipate and minimize the harm which was caused by the same flood. In addition it was intended to maintain the available natural resources. Technically, this study intended to know the river capacity due to the design flood in the section of Sampean Lama weir-estuary and to know the accurate handling for increasing river capacity in the section of Sampean lama-estuary on the effort of flood management in Sampean River

MATERIALS AND METHODS

The regency of Bondowoso and Situbondo is passed by Sampean River and there is small storage like bowl which is surrounded by the mountains of Ijen, Raung, and Argopuro. The source of Sampean River is in the slope of Arjuno Mountain and estuaried in Selat Madura. At about 80% of Sampean watershed is located in Bondowoso Regency and the other is in Situbondo Regency. Map of location was as in Figure 1 and map of watershed was as in Figure 2.

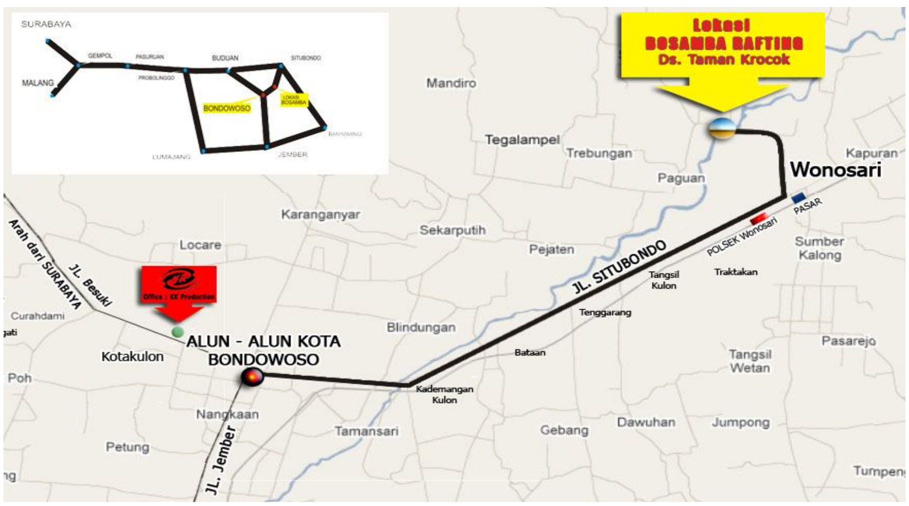

Figure 1 Map of location

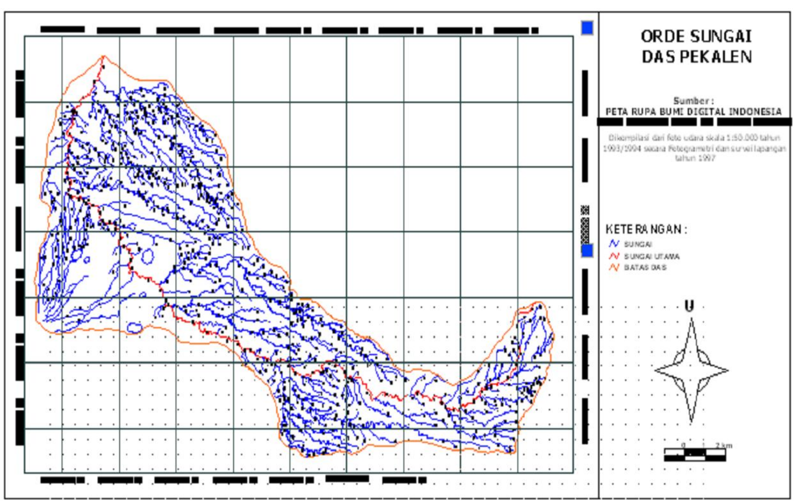

Figure 2 Map of Sampean watershed

This study used the analysis of hydrology and hydraulic with the steps were as follow: [6][7][8]

1. Analysis of hydrology which included:
   a. Consistency test of rainfall data by using raps method and inlier-outlier test.
   b. Analysis of area averaged rainfall by using Polygon Thiessen method.
   c. Analysis of design rainfall.
   d. Testing of goodness of fit by using Smirnov-Kolmogorof test and chi square test [9]
   e. Analysis of rainfall intensity and net rainfall by using PSA 007 method
2. Analysis of design flood by using Synthetic Unit Hydrograph of Nakayasu and based on the analysis of design rainfall with return period of 2, 5, 10, 25, 50, and 100 years.
3. Analysis of flood profile in the river by using the software of HEC RAS 3.1.3 with the model of state steady flow.
4. Analysis of river flood handling of Sampean watershed by increasing river capacity with additiuonal alternative of river capacity normalisation or dyke building as being suggested in this study.

Maximum daily averaged of area rainfall

To abtain the illustration of rainfall distribution in the whole of waterhed, there is needed to install rainfall recorder in some locations and to analyse area rainfall in this study it was used the method of Polygon Thiessen as follow: [10]

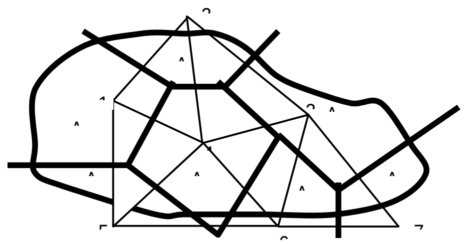

Figure 3 Scheme of Polygon Thiessen

$$d = \frac{A_1 d_1 + A_2 d_2 + \ldots\ldots\ldots\ldots A_n d_n}{A} = \sum_{i}^{n} A_i d_i \quad (1)$$

Note:

A = area number (km^2)
d = area averaged rainfall depth (mm)
$d_1, d_2, d_3 \ldots d_n$ = rainfall depth in pos 1,2,3,…..n
$A_1, A_2, A_3 \ldots A_n$ = influenced area number in pos 1,2,3,….n

Design rainfall

Design rainfall is defined as yearly maximum rainfall due to the certain return period. In this study, design rainfall was analyzed by using Log Perason III. This method is relatively flexible for any statistical conditions of data. Three parameters statistic which are used in this method is mean, standard deviation, and skewness.

Design flood

The value of design flood was due to the flood caused by running over of river and the analysis is based on the happened yearly maximum flood or rainfall. Analysis of design flood in this study was cariied out by using Synthetic Unit Hydrograph of Nakayasu as follow: [10]

$$Q\max = \frac{1}{3,6} xAx \frac{Ro}{(0,3Tp + T.0,3)} \quad (2)$$

Note:

Tp : Tg + 0,8 tr
Tg : 0,40 + 0,058 x L ⟶ if L > 15 km
Tg : 0,21 x L^{0,7} ⟶ if L < 15 km
T0,3 : ά . Tg
Qmax : peak discharge (m^3/s/mm)
A : area number (km^2)
Tp : time lag from the beginning of rainfall to peak discharge (hour)

T.0,3 : time of recession peak discharge until 30% of peak discharge (hour).
Tg : time lag between the rainfall to peak discharge (hour).
tr : time unit of rainfall (= 1hour)
L : length of river (km)

The formulation of unit hydrograph:

1. Rising curve:
   $0 \leq t \leq Tp$
   $Q_t = Q_{max} \ (t/Tp)^{2,4}$

2. Recession curve:
   If $Tp \leq t \leq (Tp + T_{0,3})$, so:
   $Qt = Q_{max} . 0,3^{[(t-Tp)/T0,3]}$
   If $(Tp + T_{0,3}) \leq t \leq (Tp + T_{0,3} + T_{0,3}{}^2)$, so
   $Qt = Qmax . 0,3^{[(t-Tp + 0,5 .T0,3)/(1,5.T0,3)]}$
   If $t \geq (Tp + T_{0,3} + 1,5 .T_{0,3})$ so
   $Qt = Q_{max} . 0,3^{[(t-Tp + 1,5 .T0,3)/(2.T0,3)]}$

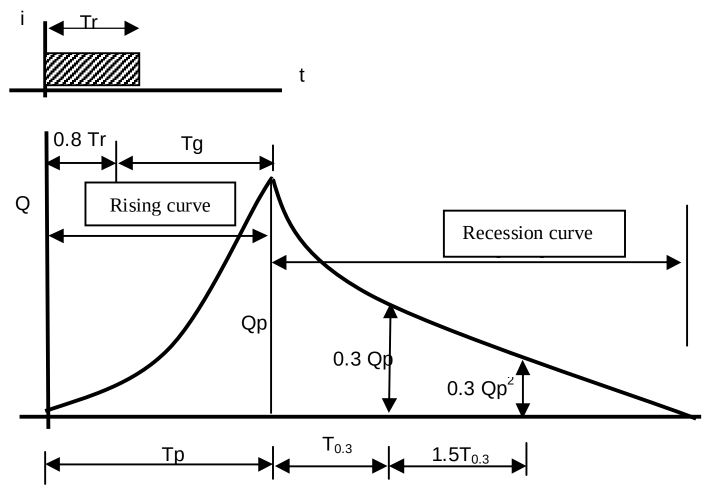

Figure 4 Synthetic Unit Hydrograph of Nakayasu

Hydraulic analysis of river

Hydraulic analysis of river is intended to analyze water level profile of flood in river with some return periods of design flood. Hydraulic analysis will analyze how far structurely the influence of flood control due to the flood water level depth and the happened running over of flood. Hydraulic analysis in this study used Hydrologic Engineering Centre-River Analyst System (HEC-RAS) versi 3.1.3 which has been developed by Hydrologic Engineering Center of the U.S Army Corps of Engineers in the edition of May 2005 [10].

HEC-RAS is as an integrated software system which is designed by using multi-task interactive [10]. This system includes Graphic User Interface (GUI), separated component of hydraulic analysis, data saving and management capability, reporting and graphic facility. HEC-RAS system has 3 components of one dimensional hydraulic analysis for 1) profile analysis of steady flow water surface; 2) simulation of unsteady flow; and 3) analysis of moveable boundary of sediment transport. Key element of the three components will use the representation of general geometric data and general analysis of hydraulic. The steps of hydraulic analysis are as follow [10]:

1. Preparation of river scheme.
2. Data input of river geometric, design flood, tide-ebb, and roughness coefficient of channel.
3. Analysis of flood water level elevation.
4. Analysis of output model such as flood water level elevation for certain period.

RESULTS AND DISCUSSION

Analysis of area averaged rainfall

By using the method of Polygon Thiessen, area averaged maximum of rainfall in Sampean watershed as in Table 1.

Table 1 Area averaged maximum of rainfall

Year	Rainfall (mm)	Year	Rainfall (mm)
1990	109.92	1999	165.23
1991	132.20	2000	92.00
1992	131.74	2001	167.27
1993	160.63	2002	167.50
1994	131.12	2003	167.50
1995	127.94	2004	112.99
1996	96.00	2005	161.34
1997	144.01	2006	117.00
1998	92.00	2007	83.57

Source: result of analysis

The process of design rainfall analysis by using Log Pearson III was as follow and the result was presented as in Table 2:

$$\log X = \overline{\log X} + k\left(\overline{S\log X}\right)$$

Mean = 2.107 mm
Standard deviation = 0.102 mm
CS = -0.391mm
k = distribution value of return period

Table 2 Design rainfall in Sampean watershed

No	Tr (year)	Pr	G	G.S	Log X	CH (mm)
1	2	50	0.0646	0.0066	2.1133	129.8117
2	5	20	0.8548	0.0869	2.1937	156.2010
3	10	10	1.2322	0.1253	2.2321	170.6340
4	25	4	1.6092	0.1637	2.2704	186.3831
5	50	2	1.8388	0.1870	2.2938	196.6806
6	100	1	2.0354	0.2070	2.3138	205.9491
7	200	0.5	2.2087	0.2246	2.3314	214.4788

Source: result of analysis

Runoff coefficient of C

Runoff coefficient of C in this study was found based on the existing land use and it was due to the area percentage of each land use [11][12]. Analysis of averaged C in Sampean watershed was as follow and the runoff coefficient was presented as in Table 3 below: [11][12][13][14]

$$C_{rerata} = \frac{C_1A_1 + C_2A_2 + ... + C_nA_3}{A_{total}}$$

Table 2 Runoff coefficient of land using in Sampean watershed

No	Land using	Area number (km^2)	% of area number	C	C x % of area number
1	Forest	206.22	16.63	0.50	0.083
2	Shrubs	95.11	7.67	0.42	0.032
3	Plantation	65.01	5.24	0.72	0.038
4	Irrigated rice area	428.98	34.60	0.72	0.249
5	Rainy rice area	110.79	8.94	0.72	0.064
6	Residence	333.66	26.91	0.65	0.175
Total		1,239.77	100.00		0.642

Source: analysis of data and land use map

Based on the analysis as above, the value of C was 0.642

Physical parameter of sybthetic unit hydrograph in Sampean watershed

Calibration was carried out by comparing the historical (observed) discharge of gauged flood and peak discharge of Nakayasu due to the gauged rainfall. Gauged historical flood in Sampean Baru weir was 2012.96 m^3/s but in the same day, this flood was known causing by the rainfall of 178 mm.

Recapitulation of Alpha value trial for Sampean Baru watershed

Trial of alpha value was intended to produce the comparison between observed discharge hydrograph and synthetic unit hydrograph of Nakayasu. Figure 5, 6, 7, 8, 9, and 10 was presented trial of alpha value for each of 1.8; 2; 2.4; 2.5; 2.6; and 2.63

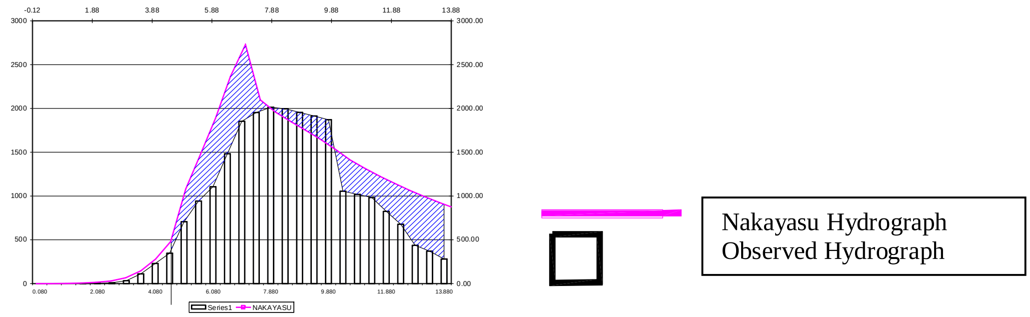

Figure 5 The comparison of Nakayasu and Observed Discharge with alpha of 1.8

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was 81,476,910.83 m^3.

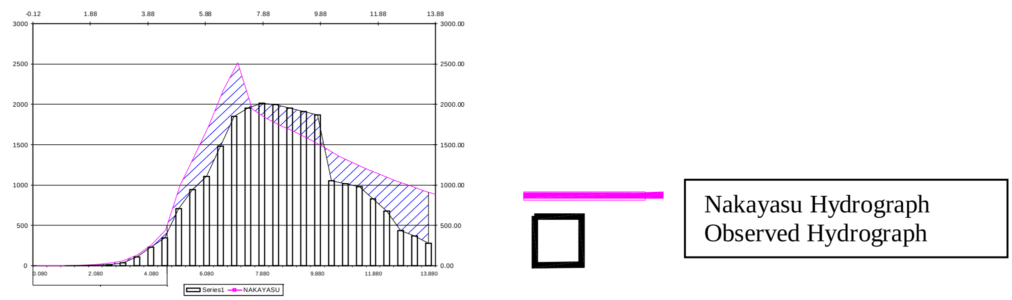

Figure 6 The comparison of Nakayasu and Observed Discharge with alpha of 2

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was78,755,708.15 m^3

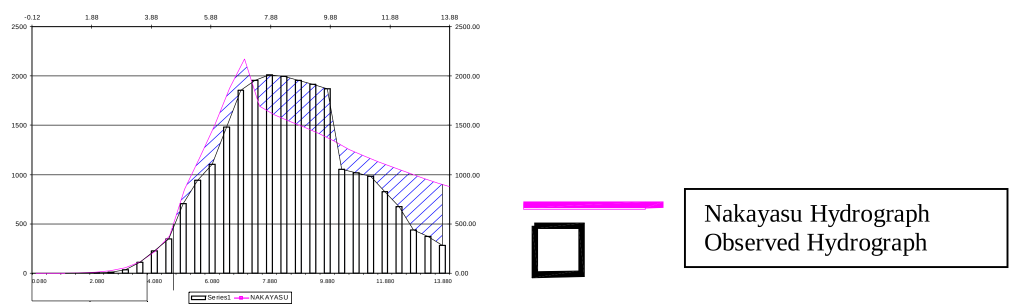

Figure 7 The comparison of Nakayasu and Observed Discharge with alpha of 2.4

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was 73,434,098.33 m^3

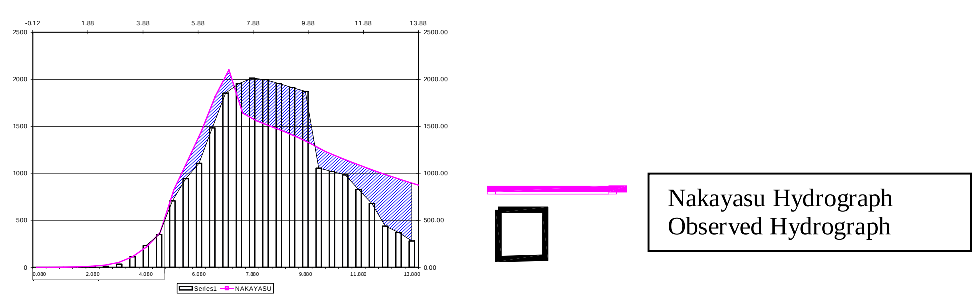

Figure 8 The comparison of Nakayasu and Observed Discharge with alpha of 2.5

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was 72,185,840.82 m^3

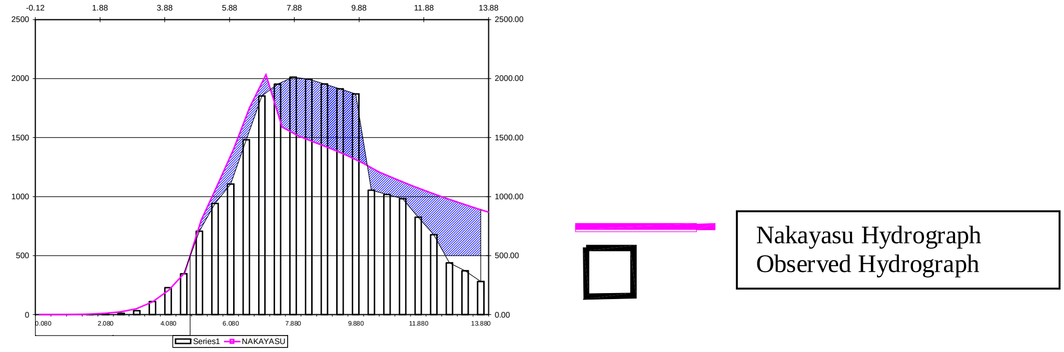

Figure 9 The comparison of Nakayasu and Observed Discharge with alpha of 2.6

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was 72,110,743.99 m^3

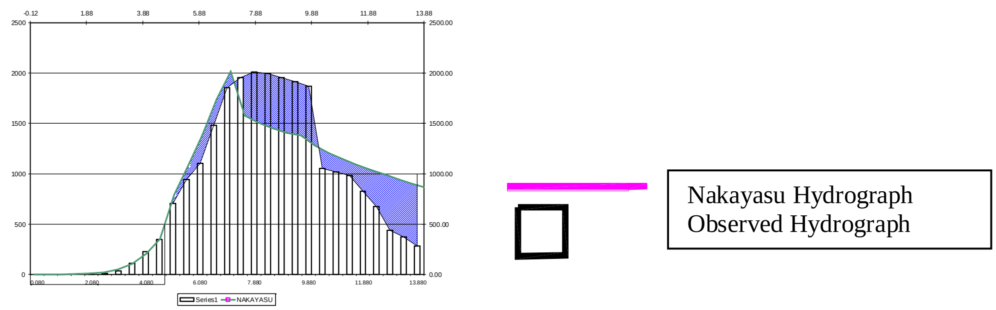

Figure 10 The comparison of Nakayasu and Observed Discharge with alpha of 2.63

Based on the analysis and the curve as above, the different volume between Nakayasu and observed hydrograph was 71,732,146.00 m^3

Control of selected alpha value due to the averaged slope of Sampean watershed

Based on the slope map of Sampean watershed, there could be analyzed the averaged slope of Sampean watershed. This value was as the evaluation of accuracy control of alpha value which was obtained from the trial of alpa as above. The accuracy of alpha value for Sampean watershed was 2.63. Table 3 presented the analysis of averaged slope in Sampean watershed.

Table 3 Analysis of averaged slope in Sampean watershed

Slope (%)	Area number km^2	% of watershed area number	Averaged slope (%)
40	651.366	0.526	21.02
15	588.404	0.475	7.12
Total			28.14

Source: analysis and result

Based on the analysis as above, it was concluded that selected alpha for Sampean watershed was 2.63 and it could be used in analysis of synthetic unit hydrograph in Sampean watershed because the averaged slope was < 30% (hilly group)

Analysis of Design Flood based on the Nakayasu Synthetic Unit Hydrograph in Sampean watershed

Table 4 presented flood design of some return period using Nakayasu formula in Sampean watershed. The result was analysed by using the formula of Nakayasu Synthetic Unit Hydrograph

Table 4 Design flood of some return period based on the Nakayasu Formula

Return period (year)	Design flood (m^3/s)
2	1,572.34
5	1,891.94
10	2,051.55
25	2,234.50
50	2,369.16
100	2,448.60

Source: analysis of result

Analysis of flood flow profile in the section river of Sampean Lama-Muara Weir

Analysis of flood flow profile in the river section was carried out by using the sofware of HEC-RAS 3.1.3.[10]. This software was as program of USCE (United State Corps of Engineers). Analysis of flood profile was due to the flood with the return periods of 2 years (Q_2), 5 yeras (Q_5), 10 years (Q_{10}), 50 years (Q_{50}), and 100 years (Q_{100}) and these results were intended for finding existing capacity of Sampean river. Result of flood profile on Sampean river presented that Sampean river capacity was not able to store the design flood with 2 years return period of 1,435.82 m^3/s especially in the downstream of estuary. Figure 11 presented the flood profile in the center section of Sampean river.

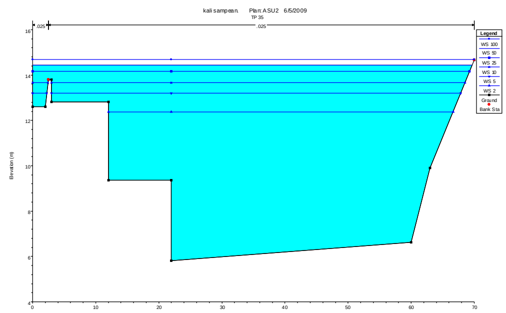

Figure 11. Flood profile in the center section of Sampean river

Flood handling in Sampean river on the section of Sampean Lama-Muara Weir

Suggested plan of flood handling in this study used design flood of 50 years return period and it was based on the historical flood in the outlet of Sampean Baru weir such as 2,012.96 m^3/s and it was as the design flood with 25 years return period (Q_{25}) and area number of watershed was 768.68 km^2. Therefore, it was used the design flood of 50 years return period (Q_{50}) of 2,369.156 m^3/s for the design safety of flood handling in the watershed. This design also consideratеd to the factor of tide-ebb depth such as HWL (High Water Level) of 2.43 m.

Analysis of Q design

Q design was determined based on the return period of happening design flood in the outlet of Sampean Baru weir such as 2,012.96 m^3/s, so that was formerly carried out the analysis of return period in the outlet of Sampean Baru weir with the physical characteristic of watershed as follow: the length of river (l) was 47.469 km; α (alpha) was 2.63; tr was 2.36 hours; unit rainfall was 1.00 hour. By the same way, there was obtained the design flood with some return period as presented in Table 5 below.

Table 5. Design flood of some return period in the outlet of Sampean Baru weir

Return period (years)	Design flood (m^3/s)
2	1466.818
5	1764.966
10	1909.563
25	2074.415
50	2167.727
100	2270.128

Source: analysis of result

Based on the analysis as above, it was concluded that historical flood in the outlet of Sampean Baru weir was 2,012.96 m^3/s and it was as the design flood of 25 years return period (Q_{25}). For design safety of flood handling, it was selected design flood with 50 years return period (Q_{50}) and it was analysed by predicting in the coming years due to the simulation that the forest has a potency to change into dry (not irrigated) field, plantation or shrubs, and dry (not irrigated) field has a potency to change into irrigated rice area, shrubs, and plantation, but residence will always increase or in the coming years the redidence will not decrease. Simulation of land use change approach in the coming years was presented in Table 6 and design flood of Nakayasu formula in Sampean watershed due to the simulation of land use change approch with the design flood of 50 years return period (Q_{50}) was presented as in Figure 12.

Table 6. Simulation of land use change approach in the coming years

Land using	Area number (km^2)	Simulation in the coming years (km^2)	% change	% of new area number	Runoff coeff (C)	C x % of area number
Forest	206.22	113.42	-45	9.15	0.50	0.046
Shrubs	95.11	29.33	-69	2.37	0.42	0.010
Plantation	65.01	95.94	32	7.74	0.72	0.056
Irrigated rice area	428.98	513.83	17	41.45	0.72	0.298
Rainy rice area	110.79	72.02	-35	5.81	0.72	0.042
Residence	333.66	415.24	20	33.49	0.65	0.218
Total				100.000		0.669

Source: analysis of result

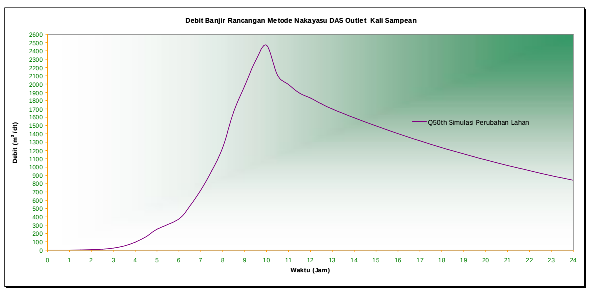

Figure 12 Design flood of Nakayasu formula in Sampean watershed due to the simulation of land use change approch with the design flood of 50 years return period (Q_{50})

Based on the analysis as above, Q design of flood handling for flood risk in the coming years used design flood with 50 years return period (Q_{50}) of 2,468.78 m^3/s. This data was used as the input of simulation by using HEC-RAS 3,1 [14], for analysis the happening flood profile in tide-ebb condition on the High Water Level (HWL) of +2.43 m.

Typical of dyke design

Figure 13 was presented type-I of dyke design

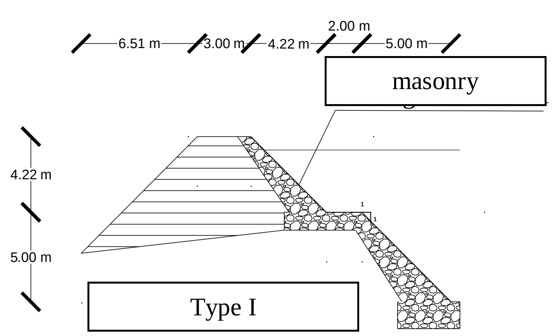

Figure 13. Type I of dyke design

Type I of dyke design was as 1 trap double dimensions dyke with the technical data as follow:

- Width of trap dyke was 2 m
- Depth of down dyke was 5 m and Z = 1:1
- Upper width of top side dyke was 3 m
- Elevation of dyke was designed as 0.75 x higher than flood water level of Q_{50} and Z = 1:1

Figure 14 was presented type II of dyke design

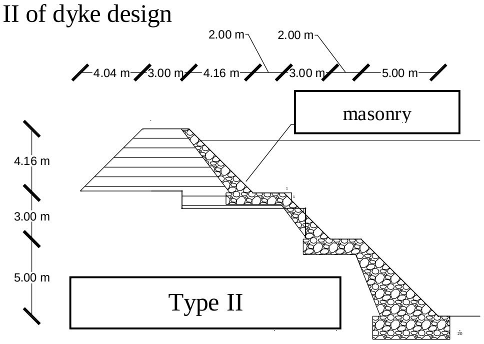

Figure 14. Type II of dyke design

Type I of dyke design was as 2 trap double dimensions dyke with the technical data as follow:

- Width of trap dyke was 2 m
- Depth of down dyke was 5 m and Z = 1:1
- Height of second trap dyke was 3 m
- Upper width of top side dyke was 3 m
- Elevation of dyke was designed as 0.75 m higher than flood water level of Q_{50} and Z = 1:1

Modelling of flood profile after design handing

Flood handling in this study was also carried out to evaluate the flood profile by using the software of HEC-RAS 3.1.3 [14]. Result of flood profile analysis indicated that handling design section has enough capacity to store the flood of Q_{50}. Figure 15 and 16 presented the river capacity ability of dyke handling design and normalization.

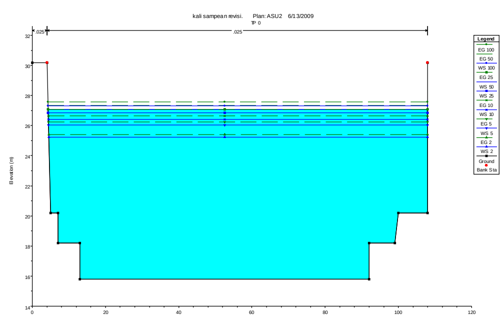

Figure 15 Flood profile of handling design in the section of TP 0

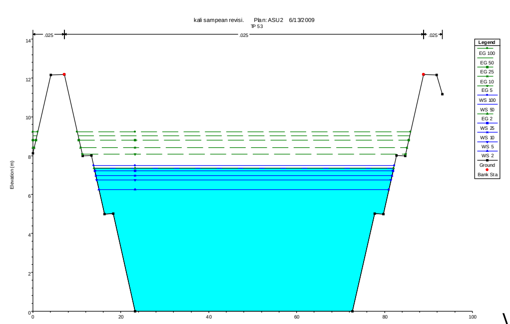

Figure 16 Flood profile of handling design in the section of TP 53

CONCLUSION

Based on the analysis as above, it was concluded as follow:

1. The capacity of Sampean river had been inability to store the design flood of 2 years return period (Q_2) of 1,435.82 m^3/s mainly in the downstream or estuary of river section. Therefore, in this study it was needed to carry out the handling design analysis for fullfiling the running over of flood.

2. Suggestion of the flood handling design by using design flood of 50 years return period (Q_{50}) was based on the historical flood in the outlet of Sampean Baru watershed such as 2,012.96 m^3/s and it was as the design flood of 25 years return period (Q_{25}) with area number of 768.68 km^2. Therefore, for the handling design safety in the outlet of Sampean watershed, it was used the design flood of 50 years return period (Q_{50}) such as 2,468.78 m^3/s. This design analysis was carried out by considerating the factor of tide-ebb height such as High Water Level (HWL) of +2.43 m. Typical of dyke design which can be applied along the section of Sampean Lama-Muara weir with Q_{50} is typical of I and II. Typical of I is as 1 trap double dimensions of dyke design but typical of II is as 2 traps double dimensions of dyke design. Design of freeboard was 0.75 m from flood water level. Besides building the dyke, the effort of flood handling also carried out the improvement and widening of river section.

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