p-ISSN 2622-2027 *e*-ISSN 2622-2035

ANALYSIS OF LOSS WATER ON PIPE DISTRIBUTION "NON REVENUE WATER (NRW)" NETWORK PDAM SURYA SEMBADA CITY OF SURABAYA WITH CAUSAL LOOP DIAGRAM (CLD)

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Abstract

Water is an important supporting factor in humanlife. The problem of clean water in an area is managed by Perusahaan Daerah Air Minum (PDAM) Surabaya. PDAM Surya Sembada as a water management company in Surabaya is expected to be able to distribute he needs of clean water, however, in the distribution network. sometimes experiencing problems that cause water is not fully channeled to the customer, to overcome this problem, the Causal Loop Diagram approach is used to identify the cause of the water loss, after knowing these factors, we have been made model with Causal Loop model, to calculate the water loss that occurred, in PDAM Surya Sembada Surabaya especially DMA 109 using Infrastructure Leakage Index (ILI) method. The Causal Loop Diagram approach, various causes of water loss include: physical water loss caused by reservoir leakage, transmission line leakage and distribution pipeline leakage; non physical water loss caused by meter fault, wild connection and water theft. Based on the data obtained, obtained NRW value at DMA 109 of $439.455.72 \text{ m}^3$ / year or by 25% with a loss of $329.591.8 \text{ m}^3$ / year. Service pipe leakage up to the customer meter is $1.757.822.8 \text{ m}^3$ / year.

Keywords: Causal Loop Diagram, Distribution Network Pipeline, Infrastructure Leakage Index (ILI), Water Loss

1. Introduction

Clean water is an important supporting factor for human survival. The need for raw water for various purposes, especially clean water for households, public places, industries and others will continue to increase from time

rastructure er Loss writer use more than one input data and use method of Infrastructure Leakage Index (ILI). Ardiansyah et al., 2005 discussed about the water distribution performance system by entering different data with data presented by the author with different processing also.

Therefore, it is necessary to analyze the water losses in the pipelines of PDAM Surya Sembada Surabaya using the Causal Loop Diagram (CLD) approach and the Infrastructure Leakage Index (ILI) method to

to time in line with the pace of development in various sectors and fields and the number of population continues to grow, expected to be able to distribute and meet the needs of clean water community well and evenly with the existing pipeline distribution system, if the distribution system is not good enough, will cause various problems such as lack of water pressure so that the flow of water is not distributed evenly. Efforts to reduce the level of water leak can be done by first monitoring the condition of water that is distributed, both cubic water and pressure.

Monitoring efforts will be easier and more accurate if done in a small area, in other words divide the vast area into small parts. To maintain water availability, PDAM utilizes technology by building District Meter Area (DMA) and renewal of old pipes that reduce pipe leakage. Technology is the latest knowledge of knowledge and practice skills in the production of consumption and distribution of products and services in the development process(Suwarno and Nurcahyanie, 2007).

Umar et al., 2014, discusses the

distribution system in predicting the magnitude and location of the leak using only one input

data, namely pressure and using the method of

Extreme Learning Machine. While in research

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determine the water loss and how to overcome it.

2. Methods

This research was conducted at PDAM Surya Sembada Kota Surabaya. The method used in this research is Causal Loop Diagram (CLD) and Infrastructure Leakage Index (ILI) approach. Data were analyzed by Causal Loop Diagram (CLD) approach and Infrastructure Leakage Index (ILI) method with the following steps:



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p-ISSN 2622-2027 *e*-ISSN 2622-2035

Figure 1. Flowchart model

1. Causal Loop

To search and investigate the location of sources of water loss in terms of initiative taking is as follows :

- 1. Passive investigation
- 2. Active investigation

Experiment to detect and measure include:

- 1. Pressure Control
- 2. Zone Metering
- 3. Distrik Metering
- 4. Waste Metering
- 5. Calculate MAAPL

- 6. Calculate CAPL
- 7. Calculate ILI (CAPL/MAAPL)
- 8. Adjustment For Intermittent Supply
- 9. Sounding regulary
- 10. Compare ILI with matrix study physical loss.

3. Result and discussion

A. Causal Loop Diagram

the modeling of causal relationship or marked "S" and "O" can be seen in the table below

Table 1.The Power of Causal Relationships

	~. ~
Sign S	Sign O
1.Reservoir leak against:	1. Leakage of reservoir against
Construction damage due to cracking	small pipe length due to large
The installation procedure is incorrect	area
 Many faulty valves and fittings 	2. Many pipe connections to
2.Incorrect installation procedure to:	incorrect installation
 Many faulty valves and fittings 	procedures
Connection leakage	5. meter error on accuracy of data
3.Construction damage due to cracking of:	4 Motor byo pass against lookage
 Insufficient pipeline depth 	4. Meter bye pass against leakage
4. The depth of the pipe is not enough against:	5 Wild connection and water
• Transmission leakage	theft against incorrect
5. Leakage of transmission to:	installation procedure
• Connection leakage	6. Water meters are damaged
6.Connection leakage to:	consumers against construction
Many pipe connections	damage due to cracks
• Many home connections	
/.Leakage of distribution pipes to:	
• Many nome connections	
• Small, long pipes due to large areas	
8.Sman pipe length due to large area against:	
• Reservoir leak	
• The installation procedure is incorrect 0. Unlisted connection to:	
 Number of pipe connections 	
10 Error meter against:	
• Small long pipes due to large areas	
 First accuracy of irregular periods 	
12. Wild connection to :	
Unlisted connection	
Water meters are damaged consumers	
the consumers are duringed consumers	



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	Table 2.Data water discharge			
DMA	Month Year 2016	TOT CUS	TAL STOMERS	USE ACCOUNTS (m ³)
109	JANUARY		3.310.00	111.127.00
	FEBRUARY		3.313.00	109.764.00
	MARCH		3.316.00	110.824.00
	APRIL		3.320.00	106.812.00
	MAY		3.322.00	108.315.00
	JUNE		3.325.00	114.518.00
	JULY		3.323.00	102.522.00
	AUGUST		3.329.00	116.437.00
	SEPTEMBER		3.335.00	100.608.00
	OKTOBER		3.337.00	107.524.00
	NOVEMBER		3.338.00	116.583.00
	DECEMBER		3.339.00	113.333.00
TOTAL		39.907.00		1.318,367.00
Average		3.325.58		109.863.3

B. Data Water discharge

(Source : PDAM Surya Sembada Surabaya city)

C. Pressure Data

Tabel 3. Pressure on PDAM Surya Sembada Surabaya city			
Month	P0 (atm)	P1 (atm)	P2 (atm)
December 2015	2.2	2.2	1.25
January	3.6	2.4	0.40
February	3.4	2.5	0.25
March	3.7	3.0	0.15
April	3.7	3.3	0.25
May	3.7	3.1	0.52
June	4.2	3.2	1.80
July	4.0	3.0	0.80
August	2.9	2.3	0.80
October	2.3	2.0	0.52
November	2.6	1.2	0.30
December	2.3	2.0	0.20
Total	40.5	31.9	7.64
Average		2.04	

(Source : PDAM Surya Sembada Surabaya city)

P0 = pressure at the beginning P1= pressure at the middle P2= pressure at the end

D. Pattern Data water usage

Table4.Pattren usage water			
Month	Stand Meter		
December 2015	4261.1		
January	4286.7		
February	4298.4		
March	4321.6		
April	4350.2		
May	4382.4		
June	4408.9		
July	4421.3		
August	4453.8		
September	4480		
October	4500,6		
November	4532.1		
December	4559.6		

(Source : PDAM Surya Sembada Surabaya city)

E. Data Accuracy in Meter

From the average customer as much as 3.325.58 or 3.326 home connections obtained the amount of the difference (liter) measuring

glass that is 663.2 liters. This meter accuracy data will be used to calculate the percent value of water loss from customer meter.

F. Data water distribution

	Table 5. Water Distribusion		
Total distribution of water (m ³ /month)	Jumlah air recordedin bill accounts (m³/ month)	GAP / difference (m ³ / month)	
146.485.24	109.863.93	36.621.31	

(Source : PDAM Surya Sembada Surabaya city)

With reference to the table of water usage patterns, then obtained the following calculation which will then be used to determine the level of water loss that occurred in PDAM Surya Sembada Surabaya on DMA 109:

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p-ISSN 2622-2027 *e*-ISSN 2622-2035

	Table 6. Calculation Pattern usage of water			
Month	Stand Meter	Usage (m ³ /month)	Average Debit (m ³ /month)	
December 2015	4261.1			
January	4286.7	25.6	24.875	
February	4298.4	11.7	24.875	
Maret	4321.6	23.2	24.875	
April	4350.2	28.6	24.875	
May	4382.4	32.2	24.875	
June	4408.9	26.5	24.875	
July	4421.3	12.4	24.875	
August	4453.8	32.5	24.875	
September	4480	26.2	24.875	
October	4500.6	20.6	24.875	
November	4532.1	31.5	24.875	
December	4559.6	27.5	24.875	
Total		298.5		

(Source : Data research, 2017)

Calculation of water usage in 1 month with water meter reading ratio: = First Stand Meter – End Stand Meter = 4286.7 – 4261.1 = 25.6 m³/ month With reference to the distribution table, we can calculate percent water loss, calculated based on the following Tornton formula : $H = \frac{D - K}{D} \times 100\%$ D = 146.485.24 m³/month x 12 = 1.757.822.88 m³/year K = 109.863.93 m³/year x 12 = 1.318.367.16 m³/year

$$H = \frac{1.757.822.88 - 1.318.367.16}{1.757.822.88} \times 100\%$$

$$H = \frac{439.455.72}{1.757.822.88} \times 100\%$$

$$= 25\%$$

Leakage in m³ = 25% x 1.757.822.88
m³ = 439.455.72 m³/year
= 36.621.31 m³/month

calculation Q average : $Q = \frac{amount \ of \ water}{amount \ of \ data} = \frac{298,5}{12} = \frac{24.875}{24.875}$ $\frac{Total \ difference \ of \ number \ water" \ meter"}{amount \ sample} x \ 100\%$ $= 1.220.7 \ m^{3}/day$ Calculates the percent value of water

Calculates the percent value of water loss from the customer "meter"

 $\frac{663.2}{3.326} \times 100\% = 19\%$ Total water distribution =146.485.24 m³ From lost water in "meter" distribusion customer and amount water distribution, we can calculation lost water: 146.485.24 x 19% = 27.832.2 m³/month = 333.986.4 m³/year

Calculation of lost water in " rupiah" The total price of water sold is

= Rp. $184,131,946.68 \text{ m}^3/\text{month}=$ Rp 2,209,583,360.16 m³/year

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Water sold in one year =			
$109,863.93 \text{ m}^3/\text{month} = 1,318,367.16$			
m ³ /tahun			
Leakage =			
25% x 1,318,367.16 m ³ /year= Rp.			
329,591.8 m ³ /tahun			
Average price = $\frac{2,209,583,360.16}{1,318,367.16}$			
$= 1,676 \ /m^{3}$			
totallostwater in rupiah = leakage x			
average price list			
= Rp. 329.591.8 m ³ /year x Rp. 1.676			
$/m^3$			
$= 552.395.856.8 \text{ m}^{3}/\text{year}$			
$= 46,032,988 \text{ m}^3/\text{month} = 1.534.432.9 \text{ m}^3/\text{day}$			

Water balance calculation:

• Water distribution at the month Januari – Desember = 146,485.24 m^3 /month = 1,757,822.88 m^3 /year

- Consumption of metered yards
- = 109,863.93 m³/month = 1,318,367.16 m³/year
- No accuracy customer "meter" = $27,832.2 \text{ m}^3/\text{month} = 333,986.4$ m³/year
- Lost water = amount water distribusion - consumsion account in meter tool = 1,757,822.88 - $1,318,367.16 = 439,455.72 \text{ m}^3/\text{year}$
- water loss
- = lost water non technical loss= 439,455.72 - 333,986.4 = 105,469.32 m³/year
- Water balance calculation can be seen in the following table:

Volume	Legal	Official Legal	Account water	Water with
Input	Consumption(2	Consumption	Consumption in	account $(17) =$
System) 1.318.367.16	(4) 1.318.367.16	meter	1.318.367.16 m ³ /
(1)	m³/ year	m ³ / year	(8) 1.318.367.16 m ³ /	year
1.757.822.			year	
88 m ³ /year			the customer "meter"	
			estimates are damaged	
			(9)	
		Legal	Consumption	Water with no
		Consumption	"meter" with no	account(NRW)
		with no account	account usage at	(18) = 439.455.72
		(5)	certain institution(10)	m ³ /year
			Consumption no	
			account $(11) = usage$	
			water by firefighters	
			and cleaning pipe	
	Lost water (3)	Lost water Non-	Konsumsi tak resmi	
	439.455.72	physic (6)	(12) = illegal	
	m ³ /year	333.986.4	Consumption	
		m ⁹ /year	No accurancy "meter"	
			customer and data	
			error $(12) 222 0.96 4 \text{ m}^3/\text{mass}$	
		Lost water	(15) 555.900.4 III / year	
		nhysic (7)	Distribusion and	
		105 469 32	Transmission (14)	
		m ³ /year	Kebocoran dan luapan	
		2	dari tangki	
			penyimpanan	
			perusahaan air minum	
			(15)	
			Leakage in main Pipe	
			until customer "meter"	
			tool (16) 105.469.32	
			$m^{3}/year \ge 10\% =$	

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Distribusi Air Bersih. Jurnal Teknik

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Eka Mitra Engineering, Jakarta.

Sistem

Pengairan, 3, 211 – 220.

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	<i>e</i> -ISSN 2622-2035
	10.546.9 m ³ /year
Calculate <i>Non – Revenue Water</i> (NRW) with <i>Infrastructure Leakage Index</i> (ILI) :Long main pipe (LM) = 5,580 km.	 Meter Error Wild Connection and Water Theft.
(NC) = 3.326	2. How to minimize water losses that occur in PDAM Surva Sembada Surabaya, can
Pressure average $(P) = 2.04$	be controlled to control leaks - leaks that
Average length of service pipes $(LP) = 15 \text{ m}$	 e Establishment of zones and sub zones e Establishment of sub zone to be
= 0.015 km	• Establishment of sub zone to be monitored
CAPL (l/year) = physical loss at this time = 374.592.12 m ³ /year	 Assessment of distribution pipeline network conditions Chapling the function and recording
= 374. 592. 120 l/year	• Checking the function and recording of water meters
LP = 0.015 x 3.326	Sub zone stabilizationMinimum Night Flow (AMM)
= 49.89 km	Leak detection
MAAPL (l/day) = (18 x LM) + (0.8 x NC) + (25 x LP) x P	5. Acknowledgment
= (18 x 5.580) + (0.8 x 3.326) + (25 x 49.89) x 2.04	This reseaches have been support from Dean UNIPA Surabaya and dan
= (100,440 + 2,660.8 + 1.247.25) x 2.04	Chairman of the Industrial Engineering Department. In addition, thank you to the PDAM Surya Sembada Surabaya and Hendro
= 104.308.05 x 2.04	Ardiyansyah have been helped and supported in this research
= 212.788.422 l/day	in this research.
= 6,383,652.66 l/month	Reference
= 76,603,831.92 l/year	1. Abbas, A.Z & Ejah, U.S & Gunadin, I.C & Umar, M.H. (2014). Sistem
$ILI = \frac{CAPL}{MAAPL}$	Deteksi Kebocoran pada Jaringan Pipa Air PDAM Menggunakan
$=\frac{374,592,120}{76,603,831.92}$	Analisis Tekanan dengan Metode Extreme Learning Machine. Jurnal
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From the analysis of the discussion	(2012). Anansa Kinerja Sistem

From the analysis of the discussion that has been described, it can be concluded as follows:

- 1. The cause of water loss in PDAM Surya Sembada Surabaya as follows:
 - a. Physical Water Loss:
 - Reservoir leak
 - Transmission pipe leaks
 - b. Non Physical Water Loss:

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