Control of Water Loss in the Drinking Water Distribution System of Malang City PDAM

Anwar Romdloni

Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia
anwarromdloni94[at]gmail.com

Abstract: ***The implementation of the Drinking Water Supply System by PDAM is responsible for providing drinking water services to the community. Losses incurred due to water loss include being unable to meet drinking water needs, reduced revenues, increased operational costs and worsening infrastructure. One of the concrete efforts of PDAM management is to control the level of water loss. Water loss is defined as the difference between production volume and collectible water volume based on customer meter. Data analysis for water loss control is done by identifying the existing PDAM conditions related to Non Revenue Water (NRW) level issues and efforts that have been made to address them. Identification of PDAM existing conditions begins with identifying the service area as a whole through an existing network map. Then the identification of existing conditions of PDAM through existing water balance data. Water balance data is available for each component of the water balance so that existing conditions are obtained for each existing component for both commercial water loss, physical water loss, and NRW level. Asset management and technology can also play a role in water loss control analysis. Currently the use of SCADA technology in water loss control is able to monitor, control, and acquire data on a particular process continuously.***

Keywords: PDAM, distribution, water loss, water balance

1. Introduction

The increasing number of residents of Malang city resulted in an increase in the need for drinking water. Malang City administratively consists of 5 sub-districts and 57 villages with a population of 843.810 people [1]. The Regional General Company Tugu Tirta Kota Malang is a Drinking Water Regional Company (PDAM) organized by the Malang City Government trying to meet the drinking water needs of the Malang City area for 24 hours with a minimum pressure of 0, 5 bar at the farthest and highest point. Based on statistical information for the period of May 2021 Total Water Production Capacity of 1.525 liters/ second with a customer number of 170.573 people.

PDAM Malang city has 2 (two) types of raw water, namely springs and drill wells. Most of the raw water supply is obtained from springs about 94%. The raw water used by PDAM Malang City is geographically not controlled directly by the Malang City Government but the majority comes from the Malang regency (1.067, 89 liters/second) and Batu City (274, 65 liters/ second), and the rest are in Malang city itself. The availability of raw water that is majority not controlled by PDAM Malang city makes PDAM management must make good use of existing raw water. One of the concrete efforts of PDAM management is to control the level of water loss. Water loss is defined as the difference between production volume and collectible water volume based on customer meter.

The water loss control program in PDAM Malang City has been started since 2009 gradually. In that year the water loss rate was 42% and every year improved until 2019 the water loss rate was 15, 93%. This is certainly already below the national target according to Permen PUPR Number 27/PRT/M/2016 concerning the Organization of Drinking Water Supply System which is a maximum water loss of 20% which is 15, 93%. PDAM water loss control strategy is relatively successful because currently the performance of PDAM Malang City in 2019 has a healthy performance predicate with a value of 3, 51 [2].

Drinking water service conducted by PDAM Malang City uses a combination of pumping system by 73% and gravity system by 27%. The target of water service quality carried out by PDAM Kota Malang is the implementation of the Drinking Water Security Plan (RPAM) – operator, by putting forward the 4K principle, namely: Quality, Quantity, Continuity and Affordability. The application of this principle is realized with various programs, one of which is the application of good asset management.

Asset management in PDAM Malang cityis a concern for directors for several reasons, including the number of assets owned by PDAM is very much, the location of assets scattered throughout the service area and prone to failure of drinking water services if assets are not properly maintained. In addition, asset management will facilitate PDAM in determining the priority of repair or addition of assets due to limited spending budgets.

The implementation of asset management in PDAM Kota Malang is supported by the Internet of Things (IoT) instrument in the form of Supervisory Control and Data Acquisition (SCADA) which has included production units and distribution units. In general, SCADA is useful in controlling Non Revenue Water (NRW), able to achieve the 4K principle, provide alarm when there is an anomaly in discharge and pressure, and operational efficiency where PDAM officers become more responsive in solving problems on the ground.

This paper is hopefully useful with regards to the best practice of water loss control. In addition to field observations, there is also the identification of problems and the preparation of settlement recommendations through case studies.

2. Literature Survey

a) Drinking Water Supply System

Drinking Water Supply is an activity to provide drinking water to meet the needs of the community in order to get a healthy, clean, and productive life. Drinking Water Supply System which is further abbreviated as SPAM is a unity of drinking water supply facilities and infrastructure [3].

The distribution system is a system that is able to distribute water to every consumer in various ways, either in the form of a house connection or a connection through a public tap [4]. Water that has been produced in the production unit must be distributed to the community as a customer of drinking water. This is to ensure certainty of quantity, quality and continuity of flow. Distribution of drinking water can be done with [5]: Piping system is the distribution of drinking water through the distribution pipeline to customers. For distribution using piping this can be done by pumping or gravitationally draining. This depends on the difference in elevation between the production unit and the service area. Non-piping systems that distribute drinking water not through distribution pipelines, but rather use transportation to transport water from production units to customers, such as tank cars, wheelbarrows, and others.

b) Distribution System Patterns

In the distribution piping system there are three patterns of distribution systems, namely the branch pattern system, the loop pattern system and the Gridiron pattern system [6]. Branch systems have the characteristics of an open system, have only a one-way flow direction, gradation of the diameter size of the pipe is clearly visible, and requires a lot of blow off because it ends at dead ends. The shape of a branch with a dead-end path resembles the branch of a tree. This form can be used for mountainous areas following its contours, it can also be used in newly developed areas as a temporary form or in areas that are no longer possible to develop. The circular system has the characteristics of a closed system, the flow does not come from a single watershed only, the gradation of the diameter size of the pipe is not clearly visible, and at peak hours the entire region can be served quickly. This system is used for relatively flat areas. The gridiron system has the characteristics of the main pipe, secondary parent pipe and main service pipe located in one box and connected to each other.

c) Flow System

To distribute drinking water to consumers with enough, quality, and pressure requires a good piping system, reservoirs, pumps, and other equipment. The types of drinking water flow systems are as follows [7]: The gravity system allows it to be used if the elevation of the water source or distribution reservoir is higher than the service area, so the pressure is enough to drain the water to the area of the population that is at the very end of the service area. This system is the most economical system. In gravity flow, the reservoir used is a ground reservoir or coupled with an elevated reservoir as a pressure enhancer to serve at maximum usage time in the farthest service areas that do not get water. In this pumping system the pump is used to increase the pressure needed to distribute water from the distribution reservoir to the consumer. This system is used if the elevation between the water source or treatment plant and the service area cannot provide sufficient pressure. Pumping water from the reservoir to the consumer is done according to the desired pressure.

The fluctuating use of water results in the need for means to balance the flow, for example with the installation of hydrophores or the arrangement of the number of pumps used. This way of pumping in addition to being more expensive than the gravity system, will also be problematic in the event of electrical power disruption. A dual system is a combination of a gravity system and a pumping system. Excess water due to the use of water that cannot be accommodated in the reservoir that will later be used to supply water at the time of water use will be many. Sometimes additional pumps are needed, for example, to supply directly in the event of a fire.

d) Water Loss

Water loss can be defined as a number that shows the difference between the volume of water supply (supplied water) and the volume of water consumed (consumed water). So, water loss is the amount of water lost and does not become income [8].

Water loss defined as physically and non-physical loss of water [9]: Physical water loss is understood as water loss in its physical form from a pressurized system to a customer meter point (distribution). This includes leaks in pipes, joints, fittings, leaks in tanks or reservoirs, overflow of water coming out of the reservoir as well as inadequate open drains or blow-offs systems. Water loss in this form is also called real losses. Non-physical water loss is understood as water loss not in its physical form but results in the same way as water loss in the technical form of loss of revenue over water management. Therefore, water loss in a non-technical form is also called commercial water loss or apparent losses. Commercial water loss includes inaccurate water meters in production water meters and customer water meters, plus unofficial consumption such as theft or illegal use.

Water Balance is the equilibrium between the amount of water supplied and the amount of water distributed or can also be interpreted as the distribution or distribution of water supplied. The water balance is structured as an auxiliary instrument to facilitate the implementation of water audits. The water balance can detail with and identify the components in NRW well. This process helps in understanding the magnitude, source and cost of NRW.

e) District Meter Area (DMA)

DMA was formed with the aim of minimizing handling difficulties in the event of a disruption to the flow system in the distribution network and facilitate maintenance and included in one of the efforts to reduce the level of leaks that occur. In principle, a DMA is formed to be able to control the amount of flow in and out of the system. So that it can be used as a study to regulate and control the system, operation,

ISSN: 2319-7064
SJIF (2020): 7.803

maintenance, and control of NRW.

A DMA must be permanently completely isolated so as not to interfere with the other DMA if there is repair work. The following is the standardization of DMA PDAM Malang City: One DMA inlet, Isolation with Blind permanently, Strainer, Master Meter, PRV, Resilient Step test valve.

f) Active Leakage Control Methods

Active leakage control is one of the actions to control water loss. There needs to be a very effective method in the search for water loss, one method that is quite famous is Steptest, which is a technique to find the location or area with the largest amount of water loss in DMA [9]. To run the steptest is done at a minimum usage time between 24: 00-02: 00. Technically the implementation of step test is to install a portable flow meter (ultrasonic flow meter) in the DMA inlet pipe that will be done step test to record water flow, and then the valve in each segment in the DMA is closed systematically and sequentially. With this method will be known the segment that has the highest indication of water loss.

3. Methods

a) Data Analysis Methods for Water Loss Control

Data analysis for water loss control is done by identifying the existing PDAM conditions related to NRW level issues and efforts that have been made to address them. Identification of PDAM existing conditions begins with identifying the service area as a whole through an existing network map. Then the identification of existing conditions of PDAM through existing water balance data. Water balance data is available for each component of the water balance so that existing conditions are obtained for each existing component for commercial water loss, physical water loss, and NRW level.

b) Observations in the field

Activities in the field aim for observation of activities that have been implemented in the provision of drinking water. In addition, activities in the field are carried out to obtain primary data. Field activities are carried out in accordance with the schedule of field trips of each section.

Activities in the field are as follows:

- Network repair work by doing split DMA;
- Step test activities at DMA Mojo 3E;
- Survey meter activities in order to lose commercial water;
- PDAM asset verification survey activities in Malang;
- Implementation of SCADA

4. Discussions

a) Water Loss and NRW

The Water Loss Section of PDAM Malang City is divided into 3 Sub-Sections, one of which is the Water Loss Control Sub-Section, which is a Sub-Section that carries out the search for physical and non-physical loss actively in the designated District Meter Area (DMA). Drinking water companies target non-physical water loss of no more than 4-6% of official consumption. Reducing non-physical water loss requires a low-level investment with a short return on investment. So that the control of non-physical water loss at the beginning of the NRW reduction program can increase the Company's revenue because activities can be carried out with in the company with little effort and immediate visible results.

B) GIS Network Map

The digital map of PDAM's piping network in Malang city currently covers the entire service area and uses water office applications accessed internally by the Company. The water office application contains SPAM technical information that can see repair history, pipe data, pipe accessories data and integrates with other applications in the PDAM Malang City, for example the android work order application. Water office view on PDAM Malang City.

c) Commercial Water Loss

Commercial losses / non-physical water loss is water that is lost and not lost. In many cases, water has already metres, but it is not recorded accurately. Includes all types of inaccuracies relating to customer meters as well as data management errors (meter readings and billing), as well as unauthorised consumption (theft or illegal use). Decreased non-physical water loss can immediately increase the volume billed and increase revenue.

Based on Figure 1 of the February 2021 water balance, it is seen that non-physical water loss is 129.946 m (3, 16%) which is divided into 2 groups, namely unofficial consumption of 5.387 m^3 (0, 13%) and inaccuracies of meters / data handling of 124.559 m^3 (3, 03%). These values are one of them obtained from non-physical water loss survey activities conducted to customers who meet the following problem criteria:

- Meter reading error
- Meter problem
- Violation
- Large/ small meter
- Illegal Connection
- Accounts Don't Arise
- Soaring Usage
- Zero Usage 3 months in a row
- Night Use
- Cover (TS and TT)
- Customers with> meters = 1 inch

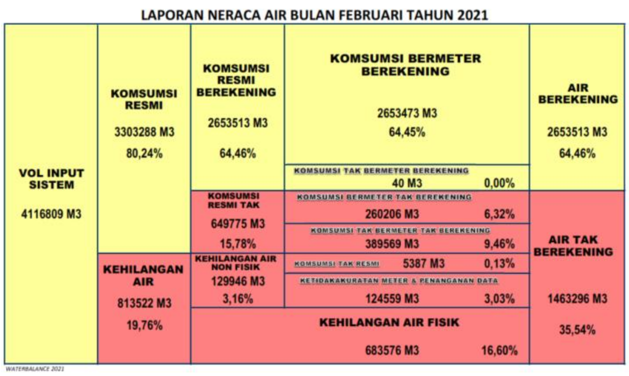

Figure 1: February 2021 Water Balance Report

The Commercial Loss Case Study at RSU Lavalette is one of the customers of PDAM Malang City with group IV C which belongs to the commercial category with a rate of 15.800/m^3 for use above 10 m^3. The average water use of this customer is in the range of 540 m^3 to 993 m^3 in the last 6 months (September 2020-February 2021).

Identification of customer water use carried out every month by PDAM Malang City shows an anomaly in the water meter in the hospital Lavalette. The Customer Information System (SIMAPEL) application shows that water use in March 2021 decreased significantly in Table 1, which was only 35 m^3. This data shows the in suffoency of water discharge compared to the average water usage in previous months.

Table1: Lavalette Hospital Water Use

Period	Meter Numbers (m^3)	Water Usage (m^3)
March 2021	32074	35
February 2021	32039	545
January 2021	31494	742
December 2020	30752	880
November 2020	29872	993
October 2020	28879	831
September 2020	28048	570

Anomalous water usage data above is used as a reference for indications of commercial water loss caused by meter inaccuracies. This indication is then responded by conducting a field examination at the location. In accurate water meters will make recording water usage by customers not in accordance with the real discharge consumed. Therefore, the anomalies found need to be monitored and checked if there are problems that must be fixed by PDAM Malang City. The water meter examination at Lavalette Hospital was conducted at two times, namely on March 9, 2021 and April 1, 2021.

The first examination conducted on March 9, 2021, the method used is the installation of new water meters in the Series of Figure 2 to be a comparison to the recording of water usage on existing meters. While the second examination conducted on April 1 was the recording of discharge on both meters and then comparing the results.

Figure 2: Serial Installation of New Water Meters at Lavalette Hospital

The results of the examination in table 2 meters of water at Lavalette Hospital showed the difference in discharge volume of use between the new meter and the existing meter. The results obtained provide information to PDAM Malang City that the existing meter is in a state of disrepair and must be replaced.

Table 2: Water meter examination results at Lavalette Hospital

Water Meter	Observation 1	Observation 2	Usage difference
Existing Meter	32077 m3	32082 m3	5 m3
New Meter	0 m3	46 m3	46 m3

The volume of water usage recorded at 46 m3 during the 20 days of monitoring in new water meters is still smaller than the average water usage of Lavalette Hospital in previous months. Based on information obtained from the hospital.

Lavalette water use decreases due to the transfer of Hemodiization (washing of blood) and using ground water substitution. In accuracies of water meters can be caused by damaged water meter source in hospitals. Lavalette is so small that water meters cannot read accurately. So that it is necessary to resizing the water meter in order to maximize the flow of incoming water.

d) Physical Water Loss

Physical water loss has several categories of water loss, namely leaks in pipes and equipment; leakage of service pipes up to the customer meter; tank/ reservoir over flow. Total water loss is the accumulation of non-physical water loss and physical water loss.

Based on Figure 1 of the Water Balance perumdaTugu Tirta Kota Malang in February 2021, it is seen that the physical water loss is 683.576 m3 (16, 60%) and is the largest water loss category in Malang City. The effort that PDAM has done is to actively search for leaks, through active leakage control (ALC) activities both in the transmission network, main distribution, and within the DMA.

Active Leakage Control or more accurately referred to as Active Leak Control is one of the activities of the 4 pillars of the strategy to reduce the number of water loss. Active Leakage Control (ALC) is a very important activity for leak management at a relatively cheap, effective and efficient cost, so that this activity can be referred to as an integrated effort to find the source and location of the leak through systematic and integrated planning by involving all existing resources.

Physical Water Loss Control Case Study by conducting active leakage control (ALC) at DMA Mojo 3E on Tombro Ikan Road, this steptest consists of 9 steps that are done by closing the valve from the farthest with a water meter (inlet). This steptest activity is divided into 2 (two) teams, namely the debit recording team and the valve closure team by coordinating through mobile phones. Here is a Figure 3 Plan of Step test Activities DMA Mojo 3E.

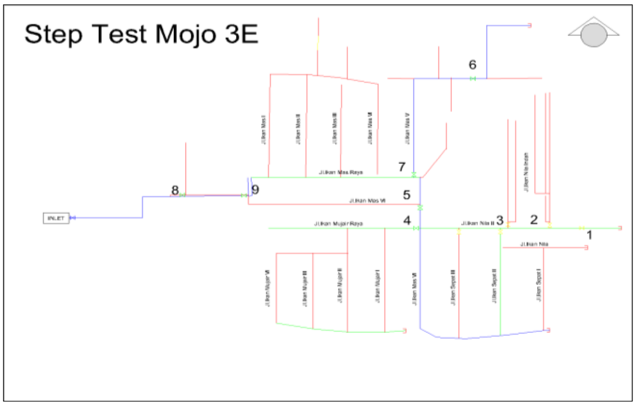

Figure 3: Steptest DMA Mojo 3E Activity Plan

The indication of leakage in figure4 is obtained from calculating a high debit difference before and after the closing of the valve depicted with figure 5 graph, there is an indication of leakage in step 5.

STEP	V1	V2	V3	V4	V5	V6	V7	V8	V8	BOCORAN PIPA YANG DIPANTAU	WAKTU JAM	DEBIT (L/dtk) Q AVG	Tekanan	KEHILANGAN AIR (L/dtk)	dSR	dQ/dSR	KELAS BOCOR
MULAI	O	O	O	O	O	O	O	O	O			2.106					
STEP 1	C	O	O	O	O	O	O	O	O	1		2.079		0.027	4	0.0067	Sedang
STEP 2	C	C	O	O	O	O	O	O	O	2		2.007		0.072	29	0.0025	Rendah
STEP 3	C	C	C	O	O	O	O	O	O	3		1.942		0.065	31	0.0021	Rendah
STEP 4	C	C	C	C	O	O	O	O	O	4		1.843		0.099	75	0.0013	Rendah
STEP 5	C	C	C	C	C	O	O	O	O	5		1.034		0.809	131	0.0062	Sedang
STEP 6	C	C	C	C	C	C	O	O	O	6		0.932		0.102	34	0.0030	Rendah
STEP 7	C	C	C	C	C	C	C	O	O	7		0.644		0.288	37	0.0078	Sedang
STEP 8	C	C	C	C	C	C	C	C	O	8		0.619		0.025	44	0.0006	Rendah
STEP 9	C	C	C	C	C	C	C	C	C	9		0.000		0.619	102	0.0061	Sedang
SELESAI	O	O	O	O	O	O	O	O	O						487		

Figure 4: Blanko fill step test DMA Mojo 3E

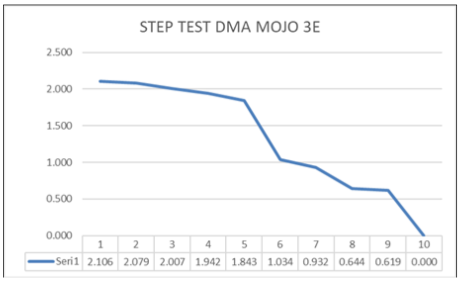

Figure 5: DMA Mojo 3E Step Test Graphic

After getting an indication of a leak in Step 5 then close the valve at point 5 and open the valve before at point 5 to drain the water back for the leak point search through using a leak detection tool. Once found the leak point officers mark the location for processing for leak repair. To ensure the leak is carried out excavation officers in the morning by asking the permission of the home owner because it is in the yard of the house. Then after the leak is found, reporting to the treatment department. After the maintenance officer makes improvements by providing data information and photo evidence of the realization of improvements in the Work Order Android (WONDROID) application that aims to update the completed repair work data (closethecase).

e) Other Observations

DMA repair work is carried out because there is a low pressure problem at the farthest point (Critical Point Perum PBI). The pressure on Critical Point at peak usage hours is still often below 0.5 bar (January-February 2021), so it is necessary to set the network with split DMA. Inlet DMA exists to be one of DMA Mojo 4 and DMA W2B. The plan is to install gate valve 8" (set close) to separate the inlet path. At the time of excavation in Figure 6 found the condition of the pipe that does not allow the installation of the gate valve because the length of the bend (position Y) is not enough, so that an alternative scheme is carried out pair blind or shift the existing valve, in accordance with Figure 7.

Figure 6: Split DMA Excavation Work

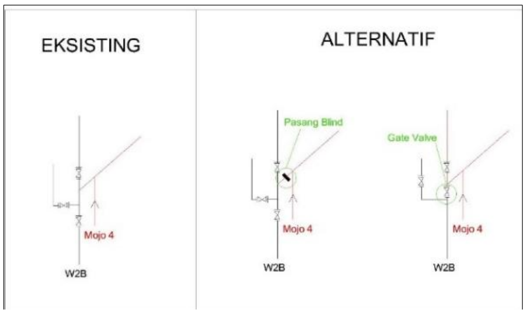

Figure 7: Split DMA Mojo 4 Scheme with DMA W2B

After the DMA split, the pressure on critical point at peak usage hours is in accordance with the target of 0.5 bar<P<1 bar (Observations may 2021), as shown in Table 3.

Table 3: Comparison of Pressure at Critical Point

Hour	Feb 2021	March 2021	April 2021	May 2021
08.00 (JPP)	0, 127	0, 127	0, 789	0, 967
02.00 (PMM)	0, 636	0, 636	0, 840	1, 170

Each asset is given a barcode that can be scanned. After the scan, general information will appear about the asset profile, its monitoring history and details of the parameters assessed. Examples of barcode asset information on SPAM assets can be seen in Figure 8.

Figure 8: Asset Data Information contained in asset barcodes

Pressure management which is one way of controlling water loss will also be helped by the implementation of SCADA, especially pressure data. Pressure management in PDAM Malang City uses a lot of Pressure Reducing Valve (PRV). The installation of THE PRV must be fitting so that it can lower the pressure as desired and with SCADA can be quickly known the pressure is still not appropriate, so that adjustments can be made immediately (PRV reset). In Figure 9. See the water pressure graph on SCADA, as the basis for the PRV setting.

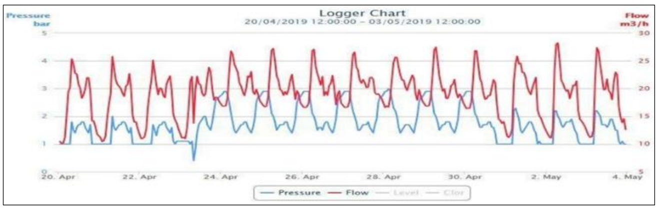

Figure 9: Pressure Graph on SCADA

Based on Figure 9. High pressure shows indications that the use of PRV is failing, so it is necessary to reset. After the reset, the water pressure will return to its normal position. In general, the benefits derived from the implementation of IoT in SPAM services are:

- 3K service;
- The distribution system is more organized and easy to control;
- SPAM monitoring and control are more integrated;
- The resulting data is more accurate;
- Human resources become more competent.

5. Conclusions

Water balance is a pre-requisite for controlling water loss used as a baseline. PDAM Malang city already has a water balance an disupdated every month and conducts an analysis of the causes of water loss. DMA (District Meter Area) methods can help leak detection by continuously monitoring the flow and pressure of sectoral pipelines. Furthermore, the development and evaluation of DMA is carried out by PDAM to date. Water loss control program can not only be done in a short period of time, but rather requires consistency that can be a daily job of PDAM. Physical water loss control uses Active Leakage Control (ALC) is carried out twice a week in the DMA of each region, namely east and west using the steptest method. Control of non-physical water loss is carried out by monitoring the customer's meter record within a certain period of time. There are 2 (two) conditions that need more attention, namely when the meter record shows 0 uses for 3 months and there is a significant decrease in water use. The use of SCADA systems in the management of SPAM provides benefits in the implementation of NRW level control programs. In relation to the NRW drop, automation systems such as SCADA will make it easier to detect leaks in pipes. Theoretically, if the discharge increases then the pressure in the pipe will decrease, and conversely the lower the discharge usage then the pressure will increase. As with the step test procedure, pipe leakage is indicated by significant discharge and pressure changes in a step area of a DMA that is done leak detection. And related to leak repair, PDAM must manage assets neatly one of which is the use of barcodes so that the history of asset maintenance can be known on a regular basis.

References

[1] Badan Pusat Statistik (BPS). (2021). KOTA MALANG DALAM ANGKA, *Malang Municipality in Figures*, 2021. Kota Malang.

[2] Direktorat Air Minum Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2020). Buku Kinerja BUMD Air MinumTahun 2020.

[3] Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat No.27/PRT/M/2016tentang Penyelenggaraan Sistem Penyediaan Air Minum, X 67 hal (2016).

[4] Syabani, Rizki Muhammad. (2016). Penerapan Jaringan Distribusi Sistem District Meter Air (DMA) Dalam OptimalisasiPenurunanKehilangan Air FisikDitinjau Dari Aspek Teknis Dan Finansial (Studi Kasus: Wilayah Layanan IPA Bengkuring PDAM Tirta Kencana Kota Samarinda). InstitutTeknologi Bandung: Bandung.

[5] Masduqi, A., Assomadi, AF. (2012). Operasi dan Proses Pengolahan Air. Surabaya: ITS Press.

[6] Lampiran II Peraturan Menteri Pekerjaan Umum Nomor 8/PRT/M/2020, tentangPetunjukOperasionalPenyelenggaraan Dana Alokasi Khusus Infrastruktur Pekerjaan Umum dan Perumahan Rakyat. Jakarta.

[7] Sari, Putri Rihaya. (2012). AnalisisJaringanDistribusi Air Bersih PDAM Bengkuring (PerumahanBengkuring, Kelurahan Sempaja Selatan). Universitas Mulawarman: Samarinda.

[8] Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2018). Modul Air TakBerekeningTahun 2018 (1st ed., p.218 hal).

[9] Hou, Y. (2018). Water Distribution System Leakage Control by DMA Management: A Case Study. WDSA/CCWI Joint Conference Proceedings, Vol.1.

Paper ID: SR21903124434 DOI: 10.21275/SR21903124434