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Effectiveness of Sediment Flushing by Using Overflow Flush Canal

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Abstract

The objective of this dissertation was to analyze the effectiveness of sediment flushing system of over flow channel with 1 door, 2 door and 3 door at a floodway.To determine which was the most effective, then empirical model ofeffectiveness of each channel of sediment flushing were built. The object model of this study wasthe Floodway Sedayu Lawas, located in Lamongan, East Java Province.This study uses Hydraulic Physical Model Test. Built and test the model conductedin the Laboratory of Balai Sungai Surakarta. The variables of this study were sediment weight (W), water depth(H), sediment mass density (ρs), sediment diameter (ds), water flow rate (Q), and floodway wide(Bo), then the result of this study were:

$$W = 9778\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta\mathrm{H}}{\sqrt{gH^5}}\right]^{1,169} \quad \text{for 1 door channel,}$$

$$W = 23248\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta\mathrm{H}}{\sqrt{gH^5}}\right]^{1,154} \quad \text{for 2 door channel,}$$

$$W = 39599\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta\mathrm{H}}{\sqrt{gH^5}}\right]^{1,131} \quad \text{for 3 door channel}$$

The most effective sediment flushing channel of over flow was 3 door.
Keywords: floodway, sediment, flushing.

1. Preface

Sedayu Lawas Floodway is a flood control construction in the form of canals built in Bengawan Solo River downstream and empties into Laut Jawa. The location, find it in Figure 1, is located in Babat district, Lamongan, East Java. This floodway was built in 2000 with a length of 12.3 kilometers, the width of the canal is 100 meters, the slope of the riverbed (i) = 0.0002433, and the rate of flow plan 640 m3 / sec.

This floodway, see Figure 2, has the stop lock door (door lift) on its inlet construction, the width of the door 3 x 12.5 meters and the width of flushing doors 1 x 2 meters. In the downstream, see Figure 3, there is a rubber dam, which has 4 x 25 meters of widht, 3 meters of height and a pillar prism with 5 meters of bottom thickness and 1.67 meters of top thickness.

Figure 1. Map for Floodway of Sedayu Lawas

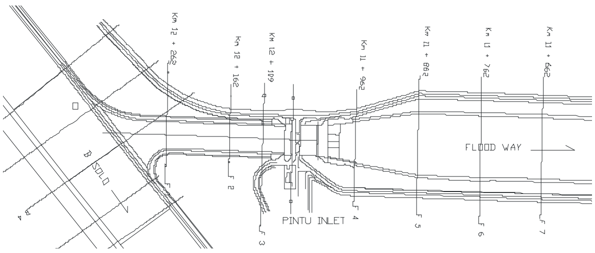
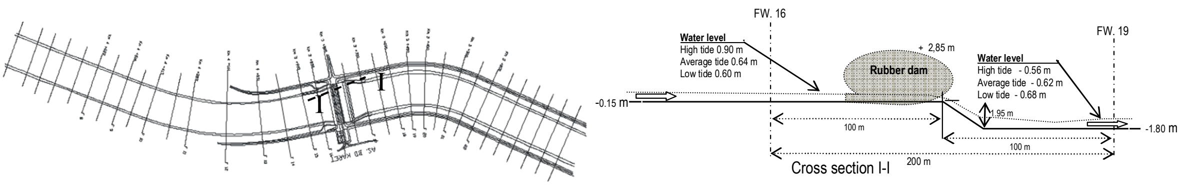


Figure 2. The inlet of floodway



(a) (b)

Figure 3. The rubber dam of floodway: (a) top view, and (b) cross section I-I view

Sedayu Lawas Floodway was built in order to reduce the water level in the upstream and downstream areas, to reduce flooding in Bengawan Solo River. However, in every rainy season, the floodway is less able to function as it should. Water level in the upstream area is high and the downstream is still flooding. Lack of effective function of Sedayu Lawas Floodway is caused by several factors, one of them is due to the high sedimentation along the floodway. Sedimentation in floodway will be reduced by building a flushing construction. The overflow flush canal was chosen instead of other types of canals. In order to determine the number and the width of the flushing doors required, the laboratory analysis is needed.

This research uses a hydraulic-physical model test method and held in Laboratorium Balai Sungai Surakarta. The physical model of Sedayu Lawas floodway was built using the same horizontal scale with the vertical scale, 1: 66.667. Due to the limited capacity of the pump and the existing land in Laboratorium Balai Sungai Surakarta, see Figure 4 and Figure 5, the physical model is made along the 2200 meters: physical model of 1700 meters length of the rubber dam into upstream area and 500 meters from rubber dam into downstream ,

The characteristic of the drainage is surface water free, the acceleration of Earth's gravity is the dominant parameter, so the requirement that should be fullfiled is the dynamic unvarying characteristic between the models and the prototypes. In this case, the Froude number (Fr) in the model must be the same as the prototype and the gravity in the prototype is the same with the model, so that the hydraulic physical model test parameters scale as shown in Table 1.

Table 1. Hydraulic-Physical Model Test Parameter

PARAMETER	NOTATION	SCALE
Height	H	$N_h = 66,667$
Length	L	$N_l = 66,667$
Velocity	V	$N_v = N_h^{½} = (66,667)^{1/2} = 8,165$
Time	T	$N_t = N_h^{½} = (66,667)^{1/2} = 8,165$
Debit	Q	$N_Q = N_h^{5/2} = (66,667)^{5/2} = 36289$
Manning Value	N	$N_n = N_h^{1/6} = (66,667)^{1/6} = 2,014$

Movable bed with the coal powder material was made order to know the pattern of the sediment movement in the upstream of rubber dam. Physical model was created to examine the effect of changes in flow rate, and the width of the flushing door towards the flush sediment.

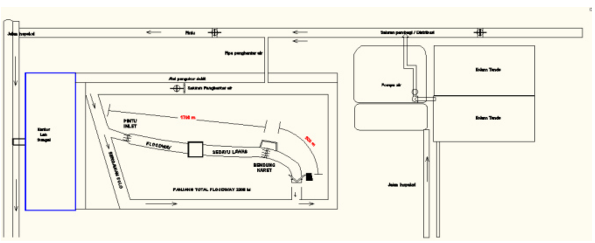


Figure 4. Top view of floodway model

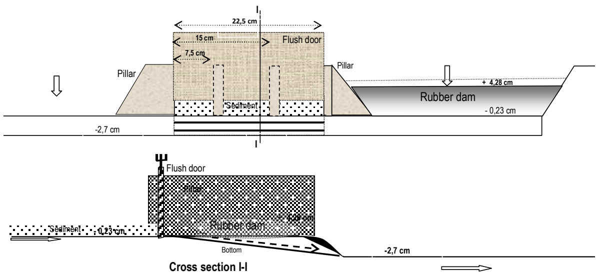


Figure 5. The model of flush cannal

2. Literature Review

The research related on sediment flushing in the floodway and motion weir located at the mouth of the river or close to the waterfront has much done. Three of them were done by Ji *et al.* (2011), Muntolib (2006), and Isnugroho (2008). By using numerical models, Ji *et al.* (2011) analyzes the sediment flushing in rubber dam at the mouth of the Nakdong River, South Korea, at the time of the sea water at low tide conditions minimum. In the research, *Ji et al*. (2011) did not use the flush canal.

Muntolib (2006) simulated the opening door of the flood control in Dombo floodway, Sayung, Central Java, on the 4 conditions. The research concluded that the door of the flood control on the floodway is ineffective. In his research, Muntolib (2006) did not use the flush canal and did not take into account the influence of the tide. By using hydraulic model, Isnugroho (2008) analyzes sediment flushing in Bojonegoro rubber dam, East Java. In this research, Isnugroho (2008) did not also use the flush canal and did not take into account the influence of the tide. Up until now, when this research was conducted, there has been no research on sediment flushing of the floodway using rubber dam, which is located in northern coast of Java, which uses flush cannal, and takes into account the influence of the tide. Therefore, this research was conducted.

Basson and Rooseboom (1966) and Tomasi (1996) explains that there are three types of hydraulic flushes, they are sluicing operation, venting of density current and flushing operation. Flushing operation is aimed to erode the settles sediment in the upstream and it typically has larger granules (coarse material), so that the eroded sediment load will be carried to the downstream by the flow of water and flush out through the door of the flusing operation. Flushing sediment tecnique is applied by increasing the speed of water flow on the disposal door, so that the speed of water flow becomes greater and enough to grind or erode the sediment that has been accumulated through the door system, for example in the bottom outlet system (Tomasi, 1996; White, 1990) ,

Generally, flushing can be classified into two categories, Empty or Free-flow Flushing and Flushing with Partial Drawdown (Fan & Jiang, 1980; Morris & Fan, 1998). Empty or free-flow flushing is a flushing tecnique implemented by making the water reservoir empty, while the river water flow is maintained into the reservoir, then used the water as the sediment flush out through the bottom outlet.

3. Research Method

In order to identify the variables that should be investigated, this research uses non-dimensional numerical analysis by applyes method of Buckingham π. The influencing parameters are: H, g, ρs, q, ΔH, W, ds. The definitions as follows:

H = height of water surface in Sta. FW16 (cm)
g = gravitation (cm/s^2)
ρ_s = sediment mass density (gr/cm^3)
q = water discharge (Q) : channel width (B) (cm^3/s : cm $=cm^2/s$)
ΔH = the difference elevation height of water surface between Sta. FW16 and Sta. FW19 (cm)
W = weight of flush sediment (gr)
d_s = sediment diameter (cm)

Each of these parameters have been chosen based on the dimensions of: M (mass), L (long), and T (time), as in the Table 2 below:

Table 2.Parameter Dimension

	H	g	ρ_s	q	ΔH	W	d_s
M	0	0	1	0	0	1	0
L	1	1	-3	2	1	0	1
T	0	-2	0	-1	0	0	0

Based on the analysis of non-dimensional number, the variables that should be investigated are: high water level in Sta. FW16 (H), sediment mass density (ρs), sediment diameter (ds), water discharge (Q), channel width (B), the difference elevation height of water surface between Sta. FW16 and Sta. FW19 (ΔH), and flush sediment weight (W).
Furthermore, the data measurements taken are as in Table 3.

Table 3. Eksperiment data

NO	Channel Width (cm)	Tide	Bottom Elevation Sta. FW16 (cm)	Water Level Sta. FW16 (cm)	Water Level Sta. FW19 (cm)	Q (ltr/s)	W (kg)
1	7.50	High	-0.23	1.43	-0.96	2.78	39.30
2	7.50	High	-0.23	1.42	-0.96	2.78	41.30
3	7.50	High	-0.23	1.35	-0.96	2.78	42.30
4	7.50	High	-0.23	1.32	-0.96	2.78	43.30
5	7.50	High	-0.23	1.27	-0.92	2.78	45.30
6	7.50	Average	-0.23	1.02	-1.16	3.03	46.60
7	7.50	Average	-0.23	0.97	-1.16	3.03	49.60
8	7.50	Average	-0.23	0.95	-1.16	3.03	51.60
9	7.50	Average	-0.23	0.92	-1.16	3.03	53.60
10	7.50	Average	-0.23	0.87	-1.13	3.03	56.60
11	7.50	Low	-0.23	0.85	-1.19	3.14	53.80
12	7.50	Low	-0.23	0.83	-1.19	3.14	57.80
13	7.50	Low	-0.23	0.82	-1.19	3.14	60.80
14	7.50	Low	-0.23	0.81	-1.19	3.14	63.80
15	7.50	Low	-0.23	0.79	-1.18	3.14	67.80
16	15.00	High	-0.23	1.42	-0.97	2.78	39.55
17	15.00	High	-0.23	1.39	-0.97	2.78	42.55
18	15.00	High	-0.23	1.34	-0.97	2.78	44.55
19	15.00	High	-0.23	1.27	-0.97	2.78	46.55
20	15.00	High	-0.23	1.32	-0.90	2.78	49.55
21	15.00	Average	-0.23	1.02	-1.16	3.03	45.44
22	15.00	Average	-0.23	0.97	-1.16	3.03	49.44
23	15.00	Average	-0.23	0.95	-1.16	3.03	52.44
24	15.00	Average	-0.23	0.87	-1.16	3.03	55.44
25	15.00	Average	-0.23	0.77	-1.08	3.03	59.44
26	15.00	Low	-0.23	0.87	-1.20	3.14	53.15
27	15.00	Low	-0.23	0.85	-1.20	3.14	58.15
28	15.00	Low	-0.23	0.81	-1.20	3.14	62.15
29	15.00	Low	-0.23	0.77	-1.20	3.14	66.15
30	15.00	Low	-0.23	0.72	-1.16	3.14	71.15
31	22.50	High	-0.23	1.47	-0.98	2.78	42.60
32	22.50	High	-0.23	1.37	-0.98	2.78	45.60
33	22.50	High	-0.23	1.33	-0.98	2.78	46.60
34	22.50	High	-0.23	1.27	-0.98	2.78	47.60
35	22.50	High	-0.23	1.22	-0.92	2.78	50.60
36	22.50	Average	-0.23	0.97	-1.17	3.03	46.60
37	22.50	Average	-0.23	0.95	-1.17	3.03	51.60
38	22.50	Average	-0.23	0.94	-1.17	3.03	54.60
39	22.50	Average	-0.23	0.87	-1.17	3.03	57.60
40	22.50	Average	-0.23	0.82	-1.10	3.03	62.60
41	22.50	Low	-0.23	0.92	-1.22	3.14	52.20
42	22.50	Low	-0.23	0.87	-1.22	3.14	58.20
43	22.50	Low	-0.23	0.79	-1.22	3.14	63.20
44	22.50	Low	-0.23	0.77	-1.22	3.14	68.20
45	22.50	Low	-0.23	0.74	-1.20	3.14	74.20

The repeat paratameters are: H, g, dan ρ_w.

$\pi_1 = H^x \cdot g^y \cdot \rho_s^z \cdot q$

$\pi_1 = H^{-1,5} . g^{-½}. \rho_s^{0} . q$

$\pi_1 = \dfrac{q}{H^{1,5}\sqrt{g}}$

$\pi_2 = H^{x}. g^{y}. \rho_s^{z}. \Delta H$

$\pi_2 = H^{-1} . g^{0} . \rho_s^{0} . \Delta H$

$\pi_2 = \dfrac{\Delta H}{H}$

$\pi_3 = H^{x}. g^{y}. \rho_w^{z}. W$

$\pi_3 = H^{-3} . g^{0} . \rho_s^{-1} . W$

$\pi_3 = \dfrac{W}{H^3 \rho_s}$

$\pi_4 = H^{x}. g^{y}. \rho_s^{z}. d_s$

$\pi_4 = H^{-1} . g^{0} . \rho_s^{0} . d_s$

$\pi_4 = \dfrac{d_s}{H}$

$$f(\pi_1, \pi_2, \pi_3, \pi_4) = f\left(\frac{q}{H^{1,5}\sqrt{g}}, \frac{\Delta H}{H}, \frac{W}{H^3 \rho_s}, \frac{d_s}{H}\right) = 0$$

It is simplified by operating multiplcation or division between non-dimensional between variables, then eliminating the constant value so that the formula becomes simpler.

$$\pi_5 = \frac{\pi_3}{\pi_4} = \frac{W}{H^3 .\ \rho_s} \cdot \frac{H}{d_s} = \frac{W}{H^2 \rho_s d_s}$$

$$\pi_6 = \pi_1 . \pi_2 = \frac{q}{H^{1,5}\sqrt{g}} \cdot \frac{\Delta H}{H} = \frac{q\ \Delta H}{H^{2,5}\sqrt{g}} = \frac{q\ \Delta H}{\sqrt{gH^5}}$$

$$f(\pi_5, \pi_6) = f\left(\frac{W}{H^2 \rho_s\, d_s}, \frac{q\ \Delta H}{\sqrt{gH^5}}\right) = 0$$

$$\frac{W}{H^2 \rho_s\, d_s} = f\left(\frac{q\ \Delta H}{\sqrt{gH^5}}\right)$$

$$W = H^2 \rho_s d_s f\left(\frac{q\ \Delta H}{\sqrt{gH^5}}\right)$$

4. The Result of Research and Discussion

The experimental results data is transformed into a system of centimetre-gram-second and a table with two columns for non-dimensional numbers, the result of dimensions analysis as shown in Table 4. Then, a graph showing the relationship between the two numbers of non-dimensional was made, $\frac{q\ \Delta H}{\sqrt{g\ H^5}}$ and $\frac{W}{H^2 d_s \rho_s}$, see Figure 6, and drawn a trendline, see Figure 7.

With the substitution x = $\frac{q\ \Delta H}{\sqrt{g\ H^5}}$ and y = $\frac{W}{H^2 d_s \rho_s}$, the formula as shown as follow:

- $W = 9778\ H^2 \rho_s d_s \left[\frac{q\ \Delta H}{\sqrt{gH^5}}\right]^{1,169}$ for 1 door cannal,
- $W = 23248\ H^2 \rho_s d_s \left[\frac{q\ \Delta H}{\sqrt{gH^5}}\right]^{1,154}$ for 2 doors cannal, and
- $W = 39599\ H^2 \rho_s d_s \left[\frac{q\ \Delta H}{\sqrt{gH^5}}\right]^{1,131}$ for 3 doors cannal.

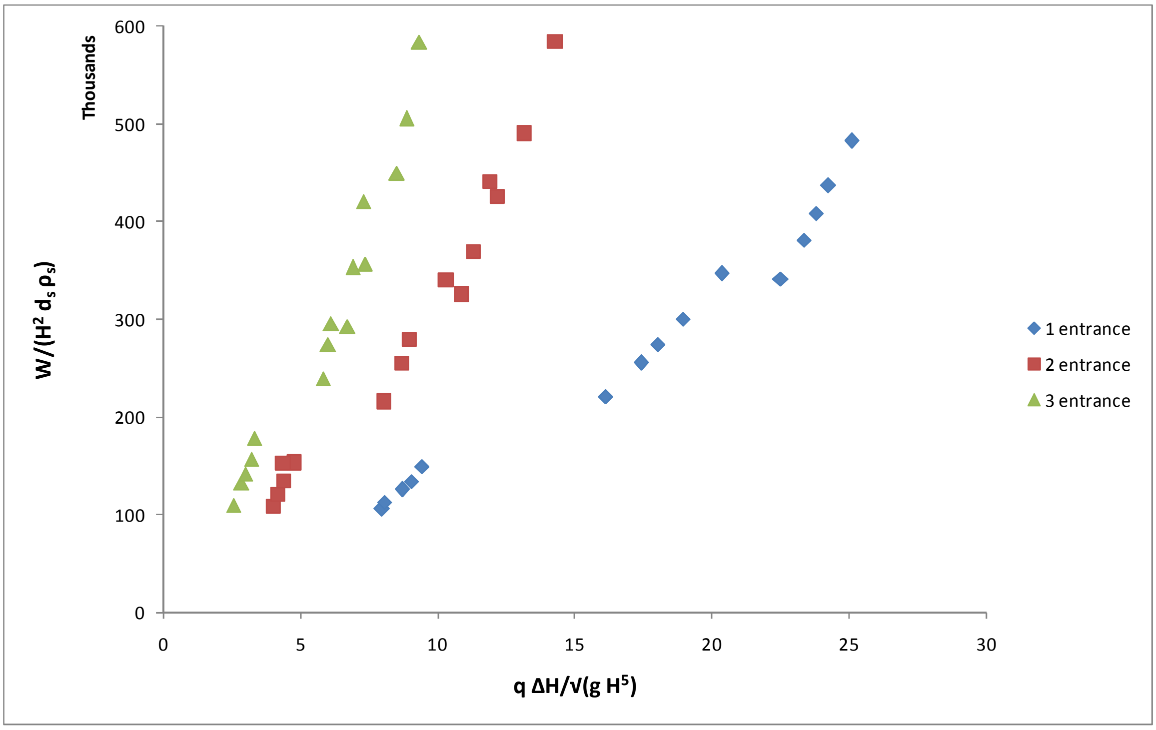


Figure 6. The correlation of two non dimensional number $\frac{q\,\Delta H}{\sqrt{gH^5}}$ and $\frac{W}{H^2 d_s \rho_s}$

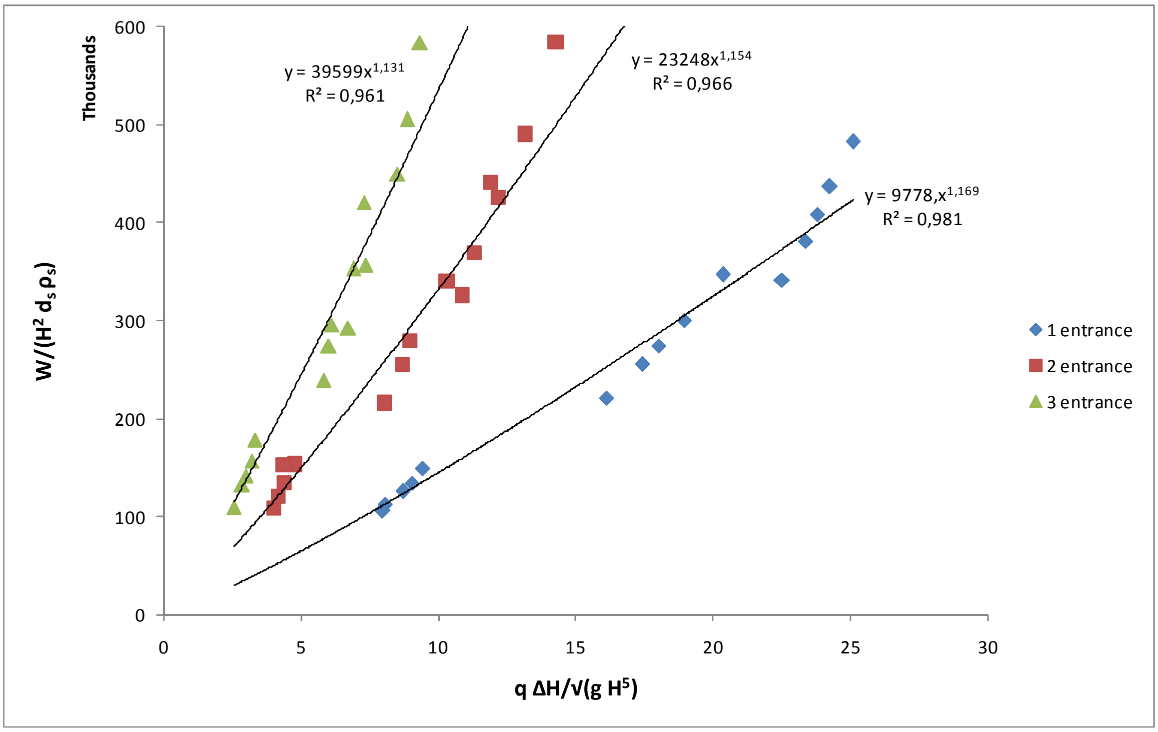


Figure 7. The trendline of two non dimensional number $\frac{q\,\Delta H}{\sqrt{gH^5}}$ and $\frac{W}{H^2 d_s \rho_s}$

Table 4. Eksperiment data in cgs system and two non dimensional number

NO	Channel Width (cm)	Tide	H_{FW16} (cm)	Δ H (cm)	Q (cm^3/dt)	W (g)	q ΔH/√(g H^5)	W/(H^2 d_s ρ_s)
1	7.50	High	1.66	2.39	2,783.20	39,300	7.98	105,643
2	7.50	High	1.65	2.38	2,783.20	41,300	8.06	112,369
3	7.50	High	1.58	2.31	2,783.20	42,300	8.72	125,514
4	7.50	High	1.55	2.28	2,783.20	43,300	9.03	133,503
5	7.50	High	1.50	2.19	2,783.20	45,300	9.42	149,136
6	7.50	Average	1.25	2.18	3,031.21	46,600	16.10	220,919
7	7.50	Average	1.20	2.13	3,031.21	49,600	17.42	255,144
8	7.50	Average	1.18	2.11	3,031.21	51,600	18.00	274,506
9	7.50	Average	1.15	2.08	3,031.21	53,600	18.93	300,217
10	7.50	Average	1.10	2.00	3,031.21	56,600	20.34	346,495
11	7.50	Low	1.08	2.04	3,141.43	53,800	22.51	341,665
12	7.50	Low	1.06	2.02	3,141.43	57,800	23.35	381,050
13	7.50	Low	1.05	2.01	3,141.43	60,800	23.79	408,499
14	7.50	Low	1.04	2.00	3,141.43	63,800	24.25	436,938
15	7.50	Low	1.02	1.97	3,141.43	67,800	25.07	482,720
16	15.00	High	1.65	2.39	2,783.20	39,550	4.05	107,608
17	15.00	High	1.62	2.36	2,783.20	42,550	4.19	120,098
18	15.00	High	1.57	2.31	2,783.20	44,550	4.43	133,880
19	15.00	High	1.50	2.24	2,783.20	46,550	4.82	153,251
20	15.00	High	1.55	2.22	2,783.20	49,550	4.40	152,773
21	15.00	Average	1.25	2.18	3,031.21	45,440	8.05	215,419
22	15.00	Average	1.20	2.13	3,031.21	49,440	8.71	254,321
23	15.00	Average	1.18	2.11	3,031.21	52,440	9.00	278,975
24	15.00	Average	1.10	2.03	3,031.21	55,440	10.32	339,394
25	15.00	Average	1.00	1.85	3,031.21	59,440	11.94	440,296
26	15.00	Low	1.10	2.07	3,141.43	53,150	10.91	325,375
27	15.00	Low	1.08	2.05	3,141.43	58,150	11.31	369,291
28	15.00	Low	1.04	2.01	3,141.43	62,150	12.18	425,638
29	15.00	Low	1.00	1.97	3,141.43	66,150	13.17	490,000
30	15.00	Low	0.95	1.88	3,141.43	71,150	14.29	583,975
31	22.50	High	1.70	2.45	2,783.20	42,600	2.57	109,189
32	22.50	High	1.60	2.35	2,783.20	45,600	2.87	131,944
33	22.50	High	1.56	2.31	2,783.20	46,600	3.00	141,841
34	22.50	High	1.50	2.25	2,783.20	47,600	3.22	156,708
35	22.50	High	1.45	2.14	2,783.20	50,600	3.34	178,271
36	22.50	Average	1.20	2.14	3,031.21	46,600	5.84	239,712
37	22.50	Average	1.18	2.12	3,031.21	51,600	6.03	274,506
38	22.50	Average	1.17	2.11	3,031.21	54,600	6.13	295,452
39	22.50	Average	1.10	2.04	3,031.21	57,600	6.91	352,617
40	22.50	Average	1.05	1.92	3,031.21	62,600	7.31	420,593
41	22.50	Low	1.15	2.14	3,141.43	52,200	6.73	292,376
42	22.50	Low	1.10	2.09	3,141.43	58,200	7.34	356,290
43	22.50	Low	1.02	2.01	3,141.43	63,200	8.53	449,969
44	22.50	Low	1.00	1.99	3,141.43	68,200	8.87	505,185
45	22.50	Low	0.97	1.94	3,141.43	74,200	9.33	584,153

5. Conclusion and Suggestions

The result of this research discovers that the sediment mass density, sediment diameter, and the flow directly proportional towards the weight of the flush sediment. This is consistent with the research belongs to Atmojo & Suripin (2012). The research takes into account the thickness of the sediment, while this research did not take it into account. The results also show that the height difference between the water level upstream and downstream of the weir is directly proportional to the weight of flush sediment, and it is consistent with research conducted by Guo et al. (2004). The results could be used as one starting point for the design of sediment in the floodway flush channel in Sedayu Lawas, and others. This research does not take into account the sediment flow patterns, so it is suggested that the next research will take it into account in order to determine the position of the flush channel sediments door.

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