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The effect of underdrain box storage (UBS) as an instrument for reducingwater runoff in Mardika residential areas at Ambon City

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Abstract— *Land use change due to housing development can damage water catchment areas indirectly. This condition results in reduced rainwater catchment areas which cause rainwater to collect in existing drainage channels.Underdrain Box Storage is a means to collect rainwater and soak it into the ground. Rainwater that falls on the roof of the house is not flowed down into the gutter or the yard of the house, but it is flowed by using water channels into the underdrain box storage (UBS) so as to reduce the amount of runoff that occurs. Based on the results of the analysis of the combination of the correlation curve between Fr and Q2 / (h15.g)1/2, it is found that the regression model Q2 / (h15.g)1/2= 0.25757Fr2 - 0.612Fr + 0.0064 and between Fr and a / h12 in the model regression a/h12 = 0.1Fr2 with the formula of flow through the hole with Cd the discharge coefficient of the contraction vein flow equation at the bottom of the tank is Q = Cd. (2gh)1/2, found the discharge coefficient (Cd) with a value of 0.85-0,96 with the regression model Cd = 0.6473.h0.144. The area of the hole for the underdrain storage box has 2 "(inch) as a diameter and the filling time which is planned to speed up the entry of water into the reservoir is 2 minutes due to the small diameter of the holes, so that the required number of holes is 12 with a distance between the holes is 13.5 - 14 meters. If there rain happened for 1 hour, the underdrain box system can reduce flooding / inundation by 25.47% for the 2-year plan rainfall 11.44% for the 5-year plan rainfall and 7.35% for the 10-year plan rainfall of the total water volume rain.*

***Keywords*— Underdrain box storage, discharge coefficient, land use, rainfall plan.**

I. INTRODUCTION

Changes in land use due to housing development can damage water catchment areas indirectly. This results in reduced rainwater catchment areas which cause rainwater to collect in existing drainage channels.This condition will increase the volume of surface water that enters the drainage channel and the forming of puddles or even flooding when the water is overflows in the channel. Drainage planning needs to put more attention to the drainage function which is based on the concept of environmentally development. This concept is related to the conservation of water resources by slowing down and controlling the flow of rainwater runoff, so that it can sink into the ground through infiltration structures such as Underdrain Box Storage. Underdrain Box Storage is a means to collect rainwater and soak it into the ground. Rainwater that falls on the roof of the house is not flowed down into the gutter or the yard of the house, but it is flowed by using water channels into the underdrain box storage (UBS) so as to reduce the amount of runoff that occurs. The value of surface runoff which is greater than the absorption capacity of the soil causes stagnation of water immediately after the rain occurs. Continuous standing water due to the inability of the soil to absorb rainwater results in flooding.

From the direct observations at densely populated residential areas in Mardika at Ambon City, it is found that there are puddles and flooding when it rains. This condition can disrupt the activities of local residents or pedestrians. For this reason, it is necessary to make an adequate channel capacity complete with Underdrain Box Storage as an alternative method to deal with the amount of runoff and inundation in the area.

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II. LITERATURE REVIEW

The Underdrain Box Storage is a drainage concept with conservation-based and the development of an existing drainage system, including infiltration well drainage, perforate precast rainwater channels, and swale drainage. The technical concept of drainage is rainwater runoff (run off) is flowed through an open channel (open channel drainage) where at the bottomthere are some holes that arranged in a series along the channel as a function to fill the long storage space. The bottom of the storage space is directly related to soil. Underdrain Box Storager construction consists of rainwater drain, vertical drain hole, and box storage. Rainwater drainage channel functions to receive surface runoff due to standing rainwater. Vertical drain hole functions to forward rainwater runoff into the storage box. Meanwhile, box storage functions as a long storage that accommodates rainwater runoff and then naturally seeps water into the soil. In this system, domestic sewage is placed separately from rainwater drains.

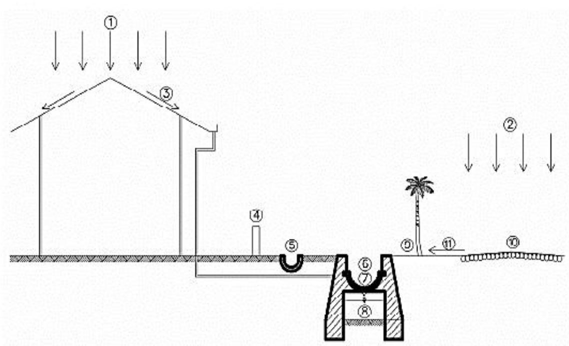

Fig 1. Underdrain Box Storage concept

Rainfall that falls on the roof, drain holes,

Rainfall that falls on the land,

The flow from the roof to the gutter,

Domestic sewer,

Rain water drain,

Vertical hole

Storage space (box-storage),

Roadside,

The Road,

Runoff Surface.

2.1 Hidrology Analysis

In order to provide reliable results, probability analysis must begin with the provision of relevant, adequate and accudischarge data sets. Relevant means that the data must be able to provide answers to the problem.The adequacy of the data mainly refers to the length of the measurement records, but then it was discovered that the data collection stations were very scarce. The accuracy of the data refers mainly to the problem of homogeneity. The selection of data is inseparable from understanding the concepts to be applied and the location of the research in order to get maximum results.

2.2 Rainfall Intensity

Rainfall intensity (I) states the amount of rainfall in a certain period expressed in units of mm / hour. To calculate the rain intensity, an empirical formula can be used, including the Monobe formula, because it can be used for any time t

$$I = \frac{R}{24}\left(\frac{24}{tc}\right)^{2/3} \qquad (1)$$

2.3 Runoff Discharge Analysis

The analysis of runoff discharge consists of land runoff, roof runoff, and runoff from the road. The analysis of land runoff uses the modified rational method formula.

Q_{lahan}= 0,00278 .Cs. C.I.A

2.4 Flow Through Hole

The liquid particles which are flowing through the holes came from all directions. Because the liquid has a thickness, some particles that have a turning path will lose energy. After flowing through the hole, the water jets will contract, which is indicated by locking the flow.Maximum contraction occurs at a little section downstream of the hole, where the water jets is more or less horizontal. The size of the contraction coefficient depends on the energy level, shape and size of the hole, with the mean value being about Cc = 0.64.

A tank with cross-section A which flows the liquid through an opening of area a which lies at the base as shown in fig. 2

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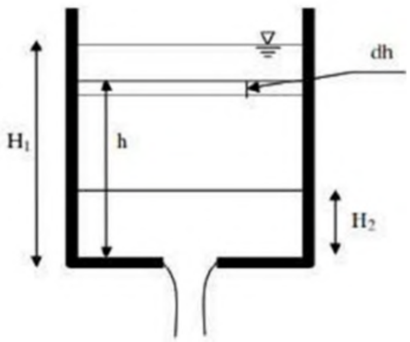

Fig. 4.2 Flow through the Hole Which is Positioned under the Tank

On a surface of the liquid in the tank that is at a height h above the hole, then the flow velocity at that time is:

$$V = Cv\sqrt{2gh} \quad (2)$$

And the flow discharge is:

$$Q = Cd.a\sqrt{2gh} \quad (3)$$

Cd value is 0,98, so that the discharge through the hole is:

$$Q = 0.98.a\sqrt{2gh} \quad (4)$$

2.5 Dimensional Analysis

Dimensional analysis using the Langhaar Matrix Method (Vries, 1997: 16) provides a dimensionless number, which states the flow parameters that need to be studied further in research, namely

$$\Pi_1 = \frac{Q2}{\sqrt{h1^5.g}}\ \Pi_2 = \frac{V_1}{\sqrt{h_1.g}} \ ; \ \Pi_3 = \frac{a_1}{h1^2} \ ; \ \Pi_3 = \frac{a_1}{h1^2} \ ;$$

$$\Pi_4 = \frac{Q2}{\sqrt{h1^5.g}} = \frac{V_1}{\sqrt{h_1.g}} \quad (5)$$

2.6 Research Procedure

Before conducting the research with a series of discharge experiments, first of all, calibratethe measuring instrument so that the discharge that passes through each measuring instrument used can be measured correctly, precisely and accurately in accordance with the conditions of the channel and the equipment used in the study.

The research was conducted with the following activity stages:

Calibrate the discharge measuring instrument and the speed measuring device to get the accuracy of the experimental discharge operation.

Installing the research device on the flume, by determining the diameter of a certain hole (d), the distance between the holes (L), according to the specified design.

The experiment was carried out by flowing a certain discharge (Q1) with several variations in the water level (h1) and the distance between the holes (L).

By measuring the volume of water that enters the storage room (V) and the time it takes until the reservoir is full (t), it will be possible to know the amount of discharge through the filling hole.

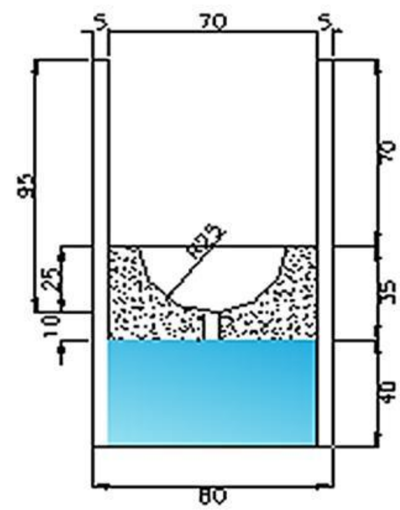

Fig 3. The Shape of The Channel Model

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III. METHODOLOGY

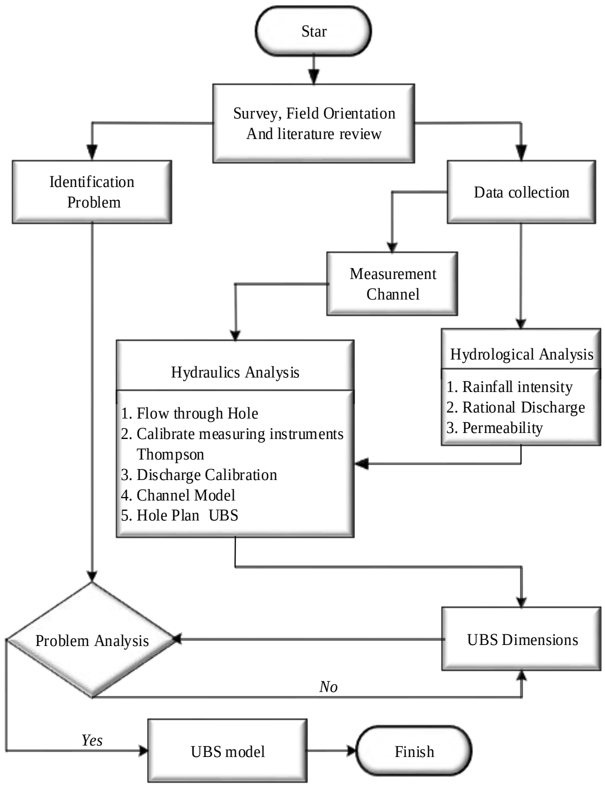

Fig 4 Research Flow Diagram

IV. Discussion and Results

4.1 The Calculation of Rainfall Intensity (I)

To calculate the amount of rainfall intensity, an empirical formula from Mononobe is used. The amount of rainfall intensity based on the results of calculations using the Mononobe formula for a concentration time of 0.491 hours (29.44 minutes) is presented in table 1

Table 1: Rainfall Intensity

Tr	Coef Runoff	Intensity	Area	Discharge
(Year)	C	(mm/hour)	(km2)	(m3/detik)
2	0.742	74.59	1.482	0.23
5		165.99		0.51
10		258.28		0.79

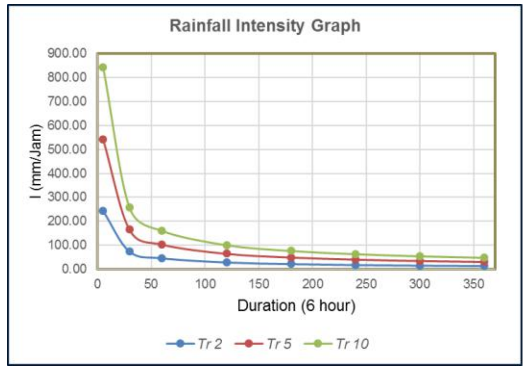

Fig. 5Rainfall Intensity Curve

4.2 Land Use Cooficient (C)

The coefficient C is defined as the ratio between the peak runoff discharge and the rain intensity. The main factors that influence the value of C are the soil infiltration discharge, land cover crops and the intensity of rain (Arsyad, 2006). The area of the research is 14818.72 m2 consisting of buildings, concrete roads and vegetation as shown

Table 2. Land Use Coefficient

Use	Area (km^2)	coefficient C	Coeff C Sub watershed
Building	1.450	0.75	1.087
Asphalt or concrete roads	0.032	0.8	0.026
Vegetation	0.025	0.2	0.005
Total	**1.507**		**0.742**

4.3 Coefficient of Cd hole

As water flow passes through the hole then it will contracts, which are indicated by the locking of the flow. Due to the influence of flow velocity in the channel, the direction of flow through the hole is not perpendicular but forms a certain angle. From the analysis, the equation for the hole discharge coefficient Cd is:

$Cd = 0.6473.h^{0.144}$

$R2 = 0.9823$

It can be seen that: The correlation coefficient = 0.9823 close to 1 means that the correlation or closeness of the relationship between the two variables is strong.

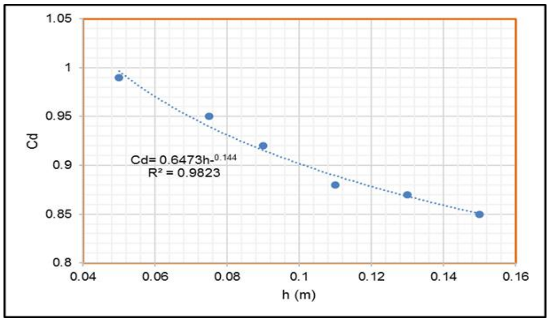

Fig 6: The Correlation between Water Level (h) and discharge Coefficient (Cd)

To determine whether the correlation between two or more variables is strong or not, it is indicated by the correlation coefficient (R). The stronger the relationship, the closer the correlation value is to the value of 1 or -1 and vice versa. Meanwhile, to determine the magnitude of the influence of the independent variables on the fixed variables, the coefficient of determination (R2) is used. Based on statistical analysis, the regression models that give better results are:

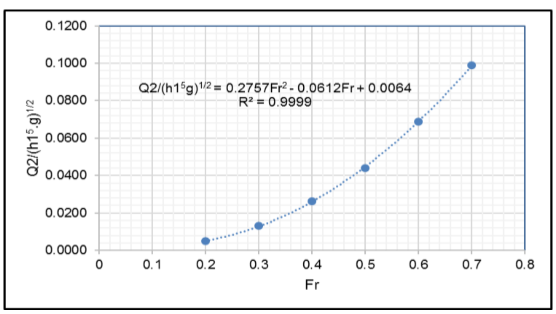

Fig 7: The Correlation Between Fr and $Q_2/(h1^5.g)^{1/2}$

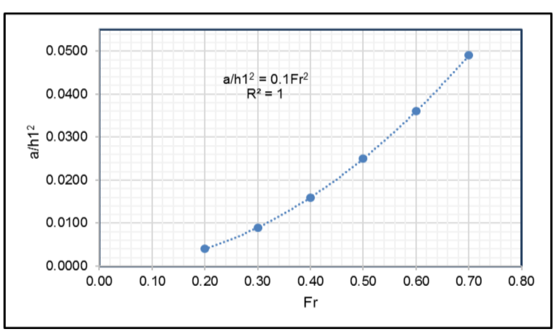

Fig 8: The Correlation Between Fr and a/h_1^2

- The correlationbetween Fr and $Q2/(h_1^5.g)^{1/2}$ (Fig7) $Q2/(h_1^5.g)^{1/2}$ = 0,2757Fr^2 – 0.612Fr + 0,0064 with correlation coefficient (R) = 0,999 and determination coefficient (R2) = 0,999.
- The correkation between Fr and a/h_1^2 (fig8) : a/h_1^2 = 0,1$Fr^2$with coorelation coefficient (R) = 1 and determination coefficient (R^2) = 1

4.4 Diameter Planning of UBS Filling Hole lubang pengisian

The planning of the filling hole is inseparable from the dimensions of the hole used for, that it is necessary to find the diameter of the hole. Calculation of channel dimensions: Planned channel shape as sketched below. b = 0.30 m d '= 0.3 m

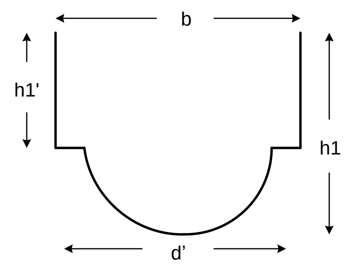

Fig 9: Plann Channel Cross Section

from the trials we found: h1’ = 0,30 m,

so h1 = h1’ + (0,5 x d’) = 0,45 m

h1 = 0.45 m

by using Froude’s number equation

$$Fr = \frac{v}{\sqrt{g.h}}$$

$$Fr = \frac{1.197}{\sqrt{9,81.0,45}} = 0,57$$

a) Based on Fig. 4.8 the correlation between Fr and $Q_2/(h1^5.g)^{1/2}$ with Froude’s number 0.57 so Q2 is 0.058 m^3/det by using the graph of Fig. 7.The correlation between water level (h) with discharge coefficient (Cd) found the area of the hole is 0.026 m^2or 5.1 cm diameter of the hole is 2”.

b) From the results of Froude's number, the area of the UBS filling hole can be found, using the graph of the correlation between Fr and a / h2. If Fr = 0.57 then it is included in the sub-critical flow, namely the flow with low velocity because Fr <1. Next, look for the area of the UBS hole as follows:

a/h_1^2 = 0,021Fr^2 + 0,005 then the value of a/h_1^2 = 0.033 andh1 = 0.45 m is 0.011 m^2 orusing the hole with 2" as its diameter.

4.4 Box storage planning

Planned dimension of box storage is

B = 0,6 m

h2 = 0,80 m

The volume of rainwater that can be accommodated is V = 77.28 m^3The time it takes to fill the reservoir is :

t = 77.28/0,0058 = 890.23 second = 1335.34 minute = 0.37 hour -To speed up the entry of water into the reservoir it is planned that the filling time is 2 minutes due to the diameter of the small holes, so that the required number of holes is 12 with a distance between the holes is 14.5 - 15 meters.

4.5 The calculation of pervasive water discharge

It is known that the value of K = 10-8 Cm / s because based on the field data, the soil at this location is vertisol soil, a kind ofclay soil. After getting the K value based on the existing theory, this K value must be below in m / s so the value = 10-8 m / sec.

Duration / peak time t = 38.64/0,0041 = 931.37 second = 15.52 minute = 0.26 hour

A = B x the total length of box storage

A = 0,6 x 161.41

$A = 96.85 m^2$

$V_R = Q_{res}\ x\ t$

$Q_{res} = K.A$

$Q_{res} = 9.68 * 10^{-7} m^3/second$

So

$V_R = Q_{res}\ x\ t$

$V_R = 0{,}000862\ m^3$

For the return period the storage plan before there is a storage box that can be seen in table 3 below

Table 3: Percentage of UBS storage

Tr	Channel Volume	UBS Volume	Runoff Volume	Reduction	Runoff magnitude
(Tahun)	(m3)	(m3)	(m3)	(m3)	(%)
2	41,97	77,48	304,24	25,47	74,53
5			677,02	11,44	88,56
10			1053,45	7,35	92,65

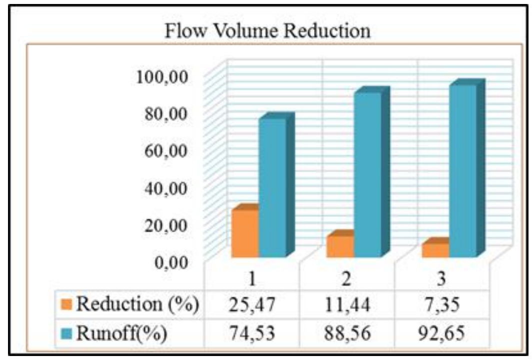

Fig10: Flow Volume Reduction Graph

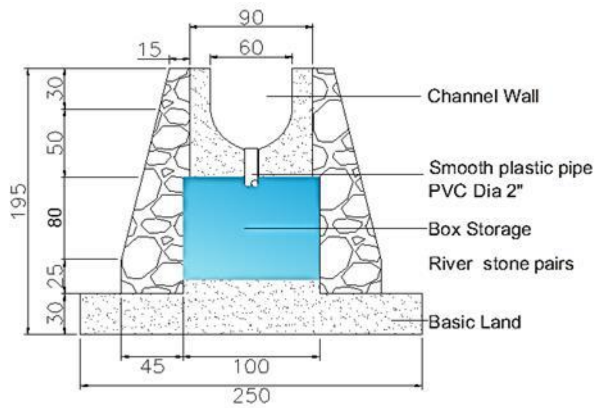

Fig 11: Design of underdrain box storage

V. CONCLUSION

Channels with flat elevations are very likely to be inundated so that a channel with several holes installed in series is required; the amount of discharge entering the hole is not the same where the downstream is getting smaller. Testing holes in the underdrain storage box can be approached in two ways

a) Combined curve of the correlation between Fr and Q2 / (h15.g) 1/2 in Figure 7 and the through-hole flow formula with Cd in Figure 6 where the equation of the discharge coefficient of the contraction vein flow equation at the bottom of the tank is Q = Cd. 2gh) 1/2, needs to be corrected so that it can be used for the calculation of the flow capacity through the catchment filling hole under the drainage channel. The experimental results are valued at 0.85-0.96 which has a theoretical difference with the average flow coefficient through the hole of 0.62

b) The correlation curve between Fr and a / h12 in Figure 8 relatively gives the same result as the approximate relationship between Fr and Q2 / (h15.g) ½

c) The area of the hole for the underdrain storage box with a diameter of 2 "and to speed up the entry of water into the reservoir, the planned filling time is 2 minutes due to the diameter of the small holes, so that the required number of holes is 12 with a distance between the holes to the holes 13.5 - 14 meters.
d) If there rain is happened for 1 hour, the underdrain box system can reduce flooding / inundation by 25.47% for the 2-year plan rainfall, 11.44% for the 5-year plan rainfall and 7.35% for the 10-year plan rainfall of the total water volume rain.

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