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Flood Overflow Modeling for Analysis of Impact Loss and Flood Control Scenario Selection (Case Study: Karang Mumus River Samarinda City)

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Abstract— *Various studies and plans for the flood control infrastructure have been carried out and some have been carried out in Samarinda City, but flooding still occurs every year. The flood overflow modeling was carried out using HEC-RAS 5.0.5 1D / 2D software. Analysis of impact losses due to floods is calculated based on criteria from BNPB. The flood discharge design of the Lower Karang Mumus sub-watershed at the time of the return of 2 years, 5 years, 10 years; 20 years; 25 years; 50 years; and 100 years was 185.5 m3/s; 213 m3/s; 231.2 m3/s; 248.6 m3/s; 254.1 m3/s; 271,1 m3/s; and 288 m3/s. The inundation area in the existing simulation at Q_{25} flood reaches 903.9 ha. The scenario of dredging the Benanga Dam in the simulation of the Q_{25} yr flood shows an inundation area of 856.6 ha; the construction of the Muang Dam shows an inundation area of 885.4 ha; and normalization of the Lower Karang Mumus River shows an inundation area of 873 ha. The normalization of Lower Karang Mumus River has the effect of reducing the number of houses most affected by floods, reaching 1680 units, compared to dredging the Benanga Dam as many as 340 units and the construction of the Muang Dam as many as 122 units.*

Keywords— *Flood, Inundation, Loss, effective.*

I. INTRODUCTION

Samarinda is a city located in the downstream area of the Mahakam River, East Kalimantan (Rofiq, 2014 in Ghozali et al., 2016). Some areas in Samarinda are swampy areas which cause Samarinda city to be prone to flooding (Ghozali et al., 2016). Samarinda city flood has become a subscription and occurs every year with varying flood heights (Sodik, 2015 in Ghozali et al., 2016). Samarinda flooding is also caused by high rainfall intensity and geographical location in the basin and downstream of the Mahakam River (Ghozali et al., 2016).

Data for the last 5 (five) years from 2014 - 2018 shows that the floods in Samarinda occurred 16 (sixteen) times, with 2 fatalities, 1 injured, suffered and displaced as many as 58,487 people. In addition, the flood also caused 3 units of heavily damaged houses, 3 units of minor damage, and 13,357 units of submerged houses. Flooding also resulted in damage to 1 unit of worship facilities and 3 units of educational facilities, as well as 6 hectares of rice fields (Indonesian National Board for Disaster Management/ BNPB, 2018).

The government has conducted technical and non-technical studies to manage and minimize the impact loss of flooding in Samarinda City. The Benanga Dam in the Benanga sub-watershed (Upper Karang Mumus) which is expected to reduce flooding, is currently in poor condition with poorly controlled sedimentation and vegetation (water hyacinth) which almost all cover the reservoir inundation areas. In addition, in several segments of the Karang Mumus River, houses have been built with semi-permanent houses due to the rapid flow of urbanization.

Until now, many studies have been conducted to overcome the flood of Samarinda City, including:

- Dredging of the Benanga Dam
- Muang Dam construction plan
- Pampang Dam construction plan
- Normalization Plan for Karang Mumus River, etc.

Some of these plans are largely unworkable, due to many factors hampering development, one of which is the amount of budget needed to realize the program.

II. RESEARCH METHODOLOGY

Karang Mumus sub-watershed is located between 0°19'28.93"S - 0°26'54.72"S and 117°12'06.24"E - 117°15'41.27"E. Karang Mumus sub-watershed has an area of 321.57 km^2 (BWS Kalimantan III, 2017). Administratively, the Karang Mumus sub-watershed is located in Samarinda City and Kutai Kartanegara Regency.

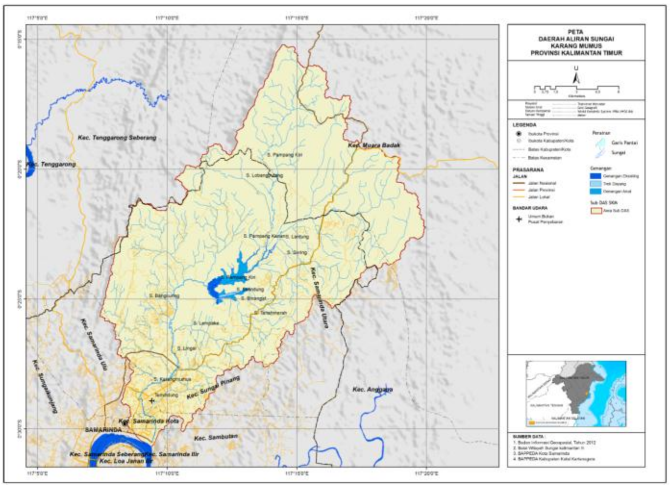

Fig. 1. Map of Karang Mumus Sub-watershed

A. Data Collection

Daily rainfall data uses Pampang Post, Sei Siring Post, Tanah Merah Post, and Temindung Climatology Post in the period 2008-2017. Tidal data of the Lower Karang Mumus River was obtained from the results of BWS Kalimantan III

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measurements on March 11, 2017 to March 26, 2017. Map of DEM from *http://tides.big.go.id/DEMNAS/*. Flood control planning data from BWS Kalimantan III and Departement of Public Work, East Kalimantan.

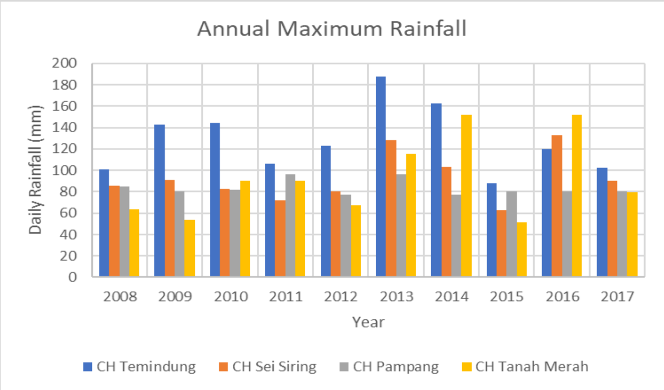

Fig. 2. Annual Maximum Rainfall

Land use data uses the Rupa Bumi Indonesia (RBI) map. Data on flood height observations were carried out by taking 7 (seven) sample points by conducting interviews with local residents. In this case, flood control plans include:

- Dredging of the Benanga Dam
- Construction of the Muang Dam
- Normalization of the Karang Mumus River

Flood hydrograph analysis was performed using the SCS and Nakayasu methods. Hydraulic analysis and modeling of flood overflows were carried out using the HEC-RAS 5.0.5 1D / 2D software. The analysis of impact losses due to flood disasters is calculated based on criteria from BNPB. Finally, the calibration results show the Nakayasu method is closer than the SCS method, so in this journal only the Nakayasu method is written.

B. *Nakayasu Method*

The formulas used in the Nakayasu method are:

$$Q_p = \frac{A.Re}{3{,}6(0{,}3T_p + T_{0.3})} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

dengan:

Q_p : Flood peak discharge (m^3/s)
Re : Unit effective rainfall (1 mm)
T_p : time from the beginning of the rain to the peak of the unit hydrograph (hour)
A : Watershed area to outlet (km^2)
$T_{0.3}$: Discharge reduction time, from peak to 30% ($T_{0.3} = \alpha . T_g$)
α : Hydrograph parameters, which
$\alpha = 2{,}0$ → In the usual drainage area
$\alpha = 1{,}5$ → In part the hydrograph is slow rising and descending fast
$\alpha = 3{,}0$ → In part the hydrograph rises fast, and descends slowly

$$T_g = 0{,}5279 + 0{,}058\, L, if\ L > 15\ km \dots\dots\dots (2)$$
$$T_g = 0{,}21\, L^{0{,}7}, if\ L < 15\ km \dots\dots\dots\dots\dots\dots (3)$$
$$T_p = T_g + 0{,}8\, t_r \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

with:

T_g : *Time lag* is the time of the rain until the peak discharge (hours)
L : River length (km)
T_p : *Peak time* (hour)
t_r : Unit of rainfall time (hour)

C. *flood Hazard Category*

BNPB (2012) categorizes flood hazard into 3 (three) classes,

- Low Risk Class : Depth < 0.76 meters
- Medium Risk Class : Depth between 0.76 - 1.50 meters
- High Risk Class : Depth > 1.5 meters

D. *Economic Analysis*

Economic analysis is done by calculating the value of NPV, IRR, and BCR with interest rate data accessed from https://www.bi.go.id/id/moneter/operasi/suku-bunga-sbi/Default.aspx.

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \dots\dots\dots\dots\dots\dots (5)$$

with:

i : Social discount rate
$1/(1+i)^t$: discount factor
B_t : Benefit in year t
C_t : Investment in year t

$$IRR = i_1 + \frac{NPV_1}{(NPV_1 - NPV_2)}(i_2 - i_1) \dots\dots\dots\dots\dots (6)$$

with:

i_1 : The discount rate that results in NPV +
i_2 : The discount rate that results in NPV –
NPV_1 : Net present value is positive
NPV_2 : Net present value is negative

$$BCR\frac{B}{C} = \frac{PW\ benefit}{PW\ cost} \geq 1 \dots\dots\dots\dots\dots\dots\dots\dots (7)$$

with:

PW benefit : Present worth benefit
PW cost : Present worth investment

III. RESULT AND DISCUSSION

A. *Hydrological Analysis*

Karang Mumus sub-watershed is divided into 3 (three) sub sub watersheds for analysis of design rainfall and design flood discharge, due to the existence of the Benanga Dam and the planned of the Muang Dam. The sub sub watersheds are:

- Benanga sub sub-watershed (Upper Karang Mumus sub sub-watershed) with an area of 168.94 km^2.
- Muang sub sub-watershed with an area of 18.35 km^2.
- Lower Karang Mumus sub sub-watershed with an area of 128.82 km^2.

The results of the design rainfall calculation on the Karang Mumus sub-watershed after the goodness of fit test were carried out with the Smirnov-Kolmogorov method, the chi square (x^2) method, and the statistical requirements were chosen by the Gumbel distribution method.

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TABLE 1. Design Rainfall of Karang Mumus Sub Watershed

No	Return Period (year)	Sub Watersheds		
		Benanga Sub sub Watershed	Muang Sub sub Watershed	Hilir Sub sub Watershed
		(mm)		
1	2	71.4	82.3	60.3
2	5	86.2	88.6	72.3
3	10	96.1	92.7	80.2
4	20	105.5	96.7	87.8
5	25	108.5	98	90.2
6	50	117.8	101.8	97.6
7	100	126.9	105.7	105
8	200	136.1	109.6	112.3
9	250	139	110.8	114.7
10	500	148.1	114.6	122
11	1000	157.2	118.5	129.3

The runoff coefficient is analyzed based on the land use map sourced from the RBI map. With Global Mapper 19.0 software, it is classified based on land use as shown in Fig 3.

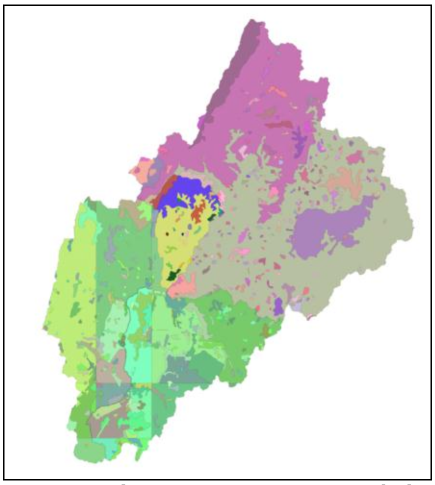


Fig. 3. Land use in Karang Mumus watershed

Runoff coefficient (C) was analyzed using *"SNI 2415: 2016 Procedure for Calculation of Flood Discharge Design"*, with results C = 0.36 for the Upper Karang Mumus sub sub-watershed, C = 0.34 for the Muang sub sub-watershed, and C = 0.37 for Lower Karang Mumus sub sub-watershed.

The design discharge calibration results show the Nakayasu method is more suitable than the SCS method with an error value of 3.70% for the Nakayasu method compared to 12.10% for the SCS method.

TABLE 2. Flood discharge design of Karang Mumus Sub-watershed (m^3/s)

Flood Control Scenarios	Sub Sub Watershed	Return Period (year)						
		2	5	10	20	25	50	100
Existing	Upper	185.4	220.9	244.7	267.2	274.4	296.8	318.6
	Muang	31.6	33.7	35.0	36.4	36.8	38.1	39.4
	Lower	185.5	213.0	231.1	248.6	254.1	271.1	288.0
Dredging of the Benanga Dam	Upper	185.4	220.9	244.7	267.2	274.4	296.8	318.6
	Muang	31.6	33.7	35.0	36.4	36.8	38.1	39.4
	Lower	185.6	212.5	230.2	247.3	252.7	269.2	285.8
Construction of the Muang Dam	Upper	185.4	220.9	244.7	267.2	274.4	296.8	318.6
	Muang	31.6	33.7	35.0	36.4	36.8	38.1	39.4
	Lower	175.9	202.4	219.8	236.6	241.9	258.2	274.5
Normalization of the Karang Mumus River	Upper	185.4	220.9	244.7	267.2	274.4	296.8	318.6
	Muang	31.6	33.7	35.0	36.4	36.8	38.1	39.4
	Lower	185.5	213.0	231.1	248.6	254.1	271.1	288.0

B. *Tidal Analysis*

Analysis of river tides is carried out at the downstream of Karang Mumus River, because the downstream water level of the Karang Mumus River is influenced by the Mahakam River which is also affected by tides. In this case, tide forecasting from seawater was not carried out due to limited data, but also because of the Mahakam River discharge which is dominant in the fluctuations in the water level downstream of the Karang Mumus River. In this case, the water level is analyzed based on the results of observations made by the Kalimantan River Region III on March 11, 2017 to March 26, 2017 (15 days with hourly measurement intervals)

By analyzing and grouping the data, important elevation values are obtained as follows:

1. HHWL = + 2.38 meters
2. MHWL = + 1.88 meters
3. MSL = + 1.35 meters
4. MLWL = + 0.77 meters
5. LLWL = + 0.54 meters
6. Tidal Range = 1.85 meters

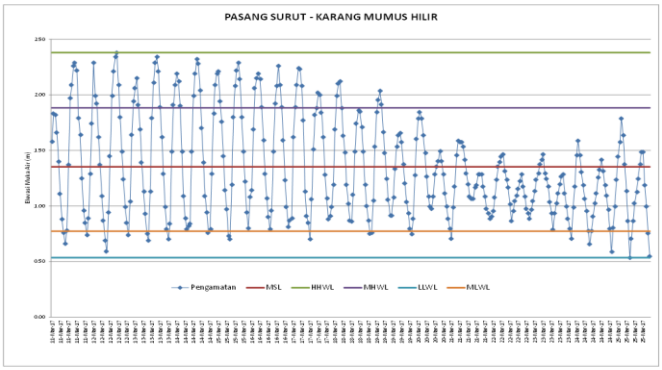


Fig. 4. Tidal of the Downstream of Karang Mumus River

C. *HEC-RAS Modeling Results*

Floods in Samarinda still occur every year based on information from local residents and BWS Kalimantan III. Based on this information, it is simulated Q_2 year floods such as Fig. 5 and Fig. 6 as follows:

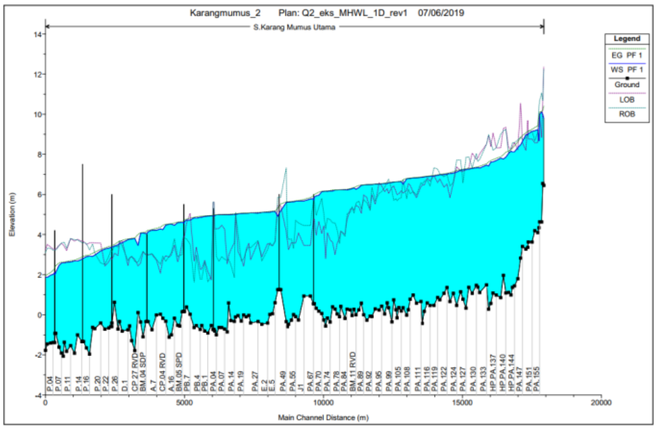


Fig. 5. Long section of Q_2 year flood with existing conditions and downstream water level at MHWL

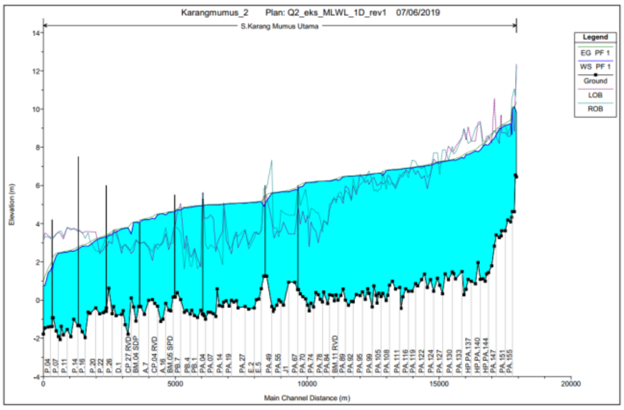


Fig. 6. Long section of Q_2 year flood with existing conditions and downstream water level at MLWL

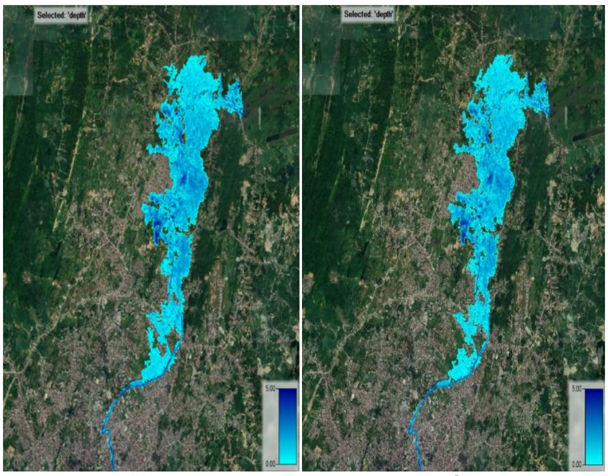
Model calibration is done by comparing the elevation of the model with the elevation of the flood in the field obtained from direct measurements based on local community information. The calibration results show the value of NSE (Nash Sutcliffe model Efficiency) of 0.673. This number is in the interval 0.50 - 0.65, which means that the value is acceptable.

MHWL and MLWL downstream conditions have the effect of changes in the elevation of flood water levels along the river, but do not have a significant change in impact, it can even be said to be almost the same as the profile of flood water levels in the MHWL and MLWL conditions along the river.

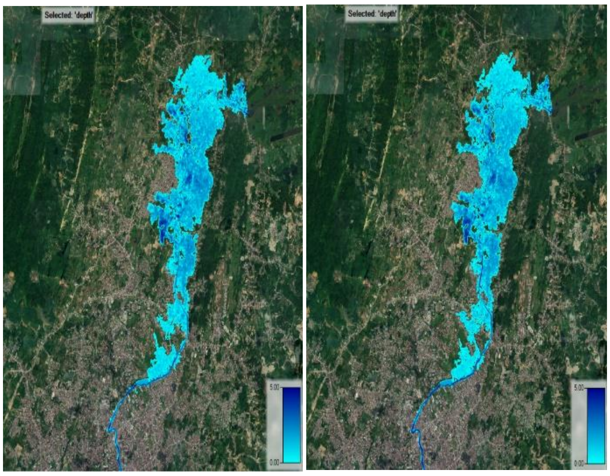
D. *Flood Inundation Analysis*

Flood simulations are carried out at the return period of Q_{25} years in various conditions, and shown as in Fig 7.

Some scenarios carried out in flood control are only able to reduce the area of a small inundation with a variation between 1.46% - 6.14% for the scenario of the dredging Benanga Dam, 1.59% - 7.01% for the Muang Dam scenario, and between 3.42% - 7.70% for the scenario of the normalization of the Karang Mumus River.

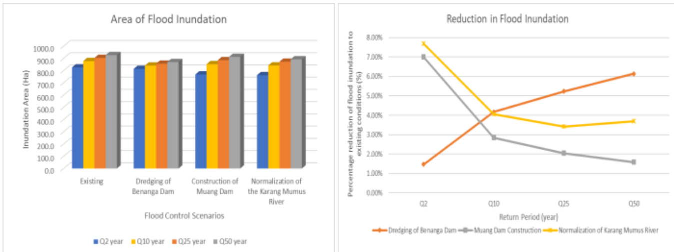


(a) (b)



(c) (d)

Fig. 7. Simulation of flood inundation area Q_{25} years with water level downstream in MHWL (a) Existing (b) Dredging of the Benanga Dam (c) Construction of the Muang Dam (d) Normalization of the Karang Mumus River.



(a) (b)

Fig. 8. (a) Area of flood inundation (b) Reduction in flood inundation

E. *Analysis of Investment and Flood Impact Losses*

Infrastructure development is assumed to be carried out starting in 2020, so the investment value to be spent is as in Table 6.

TABLE 3. Capital cost flood control scenario

Flood Control Scenarios	Year of Analysis	PV (x1000)	n	FV 2020 (x1000)
Dredging of the Benanga Dam	2015	58,675,823	5	74,921,000
Construction of the Muang Dam	2014	225,601,409	6	302,497,000
Normalization of the Karang Mumus River	2017	922,719,398	3	1,068,462,000

TABLE 4. Costs of flood control scenarios

Flood Control Scenarios	*Capital Cost*	*Damage Cost*	*Total Cost*
	(x IDR 1 billion)		
Existing	-	886.65	886.65
Dredging of the Benanga Dam	74.92	798.14	873.07
Construction of the Muang Dam	302.50	871.30	1,173.80
Normalization of the Karang Mumus River	1,068.46	363.08	1,431.54

TABLE 5. Potential of Damage Cost from flood impact

Flood Control Scenarios	Damage Cost (x IDR 1 billion)			
	Q_2	Q_{10}	Q_{25}	Q_{50}
Existing	267.26	299.43	316.66	334.05
Dredging of the Benanga Dam	257.86	276.80	285.05	293.27
Construction of the Muang Dam	241.40	291.16	311.18	324.28
Normalization of the Karang Mumus River	96.92	115.11	129.67	141.40

TABLE 6. Number of houses affected by flood Q_{25} years

Flood Control Scenarios	Low Risk	Medium Risk	High Risk	Total
Existing	1484	1229	970	3683
Dredging of the Benanga Dam	1316	1175	852	3343
Construction of the Muang Dam	1400	1176	985	3561
Normalization of the Karang Mumus River	1161	584	258	2003

TABLE 7. Difference in number of houses affected by flood Q_{25} years

Flood Control Scenarios	Low Risk	Medium Risk	High Risk	Total
Existing	0	0	0	0
Dredging of the Benanga Dam	-168	-54	-118	-340
Construction of the Muang Dam	-84	-53	15	-122
Normalization of the Karang Mumus River	-323	-645	-712	-1680

F. *Economic Analysis*

The Dredging of the Benanga Dam is assumed to start in 2020 for 4 years up to 2023 each stage with a budget of IDR 18,7B with an average interest rate of 6.7%. The building is expected to function properly in the 30 year, namely in 2049 with a total OM cost of IDR 38,2B. Benefits for Q_2 year flood amounting to IDR 9,3B; Q_{10} year flood benefit of IDR 22,6B; and benefits for Q_{25} year flood discharge of IDR 31,6B.

Based on the parameters, the NPV (Net Present Value) of IDR 33,5B; the BCR (Benefit Cost Ratio) of 1.43; and IRR (Internal Rate of Return) of 12.55%. Economically, the dredging Benanga Dam provides sufficient benefits.

The construction of the Muang Dam is assumed to begin in 2020 for 4 years up to 2023 each stage with a budget of IDR 75,6B with an average interest rate of 6.7%. The infrastructure is expected to function properly in the 50 year, namely in 2069 with a total OM cost of IDR 68,8B. Benefits for Q_2 year flood amounting to IDR 25,8B; Q_{10} year flood benefit of IDR 8,3B; and benefits for Q_{25} year flood discharge of Rp. 5,5B.

Based on the parameters, the NPV (Net Present Value) can be calculated as minus (IDR 8,1B); BCR (Benefit Cost Ratio) of 0.97; and IRR (Internal Rate of Return) of 7.20%. Economically, the Muang Dam construction plan is not profitable if the benefits are only calculated from the results of the flood reduction.

Normalization of the Lower Karang Mumus River is assumed to start in 2020 for 10 years up to 2029 each stage with a budget of IDR 106,8B with an average interest rate of 6.7%. The project is expected to function properly in the 50 year, namely in 2069 with a total OM cost of IDR 227,04B. Benefits for Q_2 year flood amounting to IDR 170,3B; Q_{10} year flood benefit of IDR 184,3B; and benefits for Q_{25} year flood discharge of IDR 186,9B.

Based on the parameters, the NPV (Net Present Value) of IDR 912,5B; BCR (Benefit Cost Ratio) of 2.13 and IRR (Internal Rate of Return) of 17.82%. Economically, the normalization plan of the Lower Karang Mumus River provides sufficient and beneficial benefits.

G. *Social and Environmental Analysis*

The plan to arrange the border of the Karang Mumus River in the framework of the normalization scenario of the Lower Karang Mumus River will experience many social and environmental constraints, because most residents do not want to move and only 25% of the land status is occupied without proof of ownership of land rights. In addition, the majority of residents around the Karang Mumus River have also lived > 10 years and are hereditary, and even 24.32% felt they were not disturbed by the floods that occur almost every year.

The scenario of the Benanga Dam dredging tends to have no social environmental problems, because the results of the disposal of sediment dredging are only disposed of in the dam area that has no direct relationship with the surrounding community. While the Muang Dam construction scenario has a significant risk considering that there must be land acquisition at the dam construction site and inundation area which involves quite a lot of people who have land at the planned activity site. However, this problem will be overcome if the Government has enough budget to conduct land acquisition and the community in principle agrees with the Muang Dam construction plan.

H. *Sedimentation and Erosion Analysis*

Analysis of river sedimentation and erosion is based on the river bedform approach due to data limitations. Engelund and Hansen (1966) in Yang (1996) conducted a study of the stability of bedforms in the laboratory and grouped them into 3 (three) categories of bedforms, namely: Plane bed, Dunes, and Antidunes.

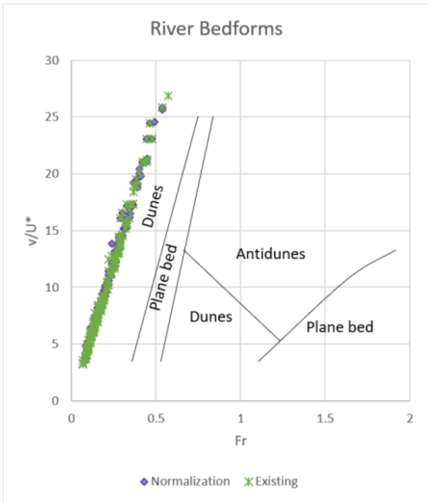


Fig. 9. Changes in bedforms during Q_{25} year flood discharge

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IV. CONCLUSION

The plan to normalize the Karang Mumus River is the most effective solution with an estimate to reduce the number of houses affected by flooding in the Q_{25} simulation of 1680 housing units, compared to 340 units of the Benanga Dam dredging, and the construction of the Muang Dam by 122 units. However, the plan to restructure the Karang Mumus River within the framework of the normalization scenario of the Lower Karang Mumus River is expected to experience many social and environmental constraints, because most of the residents do not want to move and only 25% of the land is occupied without proof of land ownership. In addition, the majority of residents around the Karang Mumus River have also lived > 10 years and are hereditary, and even 24.32% felt they were not disturbed by the floods that occur almost every year.

The OM implementation plan must be maximally pursued because based on the simulation of bedforms the results of river bedforms are in the form of dunes which means that there is a great potential for river sedimentation.

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