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The road drainage planning for flood control in Dr. Djunjunan road, Pasteur – Bandung

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Abstract. Recently, flood is an important phenomenon which often occurs in cities recently. The Case of this paper is the flood in Dr. Junjunan Road which is the one of high density roads in Bandung and the main road to Cipularang Toll Road. The flood's inundation depth on this road is up to 40-50cm, and the average of flood duration is about 30 minutes. The rainfall used for calculation in this research is a return period 25 years with the rainfall value of 80.1 mm. The solution for reducing the floods is by increasing the drainage capacity as well as increasing the water infiltration to the ground. The research method uses the physical experimental model, using the scale mode of 1:30. The experimental results are tested through validation process using Hec-RAS 5.0.7. The experiment uses two variables, in which changing two drainage streams and diverting a river which leads to Citepus river through Box Culvert. The results of the validating model indicate that increasing the drainage capacity along the Road is the most effective solution in decreasing the potential of floods.

1. Introduction

1.1. Background
Drainage, according to Pd.T-02-2006-B, refers to an infrastructure used to drain the surface's water from the area with excess of water to the body of water or to artificial infiltration building. The unplanned drainage system in the area of Dr. Djunjunan road has resulted some surface water runoff causing floods, it means that the solution of floods should use higher standard than road drainage. As reported in the drainage master plan of Bandung, the high water area is 394.145 Ha -specifically, 3.10 Ha from Pagarsih to Pasteur. By the rainfall characteristics from 2006 to 2015, this study discovers that 115 rainy days in a year have been recorded. Based on the report, 80 days have the high intensity of rainfall with the water level, reaches 0.4 - 0.7 meters in height and the inundation for about 60 minutes [1].

1.2. Research question
The formulation of this research is how to design a drainage system as an infrastructure to control floods in Dr. Djunjunan Road.

1.3. Goal research
Based on the research question above, this study has two objectives as follows:

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- Analyzing the cause of floods along Dr. Djunjunan Road in Pasteur.
- Exploring the drainage infrastructure system which can be used as the flood control by considering the drainage system.

1.4. Scope of study
The scopes of research used esprcially are as followed:

- Hydrological study on the cause of surface water runoff along Dr. Djunjunan Road where the load flows from 3 Babakan Jeruk Road, Sukamulya Road, Sukagalih Road, and Dr. Djunjunan Road in Pasteur
- The solution of floods in Dr. Djunjunan Road by redesigning the drainase system in this area.

1.5. Location of the study
The location of research is divided into four research Zones, as followed:

- Zone 1: The water flow scheme from 1 Babakan Jeruk Road as the upstream and Dr. Djunjunan Road as the downstream.
- Zone 2: The water flow scheme from 2 Babakan Jeruk Road where Sukahaji Road as the upstream and Dr Djunjunan Paster as the downstream.
- Zone 3: The water flow scheme from 4 Babakan Jeruk Road as the upstream and starting from Dr Djunjunan Pasteur to Sukamulya Road as the downstream.
- Zone 4: The water flow scheme along Dr Djunjunan Road.

Figure 1. Location of the study.

2. Literature review
The hydrology analysis is conducted by calculating the water discharge resulting from the rainfall in the catchment areas using the data collected from the three rain stations, such as distribution selection method, return period calculation, and rainwater discharge calculation applying a rational method [2].

A previous study on the water flow path categorization that was conducted in 2014 has revealed that analyzing and managing the flow path pattern or mapping the water flow pattern as the downward flow protection -to protect a basin area - can be the solution for the flooding problem which is applicable in urban areas. A water gate is also designed as an alternative flood barrier protecting the basin area by transferring the water flow to another place. It can be positioned in between the place where the water comes in and the basin area [3].

The other study on the drainage dimensional increment investigating the flooding issue in Jakarta. One of the flooding causes in Jakarta is the insufficient drainage capacity which is then resulting in slow water disposal. As a result, the puddle stays a little bit longer. This study shows that the drainage dimensional increment in the targeted areas has the capability to accommodate water discharge passing through the drainage. Thus, the increased runoff can be prevented [4].

The experimental results are tested through validation process using Hec-RAS 5.0.7. HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. Prior to the 2016 update to Version 5.0, the program was one-dimensional, meaning that there is no direct modeling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The release of Version 5.0 introduced two-dimensional modeling of flow as well as sediment transfer modeling capabilities. The program was developed by the United States Army Corps of Engineers in order to manage the rivers, harbors, and other public works under their jurisdiction; it has found wide acceptance by many others since its public release in 1995 [5].

3. Methodology

This study starts with the flooding factor analysis using a physical model with the scale 1:30, secondary data, and literature review. Next, an experiment using a physical model is conducted to control floods by widening box culverts, increase the drainage capacity, combine the two solutions, as well as adding box culverts as a new pathway. Rational equations are used to calculate the water discharge as well as manage the data. Meanwhile, the physical experiment is verified using HEC-RAS. Moreover, the physical experiment is applicable to the alternative solution. Specifically, the study process will be elaborated in the following figure.

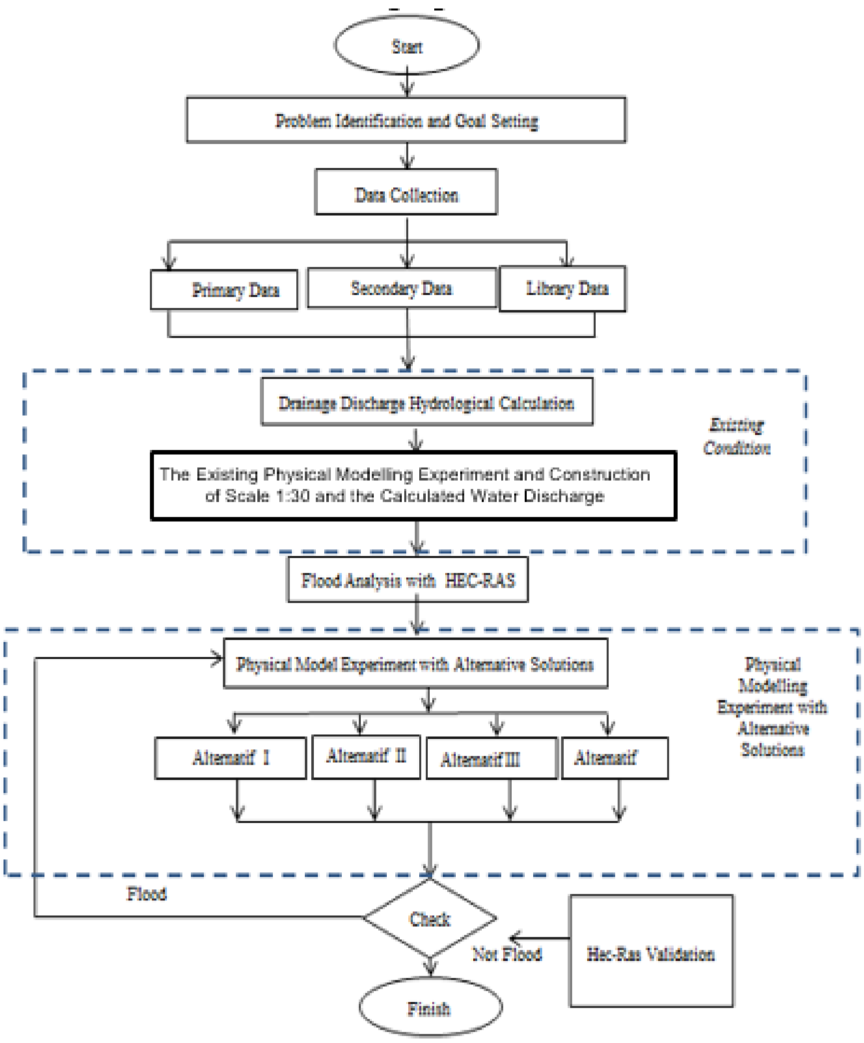

Figure 2. Research flow chart.

4. Calculation and discussion

4.1. Calculation of dispersion

The data show that the length of Citepus River is 9,331 km and its river flow area is 10.37 km2 where the catchment area covers 2,6 km2. The rainfall for the 25-year return period is 80.71 mm. Dispersion with the logarithm analysis is applied to “Log Normal” and “3-type Log Person”. Hence, the Standard Deviation (S), Skewness Coefficient (Cs), Curtosis Measurement (Ck), and Variation Coefficient (Cv) have been multiplied using the logarithm. Furthermore, the dispersion calculation result using the logarithm can be seen in table 1.

Table 1. Resumes of dispersion calculation.

Distribution	Sk	Cs	Ck	Cv
Normal	10.879	0.088	2.947	0.135
Gumbel	10.879	0.088	2.947	0.135
Log Normal	0.059	-0.329	3.025	0.001
Log Pearson III	0.059	-0.329	3.025	0.001

To determine the distributional calculation used in the next analysis, the double cross check needs to be completed. The requirements of each distributional method, along with the calculation results, have to be input into table 2. Then, the distribution that meets the requirements will be found.

Table 2. Table of distribution terms (SNI 2415:2016 the procedure for calculating flood discharge).

Distribution	Term		Result	Information
Normal	Cs	0	0.088	Not Fulfilled
	Ck	3	2.947	Not Fulfilled
Gumbel	Cs	1.14	0.088	Not Fulfilled
	Ck	5.5	2.947	Not Fulfilled
Log Normal	Cs = 3 Cv + Cv^3	0.000	-0.329	Not Fulfilled
	Ck = Cv^8 + 6 Cv^6 + 15 Cv^4 +16 Cv^2 +3	3.000	3.025	Not Fulfilled
Log Pearson III	Except value above		-0.329	Fulfilled
			3.025	Fulfilled

Table 2 shows that Log Person III is the one that meets the requirements. Therefore, distribution matching needs to be applied to check whether the selected type of the distribution is valid or not. The distribution type tested here is the one fulfilling the requirements: ***Log Pearson III***.

4.2. Rain water discharge

Rainwater Discharge is defined as the volume of rainwater realized in per unit time that does not experience infiltration and will be terminated through a drainage channel. Rainwater discharge (Qah) will be determined by run off (C), rainfall intensity (I), and Catchment Area (A). Rainwater discharge can be calculated using Rational Method with the equation below:

$$Q = 0.278\ C\ I\ A.$$

Table 3. Calculation of rainfall discharge of 25 years return periode.

Zona	Time Consentration	Area (A)	Scope Area	Rainfall Intensity	Total Discharge (Q)
	(Tc)	(Km2)		(mm/hour)	(m3/second)
Zona 1	0.45189	0.8	0.8	59.336	9.237
Zona 2	0.35331	0.51	0.51	69.914	6.939
Zona 3	0.20109	1.31	1.31	101.799	25.951
Zona 4	0.4904	0.008	0.008	56.187	0.087

From the clculation above, it can be seen that the values of dischare in each ZONE are as followed:
Zone 1: 9.237 m3/second

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Zone 2: 6.9 m3/second
Zone 3: 25.95 m3/second
Zone 4: 0.087 m3/second

4.3. Physical model experiment

4.3.1. Existing physical model

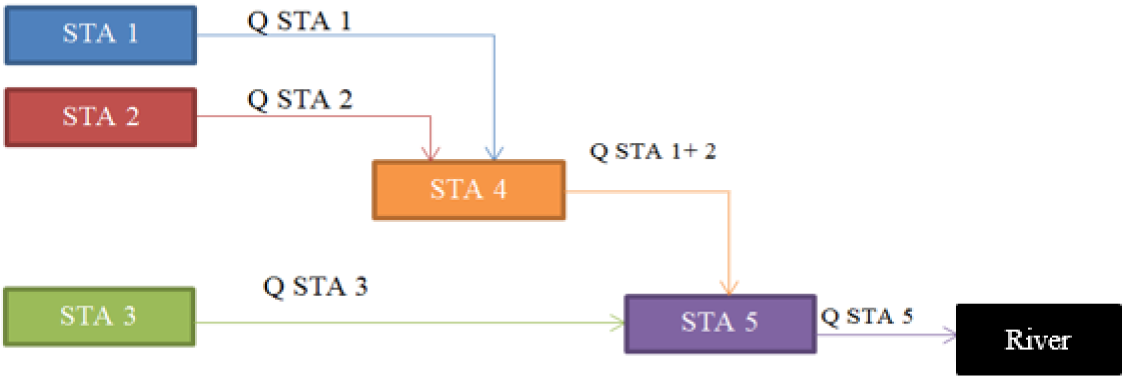

Figure 3. The existing physical model scheme.

Figure 4. The existing physical model.

The existing capacity checking can be conducted after gaining the value of cross section capacity in each STA. The experiment of the existing physical model has been carried out by draining each STA based on the calculated rainwater discharge. The experiment has discovered the overflow of water in the 50th second. The overflow speed is listed in table 4.

Table 4. Results of existing model experiment.

STA	Debit (Q)	Velocity
STA 1	9.23	0.3
STA 2	6.3	0.4
STA 3	25.37	0.4
Box Culvert	40.9	0.7

The experiment also shows that STA:
STA 1: the rainwater discharge of 9.237 m^3/seconds has the speed of 0.3m/second.
STA 2: the rainwater discharge of 6.3 m^3/second has the speed of 0.4 m/second.
STA 3: the rainwater discharge of 25.95 m^3/second has the speed of 0.4 m/second.
While the speed in Box Culvert is 0.7m/second. The result also shows the overflow of water occurs in the 50^{th} minutes.

4.4. *Physical model with alternative solution*

An alternative flood control has been tested using the physical model with the purpose to check on the flooded part in the existing condition experiment. Moreover, the design and scheme of the flood control can be seen below:

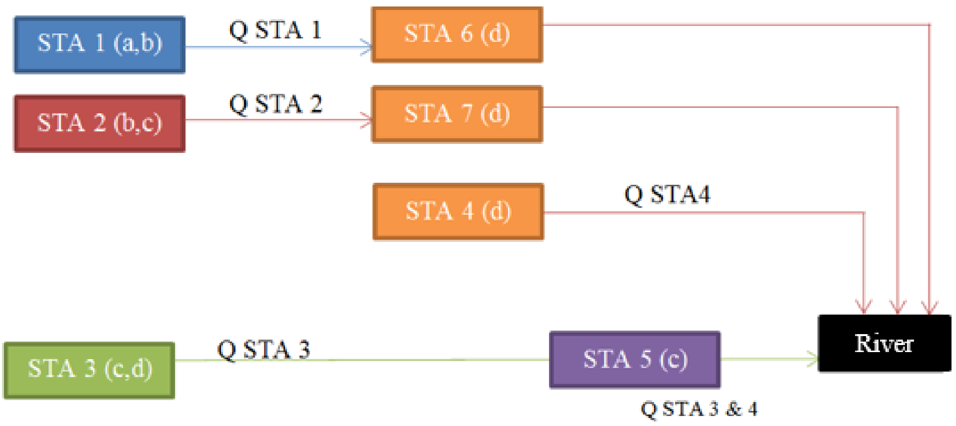

Figure 5. Scheme of model with alternative solution.

From the experiment scheme above, it can be known that there are 4 alternative solutions of flood control:

4.4.1. Alternative solution I. The flood control based on the alternative solution I can be conducted by widening a line of box culvert that is expected to be able to accelerate the water flow. As a result, the water overflow can be prevented. Alternative Solution I reveals that the water overflow experiences the decrease in speed after widening one line of Box Culvert. Yet, the puddle is still found in the 48th second. This puddle is associated with the presence of a detention in STA causing the puddles in STA 2 and STA 3.

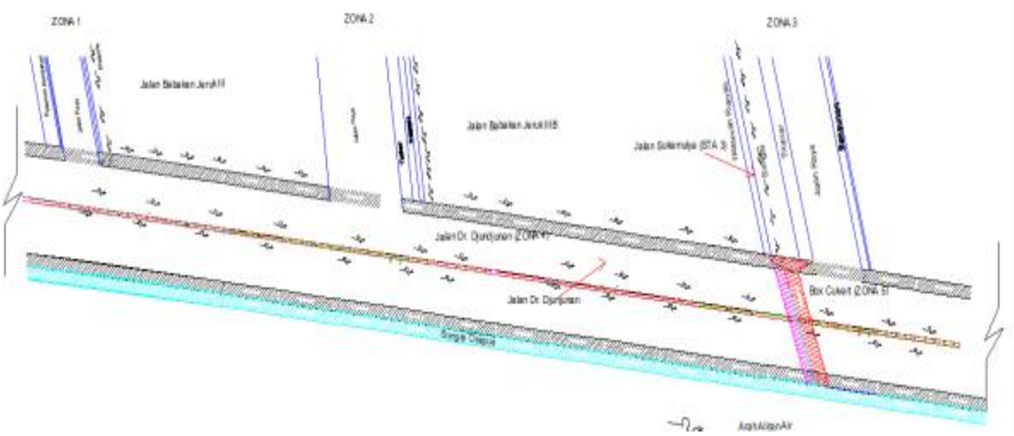

Figure 6. Physical model with alternative solution I.

4.4.2. Alternative solution II. The second experiment has been conducted by increasing the road drainage dimension in STA 1 and STA 2. The increment is realized through the road dimensional widening in which the widening size follows the existing width (1.5 meter) with 1 meter in depth. Despite the puddles, the water flow speed decrease in each STA is still noticeable. To be more specific, the alternative solution 2 summary is depicted in figure 7.

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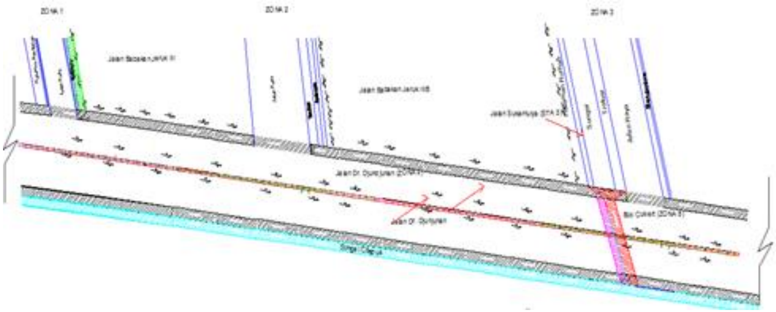

Figure 7. Physical model with alternative solution II.

4.4.3. Alternative solution III. The third experiment is focused on STA 2 due to the lower area. This condition enables the puddle formation. Alternative Solution III is the combination of Alternative Solution I and Alternative Solution II. Also, in Alternative Solution III, the 1-box culvert line addition and 2-line box culvert widening using the same dimensions as the existing box culvert size have been completed. To be more specific, the box culvert widening planning is depicted in Figure 8. In spite of the speed decrease in each Zone, floods still occurs in the 31st minute. It is associated with the 2 alternative's capability; it overcomes the puddle for 6 minutes.

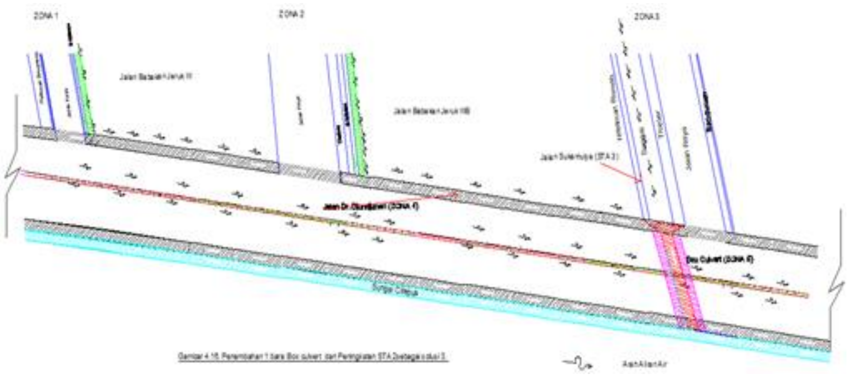

Figure 8. Physical model with alternative solution 3.

4.4.4. Alternative solution IV. Alternative Solution IV is the combination of Alternative Solution I, II, and III. Here, a new route addition of Box Culvert in STA 2, drainage dimensional increment of STA 2, road media drainage increment, road drainage increment (from Dr Djunjunan Road to the box culvert in STA 3) have been conducted. Alternative Solution IV is realized in Figure 9. Alternative Solution IV results in the absence of water overflow in each STA. Based on this result, this study assumes that Alternative Solution 4 can be implemented to overcome puddles due to the high-intensity rainfall.

Figure 9. Physical model with alternative solution IV.

4.4.5. Result resume of alternative solution. Based on all of the experiments, this study has discovered both speed increase and decrease in each alternative solution. Furthermore, the results can be seen in figure 10 and table 5.

Table 5. Resume of result of alternative solution.

STA	Debit (Q)	Velocity (V) (m/s)				
	(L/S)	Existing	Solution 1	Solution 2	Solution 3	Solution 4
STA 1	0.34	0.3	0.3	0.2	0.2	0
STA 2	0.25	0.4	0.3	0.1	0.1	0.2
STA 3	0.96	0.4	0.3	0.3	0.3	0.4
STA 4	0	0	0.1	0.1	0.1	0.1
STA 5	0	0.7	0.4	0.7	0.4	0.4
STA 6	0	-	-	-	-	0.2
STA 7	0	-	-	-	-	0.1
Time Flood	0	50	48	25	31	0

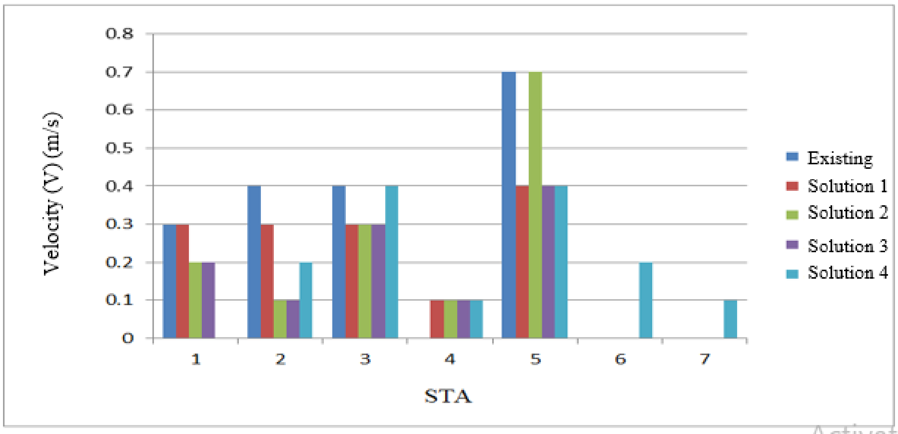

Figure 10. Resume of the overall results as alternative solutions.

From the Figure above, it can be known that:

- STA 1 with the water discharge of 9.3237 m^3/second, has a stable speed; that is to say, there is no any speed decrease of 0.2 m/second, found in a condition after the alternative solution addition.
- STA 2 with the water discharge of 6.3 m^3/second does not experience either speed increase or decrease; that is to say, the speed is 0.1 m/second after the addition of Alternative 2.
- STA 3 with the water discharge of 25.95 m^3/second experiences the speed increase of 0.1 m/second (it was 0.3 m/second and changed into 0.4 m/second) after the addition of the alternative.
- STA 4 (road) does not experience either the flow speed increase or decrease. The flow speed in Zone 4 is said to be static.
- STA 5 (Box Culvert) has the speed of 0.7 m/second. It experiences the speed decrease if 0.3 m/second (it was 0.7 m/second and changed into 0.4 m/second) after the addition of the Alternative
- The addition of the alternative, the positive result is also found in the flood puddle time in which the puddle in the 31st is no longer noticeable. The diagram shows that box culvert (5) still has the highest speed of all STAs

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5. Conclusion and suggestion

5.1. Conclusion
According to the result of the research, several points can be concluded as followed:

- Flood occurs along Dr Djunjunan Road in Pasteur is caused by the high rainfall volume that cannot be accommodated by the existing drainage. To overcome this issue, the adjustment of a drainage capacity increment is needed. Therefore, the water discharge can be accommodated anytime.
- The drainage capacity increment and a new route addition are seen as the most effective alternatives. The combination of these two alternatives can accommodate water discharge in a larger amount and accelerate the flow in a Zone with the most critical flow distance.
- A drainage channel dimensional increment can be implemented in areas that have either narrow or big spaces; the dimensional increment is not only realized in the form of widening but also deepening a channel. A new water flow path addition can be implemented in areas with a lower topography as an alternative water flow path that has long distance to the end path (river).

5.2. Suggestion
Based on the experiment, this study suggest that a drainage dimensional increment is needed, to be explore in the next experiment without a new water flow path, to explore the effectiveness of the drainage dimensional increment to accommodate the water flow.

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