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The Two Stage/Compound Channel Design to Prevent Sedimentation in the Channel

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Abstract— *The drainage channels in Samarinda generally consist of single-section channels. The large dimensions of these channels only carry residential discharge during the dry season. As a result, the flow is small, sluggish, and produces an unpleasant odor. In addition, the sludge content in the water easily settles and causes the channels to become shallower. In this study, a two stage section channel is planned to convey flood discharge as well as to carry the minimum discharge from residential/ domestic wastewater. The analysis conducted includes hydrological analysis, soil sample analysis, and hydraulic analysis. The design flood discharge based on the design rainfall value that meets distribution parameters and the Kolmogorov-Smirnov goodness-of-fit tests and generated from a modified rational method. The domestic waste flow is calculated using the Degreemont Formula. The sediment sample was tested in the laboratory to obtain the grain size (d50) and the critical shear stress values on the Shields diagram. The channel is planned to have an economical cross-section. The channel dimensions in the middle section are calculated based on domestic discharge, and the channel width is calculated based on flood discharge. The calculation results show that the additional dimensions for the minimum flow quite small compared to the dimensions for the flood flow. So, in terms of cost, they do not increase significantly, but they are able to enhance the benefits of the channel in terms of its flow.*

Keywords— *Domestic waste discharge; flood discharge; drainage channel; two stage/ compound channel; sedimentation.*

I. INTRODUCTION

Urban drainage channels are multi-purpose channels, serving to carry both rainwater runoff and domestic/ non domestic waste water simultaneously. In general, in Indonesia, the dimension fo drainage channels are planned based on flood discharge. In reality, it doesn't rain all the time, so the water flow in the channels sometimes much less than the planned flow.

The flow that will continue to pass through the channel is the continuous/ dominant flow. If the channel is designed only based on flood discharge, the flow velocity will decrease and allow the sediment contained in the water to settle. This is the beginning of the sedimentation and becomes a cause of channel shallowing.

The purpose of this study is to design a multifunctional channel that conveys both rainwater and domestic wastewater that can flow continuously during the rainy or dry season. The channel will not cause sedimentation during dry periods. Thus, the channel functions optimally in maintaining environmental health and comfort.

II. LITERATURE REVIEW

A. Hydrological Analysis

Hydrological analysis carried out includes design rainfall analysis, determination of channel catchment areas, rainfall intensity, and design flood discharge.

The estimated runoff value, especially for not very large chatchment area, can be calculated based on the relationship between rainfall and flow and the analysis of rainfall frequency. For chatchment areas that have several rainfall stations, various considerations must be reviewed to obtain the extreme values from the average rainfall within the area.

Frequency analysis is intended to determine the appropriate type of distribution in obtaining design rainfall. Four types of frequency distributions commonly used in hydrology are Normal Distribution, Log Normal Distribution, Gumbel Distribution, and Log Pearson III Distribution.

The runoff coefficient, C, is the ratio between the amount of water that flows in an area due to rainfall and the amount that falls in that area. (Subarkah, 1980 in Isnaini et al., 2019)

Rainfall intensity, I, is the amount of rain mass that falls and is expressed in terms of the volume of rain per unit of time. If the existing rain data is only daily rain data, then the intensity of rain can be calculated by the Mononobe formula. (Suripin, 2003).

A catchment area is a plain bounded by ridges or topographic boundaries to receive, store and drain rainwater that falls on it into river channels and flows into tributaries and main rivers, which then gather together into lakes, rivers or seas.

A commonly used method to estimate flood discharge or design discharge is the Rational Method. This method is used for areas with a drainage area of less than 300 ha. (Goldman et al., 1986 in Directorate General of Human Settlements, 2018). This method was then adjusted and became the Modified rational Method, which is written as follows:

$$Qp = 0{,}00278\ x\ Cs\ x\ Cx\ I\ x\ A$$

$$Cs = \frac{2\ tc}{2\ t_c + t_d}$$

Q_p = peak flood discharge (m³/s);
C = runoff coefficient;
I = rainfall intensity during the consentration time (mm/hour);
A = watershed area (km²);
Cs = retension coefficient.

B. Domestic Wastewater Discharge

Domestic waste water flow is divided into three types: average wastewater flow (Q_{ave}), peak hourly wastewater flow (Q_{peak}), and minimum wastewater flow (Q_{min}). Generally, domestic wastewater flow is determined from clean water consumption with a factor of 70-80% of clean water usage (Metcalf & Eddy in Destio, 2018). Meanwhile, the determination of daily clean water needs per person is determined based on population of the city (Ministry of Public Works, 2013).

This domestic wastewater discharge can be calculated using the Degreemont Formula as follows:

$Q_{peak} = p \times qm$

Q_{peak} = peak wastewater discharge

p = peak factor

q_m = average wastewater on the maximum day

And the domestic wastewater flow (Q_p) is Q_{peak} multiplied by the future population (Pn).

C. Two Stage/ Compound Channel

The most feasible form of a multifunctional channel is a double section channel (Fig.1). This channel consist of two main parts: the main channel, e deeper central section where water flow usually occurs under normal conditions, and the floodplain channel, a wider and shallower section on the sides, which only carries water during high flow events (for example, during heaving rain or flooding).

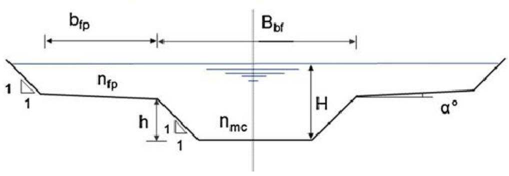

Fig. 1. Two Stage/ Compound Channel

The rectangular channel cross-section is most economical when the width of the channel base is twice the depth of water (B=2h) or the hydraulic radius is half of the water depth (R=h/2).

D. Sediment Particles Transport

The initial of motion of bottom sediment particles marks the beginning of sediment transport. The shear stress that occurs can be calculated using the following formula:

$\tau_o = \rho_w \cdot g \cdot h \cdot S$

τ_o = shear stress (kg/m^2)

g = gravitational acceleration (m/dt^2)

ρ_w = mass density (kg/m^3)

h = water depth (m)

S = channel bed slope

The movement of sediment particles follows the following: $\tau_o > \tau_{cr}$, moving; $\tau_o = \tau_{cr}$, start moving; $\tau_o < \tau_{cr}$, motionless.

III. RESEARCH METHODOLOGY

The analysis conducted includes hydrological analysis, soil sample analysis, and hydraulic analysis. The design flood discharge based on the design rainfall value that meets distribution parameters and the Kolmogorov-Smirnov goodness-of-fit tests and generated from a modified rational method. The domestic waste flow is calculated using the Degreemont Formula. The sediment sample was tested in the laboratory to obtain the grain size (d_{50}) and the critical shear stress values on the Shields diagram. The channel is planned to have an economical cross-section. The channel dimensions in the middle section are calculated based on domestic discharge, and the channel width is calculated based on flood discharge. The stages on this study as shown in Fig. 2 below.

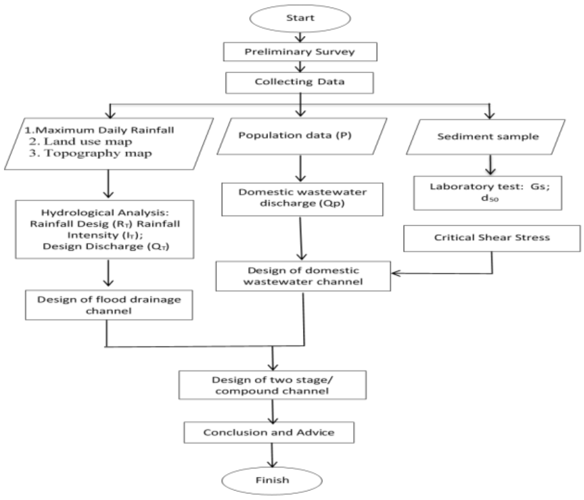

Fig. 2. The Research Flow of The Two Stage/Compound Channel Design to Prevent Sedimentation in the Channel

A. Research Sites

The research location was conducted on the Pangeran Suryanata Street, Samarinda, East Kalimantan Province. This location is showed in Fig. 3 below.

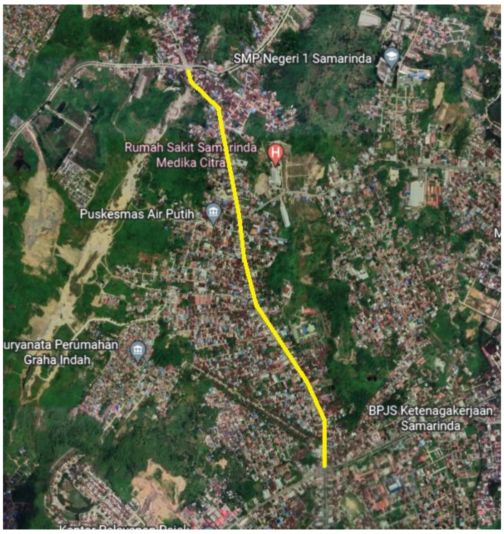

Fig. 3. Pangeran Suryanata Street, Samarinda

B. Maximum Daily Rainfall

The maximum daily rainfall data at Sempaja Rain Post in the year of 2015-2024 was obtained in Table I.

Daru Purbaningtyas, Abdurrahim Berti, Kukuh Prihatin, Dwi Yuliasari, Halizah Maulida Humaeroh, and Aidil Wahyu Becktino Budi, "A Design of Two Stage/ Compound Channel in Order to Prevent Sedimentation," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 8, Issue 8, pp. 179-183, 2026.

TABLE I. Maximum Daily Rainfall at Sempaja Rain Post

Year	Max. Daily Rainfall (mm)	Year	Max. Daily Rainfall (mm)
2015	80.0	2020	155.70
2016	85.0	2021	80.30
2017	80.0	2022	68.50
2018	124.0	2023	71.50
2019	116.1	2024	97.50

(Balai Wilayah Sungai Kalimantan IV Samarinda-Kalimantan Timur)

C. The Land Use

In Fig. 4 the following are the results of land use mapping on the P. Suryanata Street, Samarinda.

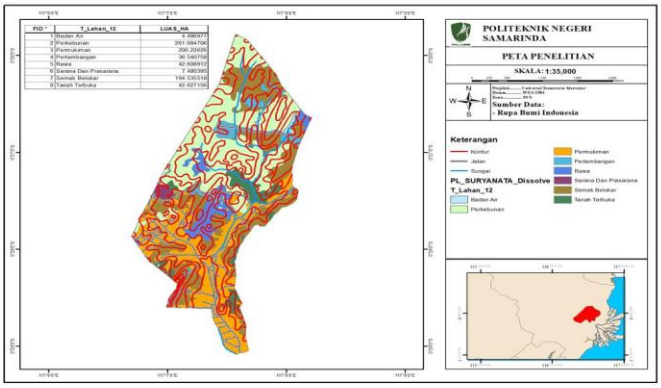

Fig. 4. The Land Use of P. Suryanata Street, Samarinda
(Badan Perencanaan Pembangunan Daerah Kota Samarinda)

D. The Population

The population data of Air Putih Subdistrict and Bukit Pinang Subdistrict is sourced from the Central Bereau of Statistics of Samarinda City. These data can be seen in Table II below.

TABLE II. Population Data

Year	The Population of Subdistrict (people)	
	Air Putih	Bukit Pinang
2018	28,713	9,007
2019	28,768	9,024
2020	29,166	11,649
2021	29,224	11,285
2022	29,984	11,768

(Badan Pusat Statistik Kota Samarinda-Kalimantan Timur)

IV. RESULT AND DISCUSSION

A. Design Rainfall

The results of rainfall calculations using the Normal Method, Gumbel Method, Log-Normal Method and Log-Person III Method are presented in the Table III below.

TABLE III. Design Rainfall

No.	Return Period (Year)	Design Rainfall (mm)			
		Normal	Log-Normal	Log-Pearson III	Gumbel
1	2	95.86	92.68	96.38	92.08
2	5	119.27	115.89	114.43	125.35
3	10	131.53	130.29	132.53	147.37
4	20	141.57	143.39	149.50	168.50

The results of parametric tests on rain design using all three methods are shown in the Table IV below.

TABLE IV. Parametric Test Results

Method	Criterion	Result	
Gumbel	Ck ~ 5.4 Cs ~ 1.14	4.84 1.26	Not eligible
Normal	Cs ≈ 0 Ck ≈ 3,0	1.26 4.84	Not eligible
Log Normal	$Ck = Cv^8 + 6\ Cv^6 + 15\ Cv^4 + 16\ Cv^2 + 3$ $4.84 \neq 4.46$ $Cs = Cv^3 + 3\ Cv$ $1.26 \neq 0.9$	4.46 0.9	Not eligible
Log Pearson III	Ck = Bebas Cs = Bebas	4.84 1,26	Eligible

The results of non-parametric tests using the Smirnov-Kolmogorov test and Chi-Square test are summarized in Table V as follows.

TABLE V. Non Parameter Test Results

Method	Smirnov - Kolmogorov Δ max < Δ kr	Result (Δ max)		Chi - Square $\chi^2 < \chi^2$ Kritis	Result (X^2)	
Gumbel	Δ max < 0.41	0.1316	Eligible	$\chi^2 <$ 5.991	3.0	Eligible
Normal	Δ max < 0.41	0.1973	Eligible	$\chi^2 <$ 5.991	8.0	Not Eligible
Log Normal	Δ max < 0.41	0.1748	Eligible	$\chi^2 <$ 5.991	3.0	Eligible
Log Pearson Tipe III	Δ max < 0.41	0.1212	Eligible	$\chi^2 <$ 5.991	3.0	Eligible

Based on the results of parametric tests, the Smirnov-Kolmogorov test, and the Chi-Square test, the Log-Pearson Type III distribution is the most likely to fit the existing data. Therefore, in the subsequent analysis, the design rainfall magnitude is used, which is derived from the calculations of the Log-Pearson Type III distribution. The design rain used in the next calculation is the 10 year return period, which is 132.53 mm.

B. The Catchment Area

A catchment area is an area that receives rainfall over a certain period of time (rainfall intensity), resulting in runoff that must be accommodated by the channel until it flows to the end of the channel (outlet). There are 3 segments on the right side and 3 segments on the left with the total catchment area is 2.48 km^2. The catchment area of the drainage channel at the research location is shown in the following Fig. 5.

C. The Design Flood Discharge

The design rainfall that falls in a certain area over a specific period of time is called rainfall intensity. The rainfall intensity for a 10 year return period for Segmen-1 to 8 is summarized in Table VI below.

And the next, the flood discharge is approached using the modified rational method. The Modified rational Method is a development of the Rational Method, in which the rainfall concentration time is longer. The calculation of the design flood discharge with a 10-year return period is presented in Table VII below.

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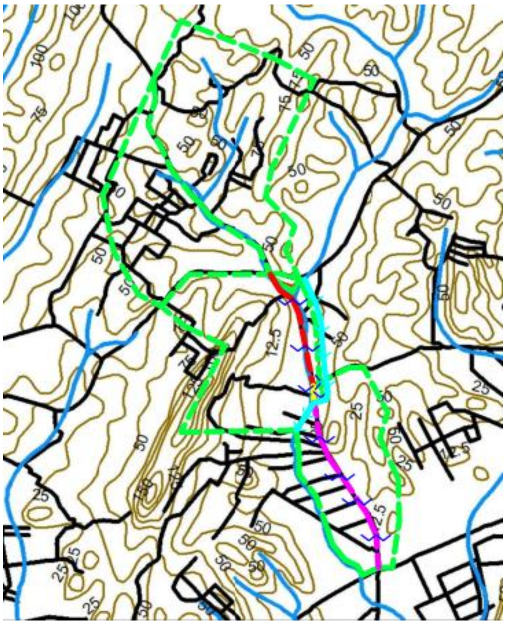

Fig. 5. The Catchment Area

TABLE VI. The Rainfall Intensity

Segmen	R_T (mm)	to (jam)	td (jam)	tc (jam)	I_T (mm/jam)
1	132.533	0.066	0.224	0.290	104.871
2	132.533	0.063	0.180	0.243	117.991
3	132.533	0.051	0.191	0.242	118.316
4	132.533	0.066	0.231	0.297	103.217
5	132.533	0.051	0.007	0.058	306.644
6	132.533	0.045	0.139	0.184	142.028
7	132.533	0.032	0.025	0.057	310.220
8	132.533	0.049	0.191	0.240	118.972

TABLE VII. Design Flood Discharge

Area	A (km^2)	C	Cs	I_T (mm/jam)	Q_T (m^3/s)
Segment 1	0.440	0.570	0.7212	104.87	5.27
Segment 2	0.640	0.42	0.7294	117.99	6.43
Segment 3	0.150	0.75	0.7174	118.32	2.65
Segment 4	0.870	0.42	0.7204	103.22	7.55
Segment 5	0.010	0.75	0.9446	306.64	0.60
Segment 6	0.050	0.75	0.7257	142.03	1.07
Segment 7	0.010	0.75	0.8209	310.22	0.53
Segment 8	0.320	0.55	0.7156	118.97	4.16

Flood discharge in drainage channel refers to the discharge that comes from the flow segments entering the cross-section of channel under consideration. For more clarity, the channel flow rates are summarized in Table VIII below.

TABLE VIII. Design Discharge of Drainage Channel

Channel	Segment	Q (m^3/s)
S1 Right	Q_{A2}	6.43
S1 Left	$Q_{A5} + Q_{A6}$	1.68
S2 Right	Q_{A2}	6.427
S2 Left	$Q_{A5} + Q_{A6} + Q_{A7}$	2.208
S3 Right	Q_{A3}	2.653
S3 Left	Q_{A8}	4.163

D. The Domestic Wastewater Discharge

Based on population data, the population growth rate in the Air Putih Subdistrict is 1.089%, and in the Bukit Pinang Subdistrict is 6.913%. therefore, the estimated population 10 years from now, in 2032, in the Air Putih Subdistrict is 33,413 people and in Bukit Pinang Subdistrict is 22,962 people.

The result of the domestic discharge flow calculations from each segments are presented in Table IX below.

TABLE IX. The Domestic Wastewater Discharge

Segment	Subdistrict	Area (km^2)	Population in 2032	Domestic wastewater flow (m^3/s)
A1	Bukit Pinang	0.44	7712	0.034
A2	Air Putih	0.64	39601	0.174
A3	Air Putih	0.15	9281	0.041
A4	Bukit Pinang	0.87	15250	0.067
A5	Air Putih	0.01	619	0.003
A6	Air Putih	0.05	3094	0.014
A7	Air Putih	0.01	619	0.003
A8	Air Putih	0.32	19800	0.087

E. The Soil Sample Testing

The specific gravity test was conducted using soil samples that passed the No. 10 sieves. And the specific gravity value obtained for Sample 1 is 2.62 and for Sample 2 is 2.60.

Sieve analysis is carried out to determine the type of particles in the collected sample. From the sieve analysis results, the soil that passed sieve no. 200 was tested with a hydrometer at 50 grams. The grain size from the sieve analysis is combined with the grain size from the hydrometer analysis, after first converting the hydrometer test results so that they can be used in the combined grain size analysis.

The results of combining sieve analysis and hydrometer testing can be used to create a combined particle size distribution graph, which can be seen in Fig. 6 below. And from the graph, the d_{50} value for Sample 1 is obtained with a grain size of 0.464 mm, and the d_{50} for Sample 2 with a grain size of 0.162 mm.

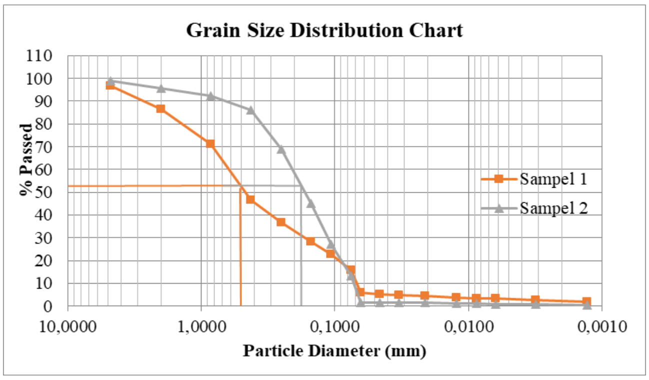

Fig. 6. The Grain Size Distribution

The critical shear stress (τ_{cr}) is calculated to determine the depth of the critical flow in a channel (h_{cr}) in order to calculate the cross-section of the minimum flow channel. The critical value is obtained from the Shield Diagram using the d_{50} value as a determinant. Determining the critical shear stress can be referred to in the Shield Diagram shown in Fig. 7 below.

Based on the Shield Diagram, the critical velocity (v_{cr}) of Sample 1 is 0.0022 m/s and the v_{cr} of Sample 2 is 0.0014 m/s. And the critical shear stress (τ_{cr}) of Sample 1 is 0.259 N/m^2 and τ_{cr} of Sample 2 is 0.173 N/m2.

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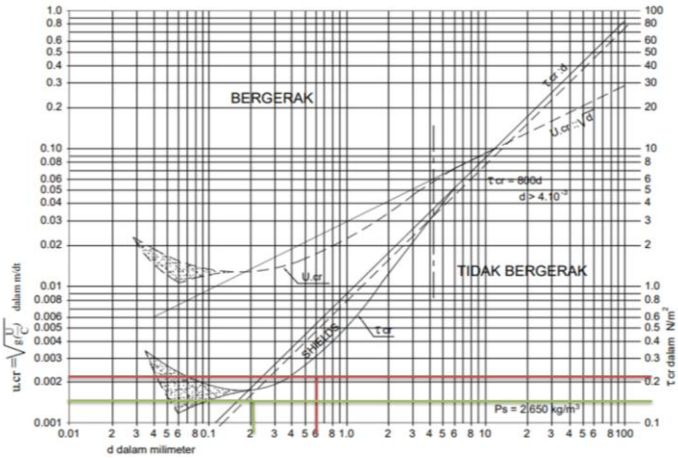

Fig. 7. Critical Shear Stress and Critical Shear Velocity of Particle d_{50}

F. The Channel Dimension

The dimension of the planned channel based on 10-year return period flood discharge use a square shaped cross-section, with the channel material made of stone masonry with n = 0.025. The calculation of cross-sectional dimensions of the planned channel are shown in Table X below.

TABLE X. The Planned Dimensions of The Flood Channel

Channel	Q (m^3/s)	v (m/s)	A (m^2)	h (m)	b (m)	w (m)	S
S1 Right	6.43	1.5	4.284	1.46	2.93	0.855	0.0021
S1 Left	1.68	1.5	1.118	0.75	1.50	0.611	0.0052
S2 Right	6.43	1.5	4.284	1.46	2.93	0.855	0.0021
S2 Left	2.21	1.5	1.472	0.86	1.72	0.655	0.0043
S3 Right	2.65	1.5	1.768	0.94	1.88	0.686	0.0038
S3 Left	4.16	1.5	2.775	1.18	2.36	0.767	0.0028

The planned channel dimensions for minimum flow are calculated based on domestic discharge for the population projected 10 years ahead. The minimum flow channel dimensions can be seen in Table XI below.

TABLE XI. The Planned Dimensions of The Minimum Flow Channel

Channel	Q_{peak} (m^3/s)	S	h (m)	b (m)	A (m^2)	v (m/s)
S1 Right	0.174	0.0021	0.38	0.76	0.286	0.61
S1 Left	0.016	0.0052	0.13	0.26	0.035	0.47
S2 Right	0.174	0.0021	0.38	0.76	0.286	0.61
S2 Left	0.019	0.0043	0.14	0.29	0.042	0.46
S3 Right	0.041	0.0038	0.20	0.39	0.077	0.53
S3 Left	0.087	0.0028	0.28	0.55	0.152	0.57

To determine wether the planned dimensions can move sediment particles, one can compare the shear stress with the critical shear stress and the flow velocity with the critical flow velocity. These both comparison can be seen in Table XII below.

TABLE XII. Comparison of τ_o with τ_o and v with v_{cr}

Channel	τ_o	τ_{cr}	v	v_{cr}	Description
S1 Right	7.904	0.2585	0.608	0.0022	moving
S1 Left	6.735	0.1728	0.471	0.0014	moving
S2 Right	7.904	0.2585	0.608	0.0022	moving
S2 Left	6.149	0.1728	0.457	0.0014	moving
S3 Right	7.408	0.2585	0.528	0.0022	moving
S3 Left	7.711	0.1728	0.570	0.0014	moving

The cross-section of the planned channel in a combined form (double-section channel) is a combination of the planned channel (flood discharge) and the minimum discharge channel dimensions (domestic discharge). The following are the dimensions of the combined form channel as shown in Fig.8 below.

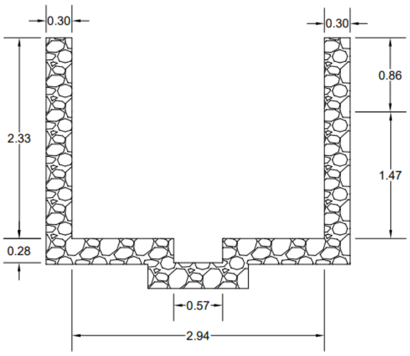

Fig. 8. The Planned Dimension of Two Stage/ Compound Channel

V. CONCLUSION

The calculation results show that the additional dimensions for the minimum flow quite small compared to the dimensions for the flood flow. So in terms of cost, they do not increase significantly, but they are able to enhance the benefits of the channel in terms of its flow. Based on additional benefits obtained from two stage/ compound channel, it is expected that future urban drainage channel designs will use two stage/ compound channel planning.

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