

Research Article

Analysis and Evaluation of West Semarang Distribution Pipe Network System Municipal Waterworks in Semarang City

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Abstract

The need for clean water is related to the growth rate and population density. High population density affects access to clean water. The population in the DWSS (Drinking Water Supply System) area of West Semarang is concentrated in three sub-districts, namely West Semarang (148,879 people), Ngaliyan (141,727 people), and Tugu (32,822 people). With the average population growth rate of Semarang City from 2011 to 2020 of 0.89%, the need for clean water will continue to increase. The condition of clean water services in Semarang City, which Municipal Waterworks manage, needs to be improved, both in terms of coverage and continuity of service distribution. The research method used is the method of field research and literature. Hydraulic data retrieval was obtained through field observations and water usage data from the internal Municipal Waterworks in Semarang City. The data were analyzed using the Epanet program. From the analysis results, there were areas with significant differences in water pressure values, and at peak hours, there were areas that did not get sufficient water supply. It can be concluded that there are problems in the piping network in the West Semarang DWSS area.

Keywords: Clean water; DWSS; pipeline network

1. Introduction

Semarang City is the capital city of Central Java Province. The city is located in lowlands 4 km from the coastline with 37,370.57 Ha consisting of 16 sub-districts and 177 urban villages, between 60 50' and 70 10' South Lat and 1090 50' 55" 1100 35' East longitude. The administrative boundaries of Semarang City are as follows: Northside: Java Sea, East: Demak Regency, Southside: Semarang Regency, and West: Kendal Regency, which can be seen in figure 1. (BPS Kota Semarang, 2022). The condition of clean water supply services in Semarang, managed by Municipal Waterworks "Tirta Moedal", still needs to be improved regarding the lack of coverage and continuity of services. Service coverage, in general, is still 31.56%, and the rate of water loss is 42.94% (BPKP audit 2020). That is proven by the service conditions that are still not good, especially in the West Semarang DWSS service area. The areas include Bongsari Village, Kembangarum Village, Bojong Salaman Village (Perumda Tirta Moedal Kota Semarang, 2022). These various problems have led to further research on the condition of the clean water distribution

pipe network in Semarang that can be immediately addressed, and the water distribution can run optimally.



Figure 1. Semarang City administration map

In analyzing the clean water distribution piping network, a tool is needed to facilitate the analysis, one of which is the epanet program. Many previous researchers have carried out simulations with the epanet program, including saying that the epanet program can assist in evaluating distribution pipe network problems and the level of water loss (Awe et al., 2020). Simulations with the epanet program can evaluate the water supply system, water demand and pump performance (Luna et al., 2019). Hydraulics modelling with epanet analyses water requirements and consumer profiles that vary from water use and topography (Kara et al., 2016). The epanet simulation serves to help analyze the process of determining the pump head and its performance through the pump curve in the epanet program (Georgescu et al., 2015). The epanet program can analyze complex pipelines and calculate the residual pressure in an area (Venkata Ramana et al., 2015). It integrated epanet and SCADA programs to obtain data in real-time in the field (Sunela & Puust, 2015). The epanet program is used to analyze the vulnerability of distribution pipelines and as a support in intervention plans that are conducted in the future (Soldi et al., 2015). The epanet program can assist in analyzing and identifying the distribution pipeline network's performance and assist in the network expansion process (Muranho et al., 2014). Modelling with epanet can help solve pipeline problems, optimize valid policies in network development plans, and expand service coverage (Morley & Tricarico, 2014).

This study analyses the clean water distribution pipeline network in the West Semarang DWSS area, Semarang City using the EPANET program and contains several recommendations for service improvement. This research aims to analyze the amount of production discharge with service needs, analyze the installed distribution pipe network system, and analyze and evaluate the condition of the hydraulic system in the distribution pipeline network for the next ten years projection. The benefits that can be provided from this research are: for the Semarang City government: as a basis for the Semarang City Government to invest in and evaluate the performance of the Semarang City Water Supply Corporation. For Municipal Waterworks in Semarang City: as one of the references for the Semarang City Water Corporation in calculating hydraulics, planning for the rehabilitation of the pipeline network as well as in making the district meter area (DMA) and district meter zone (DMZ) to calculate and analyze the level of water loss. For the public and readers: as general knowledge for the

public regarding the flow conditions in the service area of the West Semarang Branch of Municipal Waterworks Semarang City. For further research: as data and initial research conditions to be used by researchers next.

2. Methodology

The research method used is the method of field research and literature, with the following steps: Preliminary Study and Literature; preliminary studies and literature aim to find data in the form of scientific writings, dictates, books, and from the internet that are used to analyze the hydraulics of transmission and distribution pipelines using epanet modelling. Field Overview, conducting a direct observation study of the service area of the West Semarang Branch of Municipal Waterworks Semarang City. The scope of research, the problem discussed in this research is to analyze the hydraulic behavior of the drinking water distribution pipe network in the service area of the West Semarang Branch using the epanet program and the needs method based on the area the Hazen - Williams equation. Data collection: Two kinds of data are obtained, namely primary and secondary data. Data processing, Primary data: water debit for the West Semarang area, diameter and length of installed pipelines, number of customers in the West Semarang area, average usage of clean water by customers, the average increase in the number of customers each year, existing service conditions (Perumda Tirta Model Kota Semarang, 2022), the topography of service area, water pressure in distribution pipelines. Secondary data: population growth rate in the West Semarang DWSS area (BPS Kota Semarang, 2022).

After the necessary data has been collected, it can be analyzed using the epanet program. An example displays in hydraulics analysis using the epanet program can be seen in table 1. and figure 2.

Table 1. Example of an epanet modeling result

Node	Elevation(m)	Demand(lps)
1	700	0
2	700	0
3	710	150
4	700	150
5	650	200
6	700	150
7	700	0
8	830	0

Source : (Rossman, 2000)

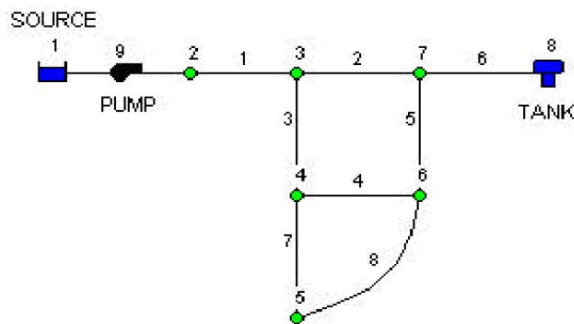


Figure 2. Example of hydraulic simulation with epanet program

Model validation, existing condition pressure data is compared with hydraulic modeling using epanet.

3. Result and Discussion

3.1. Existing hydraulic analysis in the West Semarang DWSS service area

Based on Table 2. the low pressure value at the junction is caused by several factors, namely the energy loss or head loss caused by the pipe wall and the effect of a high flow rate being inversely proportional to pressure (Surya Dharma et al., 2012). The flow rate of the distribution pipes that flows through the area is 2.97 m/s.

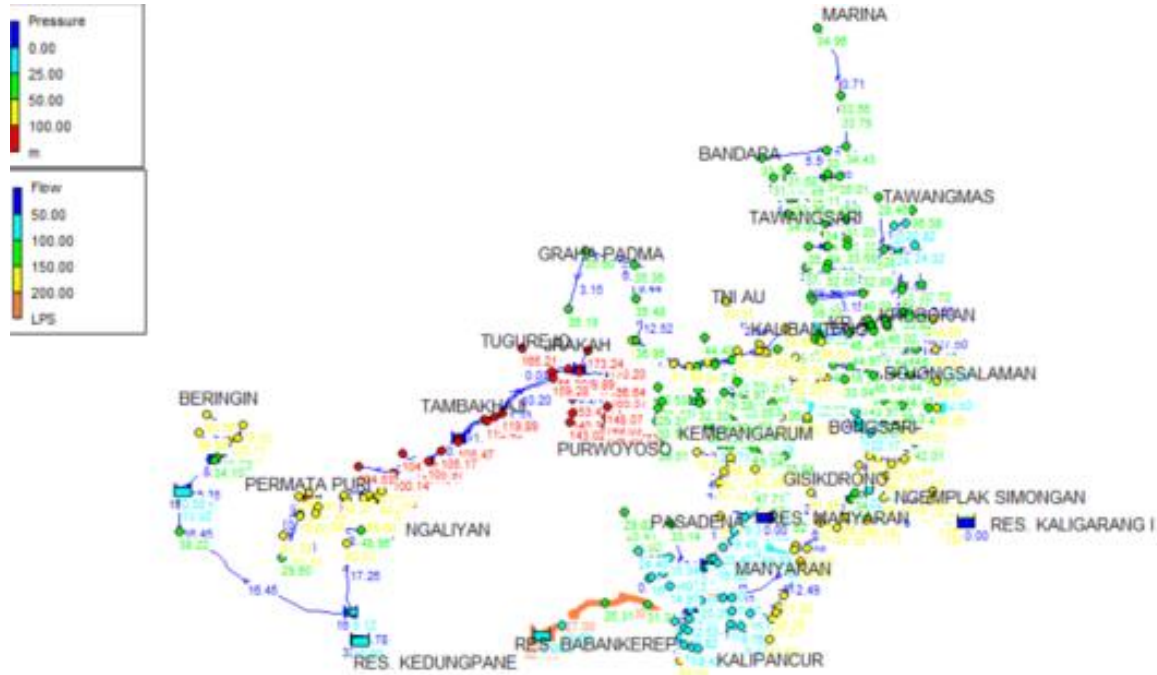


Figure 3. Simulation results with the epanet program

Table 2. Hydraulic analysis of Ngemplak Simongan, Bongsari and Salaman Mloyo areas

Node	Pressure (m)	Elevation (m)	Area
J27	-7.47	15.92	Ngemplak Simongan
J28	-21.01	14.86	
J29	-37.93	17.51	
J337	-0.05	21.32	
J338	-40.68	46.54	
J340	-64.03	57.61	
J341	-64.56	58.14	
J370	-26.49	16.88	
J371	-24.86	14.33	
J372	-28.01	34.17	
J373	-32.5	38.49	Bongsari
J374	-46.79	40.44	
J375	-54.51	48.12	
J376	-62.27	55.86	
J30	-43.95	12.61	
J31	-53.20	17.15	
J32	-57.54	15.75	
J342	-48.84	17.38	
J343	-58.71	21.59	
J344	-89.32	51.85	

Node	Pressure (m)	Elevation (m)	Area
J377	-46.25	14.82	
J379	-50.53	12.30	
J380	-50.28	11.89	
J381	-50.28	11.95	
J382	-52.96	16.16	
J383	-85.65	48.20	
J391	-57.10	15.53	
J392	-76.61	24.61	
J393	-95.53	37.70	
J33	-73.45	30.95	Bojong Salaman
J420	-74.27	31.65	
J421	-76.06	33.40	
J422	-68.47	25.56	

Based on Table 3. the low-pressure value at the junction caused by energy loss or head loss caused by the pipe wall and the diameter of the existing pipe that cannot carry the discharge as needed to increase the pressure at the critical point of service, according to Bernoulli's law the diameter of the existing pipe must be increased in capacity (Sultan et al., 2020).

Table 3. Pasadena area hydraulic analysis

Node	Pressure (m)	Elevation (m)
J19	-4.57	76.06
J20	-0.03	64.89
J205	-9.63	63.85
J21	-3.79	61.65
J358	-12.81	65.50
J359	-15.69	67.49
J360	-4.00	61.53
J361	-5.67	66.41
J362	-5.89	64.95

Based on Table 4. the low pressure at the junction has the same problem as the area in Table 3. To increase the pressure at a critical point of service, the diameter of the existing pipe must be increased.

Table 4. Hydraulic analysis of the Kembang Arum area

Node	Pressure (m)	Elevation (m)
J143	-11.75	10.76
J416	-10.76	8.51
J417	-11.44	8.73
J418	-12.04	18.65
J419	-13.24	18.56

Based on table 5, high pressure is found at nodes J289, J11, J284, and J240. This pressure exceeds the maximum pressure in the main pipe, 60 m - 80 m. Therefore, it is necessary to reduce pressure in the pipeline network, such as a pressure relief tank BPT (Break Pressure Tank) and PRV (Pressure Regulating Valve), to keep the network safe and not exceed the maximum threshold (PUPR, 2016).

Table 5. Hydraulic analysis of Kedungpane-Jrakah area

Node	Pressure (m)	Elevation (m)
J230	45.33	133.59
J232	71.47	105
J289	87.22	86.27
11	105	71.1
J284	92.82	22.49
J240	153.05	22.49

3.2. Calculation of Supply and Demand in The West Semarang Drinking Water Supply System Area

The results obtained from the internal Perumda drinking water in Tirta Moedal Semarang City, both from the input supply and customer usage data each month, are obtained as shown in table 6.

Table 6. West Semarang Water Supply System (WPS) supply and demand

Source	Q source (l/s)	House Connection	Average usage (m ³ /month)	Q average house connection (l/s)	Q demand (l/s)	Idle Capacity (l/s)	NRW (%)
Cangkiran	40	4,707	16.8	0.0065	30.60	9.40	23.51
Baban Kerep	327	14,085	22.7	0.0087	122.54	204.46	62.53
Kaligarang	180	14,440	24.9	0.0096	138.62	41.38	22.99

Source : (Perumda Tirta Moedal Kota Semarang, 2022)

From table 6. above can be seen that the supply of Kaligarang has the lowest water loss rate of 22.99% or 41.38 liters per second, while the highest level of water loss is in the supply system from Baban Kerep at 62.53% or 204.46 liters per second. For sources from the Cup system, the water loss rate is below Baban Kerep but still above the supply from Kaligarang, which is 23.51% or 9.40 liters per second. From the three sources above, the average level of water loss is still high, above 20% (PUPR, 2016). It is necessary to reduce water loss that supply continuity, service coverage, and cost efficiency increase.

3.3. Recommendations based on hydraulic analysis using epanet modelling to improve services in the West Semarang drinking water supply system (DWSS) service area

1. PRV (Pressure Regulating Valve) Installation

The installation of a pressure regulating valve (PRV) serves to regulate the function of water pressure in the pipe from a high-pressure source to produce a pressure that is to the needs of the service. The pressure regulating valve (PRV) placement must be correct so that the water pressure in the pipe is as expected. With the help of the epanet program, we can calculate how much pressure we have to lower and which position is the best to install the pressure regulating valve. The pressure regulating valve was chosen because of its easy operation and space efficiency. For the Beringin Housing area, one pressure regulating valve is installed and adjusted from input pressure of 47 m to output of 2 m; the service area decreases, which has an elevation difference of 61.6 m. The leading distribution pipeline network on the Kedungpane – Jrakah line needs to install three pressure regulating valves at three points. The source is at a higher elevation point than the furthest service. The elevation difference between the source and the service area reaches 192.22 m. This results installed distribution pipe being prone to leakage. Information from internal municipal waterworks in Semarang City that the installed pipe is more than 20 years old with PN 10 specifications for polyvinyl Chloride (PVC) (Perumda Tirta Moedal Kota Semarang, 2022). The first pressure regulating valve lowers the pressure from 53.28 m to 30 m. The second pressure regulating valve is installed to reduce the pressure from 84.36 m to 5 m. At the same time, the third

pressure regulating valve is installed to lower the pressure from 62.25 m to 25 m. By installing three pressure regulating valves, the pressure of the furthest point to be relatively safe is 38 m. This pressure is much lower than the maximum threshold determined by the copyright service, 60 m - 80 m (PUPR, 2016). For installing a pressure regulating valve in Permata Puri Housing, it is enough to install one unit that functions to lower the pressure from 80.21 m to 20 m so that the furthest service has remaining pressure of 12 m to 20 m.

Table 7. PRV installation location

No	Coordinate (UTM)	Area	Ø (mm)
1	X : 425195 Y : 9226578	Beringin Housing Area	150
2	X : 426994 Y : 9225655 X : 426994 Y : 9225655 X : 429349 Y : 9227647	Jl. Prof Hamka	200
3	X : 426473 Y : 9226087	Permata Puri Housing Area	100

2. Rehabilitation of pipelines

The location of the first pipe rehabilitation is on Jalan Simongan Raya. This rehabilitation is recommended because the old pipe network with a diameter of 150 mm high-density polyethylene (HDPE) is not able to carry a discharge of 48.72 liters per second according to the required discharge at peak hours of service, namely from 05.00 to 07.00 am and hours 5.00 to 7.00 pm. The inability of this distribution pipeline network to carry the required discharge resulted in negative pressure in the Simongan area and its surroundings that need to be rehabilitated with a 200 mm HDPE diameter distribution pipe with a length of 1772 m so that the service in the Simongan area continues to serve 24 hours. The speed of the water flow in the Simongan lane changed from 2.97 m/s to 1.9 m/s. There are three locations for rehabilitation in the Pasadena Housing area, namely on Jalan Prambanan Raya as the central input system for the Pasadena Housing from the existing distribution pipe network with a diameter of 150 mm PVC to a diameter of 200 mm HDPE along 550 m. of 26.55 liters per second. After the distribution pipe network was enlarged to a diameter of 200 mm, there was a significant change in the flow velocity from 1.7 m/s to 1.03 m/s. Rehabilitation of the distribution pipe network on Jalan Candi Tembaga from a pipe with a diameter of 75 mm PVC to a new pipe with a diameter of 150 mm HDPE along 442 m, the existing pipe is not able to carry a discharge of 8.22 liters per second with a flow rate of 1.58 m/s. After this network rehabilitated to diameter of 150 mm, the flow velocity changes to 0.5 m/s. Rehabilitation on Jalan Candi Mutiara from a distribution pipe network with a diameter of 100 mm PVC to 150 mm HDPE length of 126 m, the existing condition of the old pipe network is not able to carry a discharge of 9.36 liters per second after the pipe network was rehabilitated there was a change in the flow rate from 1.21 m/s to 0.57 m/s. The location for the last rehabilitation of distribution pipelines is on Jalan Taman Wologito. The existing distribution pipeline network with a diameter of 100 mm PVC is not able to carry the required discharge of 10.98 liters per second; with the rehabilitation of a new pipeline network with a diameter of 150 mm HDPE along 530 m, the discharge will be needs can be adequately accommodated, the flow velocity also changes from 1.41 m/s to 0.45 m/s.

Table 8. Pipeline rehabilitation locations

No	Location	Ex pipe(mm)	Type	PN	New pipe(mm)	Length (m)	Type	PN
1	Jl.Simongan Raya	150	HDPE	10	200	1772	HDPE	12.5
2	Jl. Prambanan Raya	150	PVC	10	200	550	HDPE	10
3	Jl. Candi Tembaga	75	PVC	10	150	442	HDPE	10
4	Jl. Candi Mutiara	100	PVC	10	150	126	HDPE	10
5	Jl. Taman Wologito	100	PVC	10	150	530	HDPE	10

3. Planning of pipelines in the West Semarang DWSS area must pay attention to the rate of population growth and the need for clean water.
4. It is necessary to install a district meter area (DMA) and a district meter zone (DMZ) to facilitate monitoring supply and customer discharge needs. The Baban Kerep Supply Area has a high level of water loss (NRW), this requires special attention so that service continuity can be maintained.
5. Pressure management must be applied in the implementation of flow distribution. Pressure management is the most basic thing in the strategy to reduce the rate of water loss (NRW), because the level of pressure affects the level of water loss.
6. Pay attention to demand patterns or fluctuations in customer usage, both peak hours and service saturation hours, so that the supply discharge and installed pipelines are in accordance with service needs.
7. Pay attention to technical specifications in determining the type and pressure that the design pipe can withstand.

4. Conclusions

First, the pressure in the distribution pipeline network will decrease along with the increase in flow velocity in the distribution pipeline network. To increase the water pressure in the pipeline, it is necessary to increase the capacity or rehabilitate the carrier pipeline network, such as in the Ngemplak Simongan, Bongsari, Salaman Mloyo, Pasadena and Kembang Arum areas. Meanwhile, the Kedungpane - Jrasah area has a relatively high pressure caused by a significant elevation difference between the source point and the service area. That is by Bernoulli's law for steady flow in the pipe. Second, a device such as a pressure regulating valve (PRV) is needed to regulate the pressure in the pipe to match the required pressure. High pressure will affect the level of water loss, affecting supply and demand in the service area. Third, the level of water loss is relatively high, above 20% in the supply service area of Baban Kerep at 62.53%, Cangkiran at 23.51 and Kaligarang at 22.99%.

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