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Effectiveness of Sediment Flushing by Using By-Pass Flush Canal

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Abstract: The objective of this study was to analyze the effectiveness of sediment flushing system of BY PASS channel with 1 door, 2 door and 3 door at a floodway. To determine which was the most effective, empirical model of effectiveness of each channel of sediment flushing were built. The object model of this study was the 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 River, in Surakarta, Cental of Java. The variables of this study were sediment weight (W), water depth(H), sediment mass density (ρs), sediment diameter (ds), waterflow rate (Q), and floodway wide (Bo), then the result of this study were:

$$W = 2383\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta \mathrm{H}}{\sqrt{gH^5}}\right]^{1{,}502}$$ for 1 door,

$$W = 8183\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta \mathrm{H}}{\sqrt{gH^5}}\right]^{1{,}457}$$ for 2 door, and

$$W = 24408\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta \mathrm{H}}{\sqrt{gH^5}}\right]^{1{,}256}$$ for 3 door.

Keywords: *Floodway, sediment, by-pass flush.*

1. Introduction

Sedayulawas floodway is building flood control in the form of canals built in the Solo River downstream and empties into the Java Sea. Location, see Figure 1, in the District Tripe, Lamongan, East Java. This floodway was built in 2000 with a length of 12.3 km, the groove width of 100 m, the slope of the riverbed (i) = 0.0002433, and discharge planning 640 m3 / sec. This floodway, see Figure 2, has the shape of the building inlet lock door stop (lifting door), the width of the door 3 x 12.5 m and width of doors in buildings rinsing inlet 1 x 2 m. In the downstream section, see Figure 3, there is a rubber dam (rubber dam), with a rubber dam width 4 x 25 m, height of 3 m and a rubber dam pillar prism shape with a thick bottom 5 m and 1.67 m thick top.

Figure 1: Map for Floodway of Sedayu Lawas

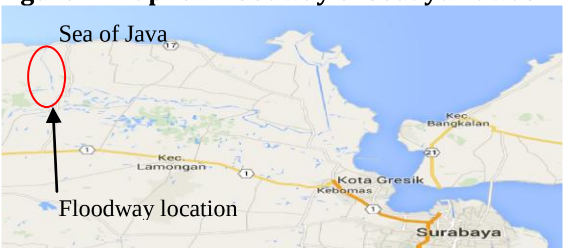


Figure 2: The inlet of floodway

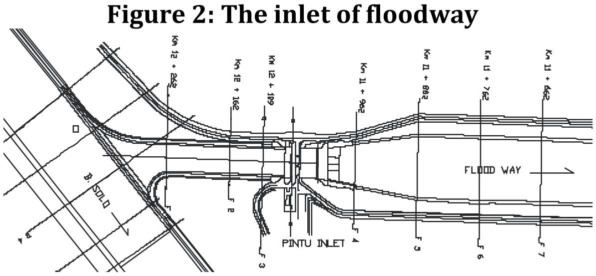
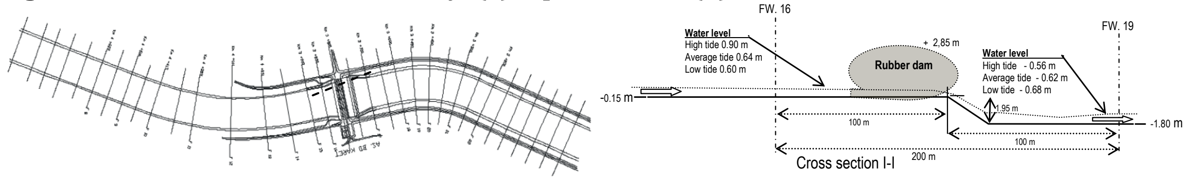


Figure 3: The rubber dam of floodway: (a) top view, and (b) cross section I-I view



(a) (b)

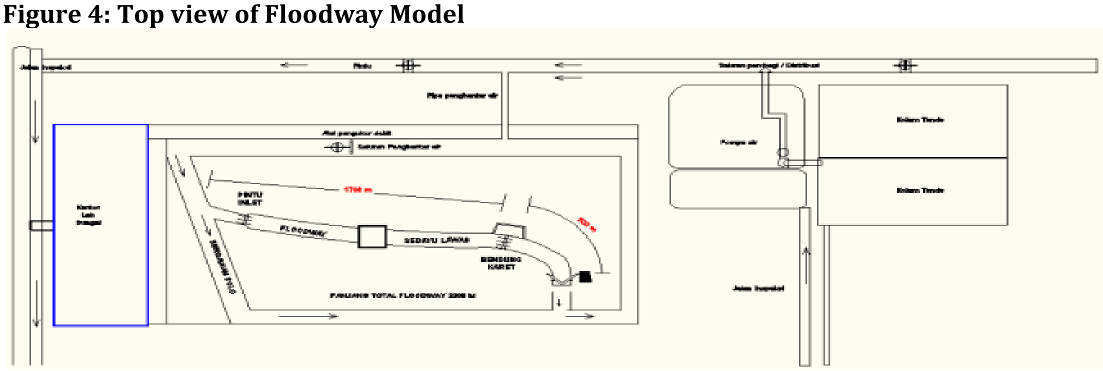
Sedayu Lawas Floodway was built in order to reduce the water level in the upstream and downstream areas, to reduce flooding in Bengawan Solo River. However, in every rainy season, the floodway is less able to function as it should. Water level in the upstream area is high and the downstream is still 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 by-pass. 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, 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	$N_Q = N_h^{5/2} = (66,667)^{5/2} =$
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



2. Literatur 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). 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. Methodology

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

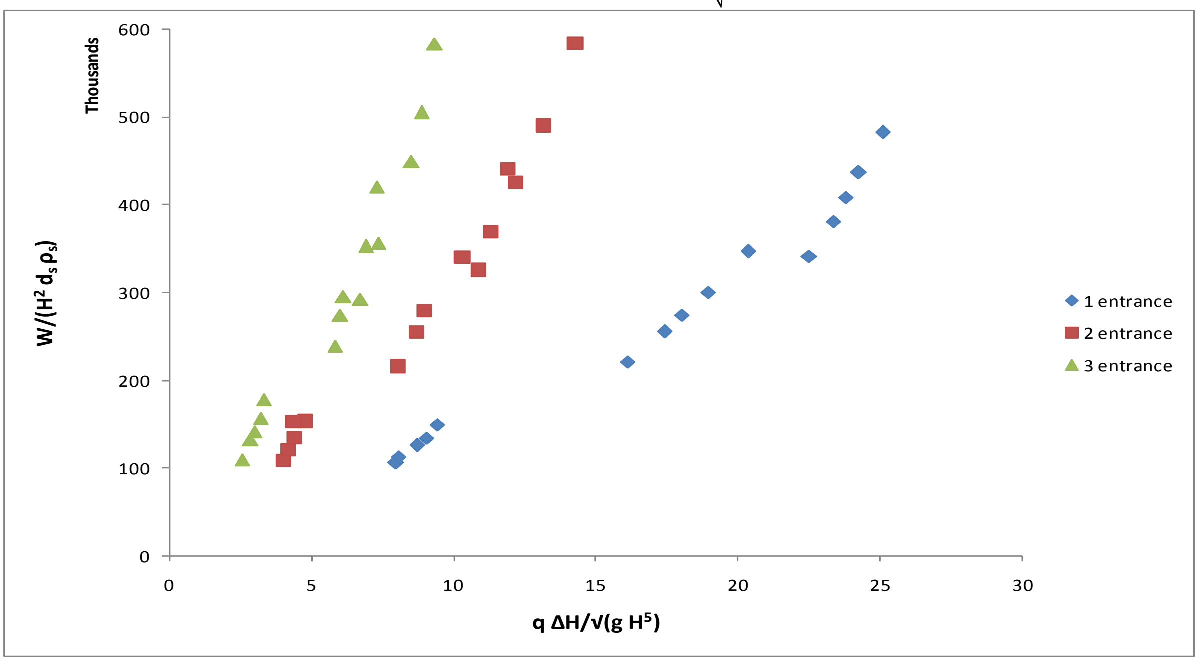


Table 4: Experiment data in CGS System and two non Dimensional Number

NO	B Sal (cm)	Air Laut	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	Pasang	1,80	2,53	2.783,20	17800	6,90	40.695,02
2	7,50	Pasang	1,65	2,38	2.783,20	19800	8,06	53.872,05
3	7,50	Pasang	1,58	2,31	2.783,20	20800	8,72	61.718,50
4	7,50	Pasang	1,55	2,28	2.783,20	21800	9,03	67.213,94
5	7,50	Pasang	1,45	2,18	2.783,20	23800	10,20	83.850,79
6	7,50	$Rata^2$	1,30	2,23	3.031,21	30640	14,93	134.297,61
7	7,50	$Rata^2$	1,20	2,13	3.031,21	33640	17,42	173.045,27
8	7,50	$Rata^2$	1,18	2,11	3.031,21	35640	18,00	189.600,69
9	7,50	$Rata^2$	1,15	2,08	3.031,21	37640	18,93	210.824,06
10	7,50	$Rata^2$	1,12	2,05	3.031,21	40640	19,93	239.984,88
11	7,50	Surut	1,09	2,05	3.141,43	33100	22,10	206.367,47
12	7,50	Surut	1,06	2,02	3.141,43	37100	23,35	244.584,21
13	7,50	Surut	1,05	2,01	3.141,43	40100	23,79	269.421,35
14	7,50	Surut	1,04	2,00	3.141,43	43100	24,25	295.173,13
15	7,50	Surut	1,02	1,98	3.141,43	47100	25,20	335.341,11
16	15,00	Pasang	1,90	2,63	2.783,20	19050	3,13	39.088,95
17	15,00	Pasang	1,70	2,43	2.783,20	22050	3,82	56.516,72
18	15,00	Pasang	1,58	2,31	2.783,20	24050	4,36	71.362,02
19	15,00	Pasang	1,50	2,23	2.783,20	26050	4,79	85.761,32
20	15,00	Pasang	1,40	2,13	2.783,20	29050	5,44	109.788,36
21	15,00	$Rata^2$	1,30	2,23	3.031,21	32700	7,47	143.326,76
22	15,00	$Rata^2$	1,25	2,18	3.031,21	36700	8,05	173.985,19
23	15,00	$Rata^2$	1,18	2,11	3.031,21	39700	9,00	211.199,42
24	15,00	$Rata^2$	1,15	2,08	3.031,21	42700	9,46	239.165,44
25	15,00	$Rata^2$	1,13	2,06	3.031,21	46700	9,79	270.910,74
26	15,00	Surut	1,20	2,16	3.141,43	33100	9,16	170.267,49
27	15,00	Surut	1,10	2,06	3.141,43	38100	10,85	233.241,51
28	15,00	Surut	1,05	2,01	3.141,43	42100	11,90	282.858,82
29	15,00	Surut	1,00	1,96	3.141,43	46100	13,11	341.481,48
30	15,00	Surut	0,95	1,91	3.141,43	51100	14,52	419.411,10
31	22,50	Pasang	1,70	2,43	2.783,20	27700	2,55	70.998,33
32	22,50	Pasang	1,60	2,33	2.783,20	30700	2,84	88.831,02
33	22,50	Pasang	1,58	2,31	2.783,20	31700	2,91	94.061,37
34	22,50	Pasang	1,55	2,28	2.783,20	32700	3,01	100.820,90
35	22,50	Pasang	1,50	2,23	2.783,20	35700	3,20	117.530,86
36	22,50	$Rata^2$	1,30	2,23	3.031,21	41100	4,98	180.144,64
37	22,50	$Rata^2$	1,20	2,13	3.031,21	46100	5,81	237.139,92
38	22,50	$Rata^2$	1,18	2,11	3.031,21	49100	6,00	261.206,34
39	22,50	$Rata^2$	1,15	2,08	3.031,21	52100	6,31	291.815,44
40	22,50	$Rata^2$	1,10	2,03	3.031,21	57100	6,88	349.556,17
41	22,50	Surut	1,20	2,16	3.141,43	33400	6,10	171.810,70
42	22,50	Surut	1,10	2,06	3.141,43	39400	7,24	241.199,88
43	22,50	Surut	1,05	2,01	3.141,43	44400	7,93	298.311,92
44	22,50	Surut	1,00	1,96	3.141,43	49400	8,74	365.925,93
45	22,50	Surut	0,90	1,86	3.141,43	55400	10,79	506.630,09

4. Results and Discussion

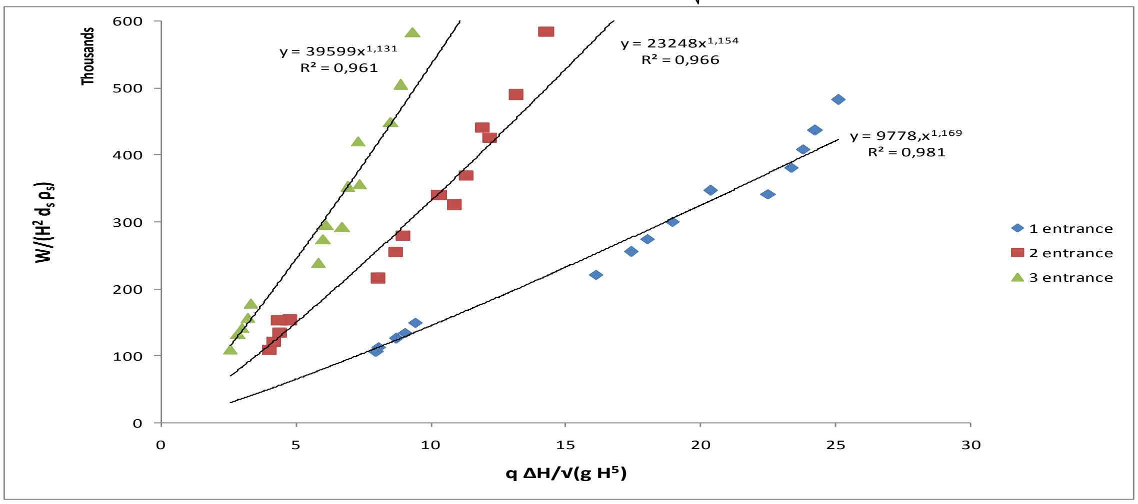
The experimental results data is transformed into a system of centimetre-gram-second and a table with two columns for non-dimensional numbers, the result of dimensions analysis as shown in Table 4. Then, a graph showing the relationship between the two numbers of non-dimensional was made, $\frac{q\ \Delta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

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:

- $W = 2383\ H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta \mathrm{H}}{\sqrt{gH^5}}\right]^{1,502}$ for 1 door cannal,

- $W = 8183\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta\mathrm{H}}{\sqrt{gH^5}}\right]^{1,457}$ for 2 door cannal, and
- $W = 24408\, H^2 \rho_s \mathrm{d_s} \left[\frac{q\ \Delta\mathrm{H}}{\sqrt{gH^5}}\right]^{1,256}$ for 3 door cannal,

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



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.

References

Atmodjo, P. S. & Suripin, L. (2012). The effect of water level on the effectiveness of sediment flushing. *International Journal Waste of Resources*, 2(2).

Basson, G. R. & Rooseboom, K. (1996). Dealing with reservoir sedimentation. Water Research Commission Report, No. TT 91/97.

Fan, J. & Jiang, R. (1980). On methods for the desiltation of reservoir. International Seminar of Expert on Reservoir Desiltation, Tunis.

Guo, Q., Fan, C. Y., Raghaven, R. & Field, R. (2004). Gate and vacuum flushing of sewer sediment: Laboratory testing. *Journal of Hydraulic Engineering,* 130(3).

Isnugroho. (2008). The role of hydraulic model test in the designing of gate operation for Bojonegoro barrage. Pusat Penelitian dan Pengembangan Sumber Daya Air, Kementerian Pekerjaan Umum, Bandung.

Ji, U., Julien, P.Y. & Park, S. K. (2011). Sediment flushing at the Nakdong river estuary barrage.*Journal of Hydraulic Engineering*, 137(11).

Muntolib, D. (2006). Evaluasi operasi pintu pengendali banjir pucang gading. Tesis, M.T., Program Pascasarjana, Universitas Diponegoro, Semarang.

Morris, G. L. & Fan, J. (1998). Reservoir sedimentation handbook design and management of dam, reservoir, and watersheds for sustainable use. McGraw-Hill Companies, Inc., New York.

Tomasi, L. (1996). Operation and maintenance problems due to sedimentation in reservoirs.Fort Collins, Colorado State University.