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EVALUATION OF THE PDAM TIRTA AGUNG PIPE NETWORK AT TUK NGASINAN SUBSYSTEM

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ABSTRACT
Simulation results using the EPANET 2.0 program show that the average demand flow in 2023 is 30.47 liters/second; by 2038, it will increase to 49.44 liters/second. Meanwhile, the existing flow is only 25 liters/second, indicating an urgent need for additional flow in Tuk Ngasinan. The hydraulic conditions within the Tuk Ngasinan network system reveal many areas that do not meet the established criteria. This study has not yet explored the impact of climate change, which could affect variability and water source availability. Furthermore, there has been no exploration of new technologies that could enhance the efficiency of water distribution. Lastly, there is a lack of analysis regarding community engagement strategies that could influence the effectiveness and adoption of PDAM services. This research highlights the need to integrate cutting-edge technology approaches and enhance community involvement to achieve more efficient and sustainable water distribution. This approach is essential to anticipate future needs and ensure the sustainability of water resources amidst increasing environmental challenges.

Keywords: *Hydraulic Simulation; EPANET 2.0, Water Distribution Efficiency, Sustainable Water Supply.*

1. Introduction

The need for clean water is a basic necessity for humans. The clean water network system was created for meet the population's clean water needs in a city or a community. Water sources raw materials can come from springs, lakes, rivers, or deep groundwater [6]. The Drinking Water Perumda Tirta Agung in Temanggung Regency is one of the company’s managing the provision of drinking water. The Pringsurat service unit is one of the service areas in the Drinking Water Perumda Tirta Agung. In the Pringsurat service unit, three water sources are used to provide clean water: Tuk Bening, Tuk Ngrancah, and Tuk Ngasinan. One of the main water supply sources for the Pringsurat Unit is the pumping system from Tuk Ngasinan, located in Rejosari Village, Pringsurat Subdistrict. However, in the Tuk Ngasinan network system service, there are still some areas where water pressure and flow are uneven, even flowing only for a few hours a day. Various factors can cause this. This is partly due to the limited capacity of water sources and the capacity of water treatment plants, the lack of op--s, limited sources of PDAM funds, and the existence of alternative water sources that cause a lack of community interest in subscribing to PDAM water [7]. With the problems occurring in the system, an evaluation of the distribution pipe network of the Tuk Ngasinan system for the next 15 years is needed. This evaluation aims to determine the clean water flow rate in the Tuk Ngasinan service area for the next 15 years, analyze the existing hydraulic conditions, and identify the problems in the network.

Access to clean water is a basic human need. Clean water network systems are designed to meet the clean water needs of populations in cities or communities. The current assessment fails to consider the impact of climate change on water resource management and the lack of a comprehensive community engagement strategy that could enhance the effectiveness of water

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distribution. Limitations in water source capacity and water treatment facilities, as well as the lack of an optimal transmission network, also affect the distribution of clean water in Tuk Ngasinan.

2. Material and Method

2.1. Location Analysis and Planning

The planning activities cover the villages of Pringsurat, Kebumen, Kupen, Pringsurat Subdistrict, and Nguwet Village, Kranggan Subdistrict, Temanggung Regency, Central Java Province.

Figure 1. Map of Village Locations for Analysis and Planning

2.2. Planning Stages

a. Search for literature studies
b. Literature review
c. Collection and inventory of secondary data
d. Primary data collection (direct field measurements)
e. Studying the research area map by observing settlement locations, road routes, and topography
f. Population projection calculations
g. Water Needs Calculation
    1) Daily Water needs Per Person
        - Knowing the billed account data from the PDAM (Water Supply Company) data
        - Calculating water needs per household connection by dividing the water usage on the billed account data by the number of days in a month divided by the number of household connections
        - Calculating water needs per person per day by dividing the water needs per household connection by the number of people in one household connection
        - Alternative water needs can refer to existing criteria.
    2) Domestic Needs
        - Calculating the number of people served by multiplying the population of the area by the service coverage
        - Calculating the number of household connections served by multiplying the number of people served by 1 household connection divided by the assumption of the number of people in 1 household connection
        - Calculating the water needs for household connections by multiplying the number of household connections by the water consumption per person per day multiplied by the number of people in 1 household connection
        - Calculating domestic water needs
    3) Non – Domestic Needs
        - Knowing non-domestic water consumption data from the billed account data
        - Calculating non-domestic water needs by multiplying non-domestic water consumption by the number of facilities multiplied by the number of facility users.

Vol. 5, No. 1, pp. 34-47, 2024
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4) Total Water Need
   Total water needs are calculated based on the projected number of water users for the next 10 years and the average water needs per user after adding 20% as a water loss factor. This total requirement determines if the selected water source can be used. If the water demand is greater than the source's flow rate, alternative additional raw water sources need to be explored.
5) Processing the obtained data using Quantum GIS software and other software tools
   a) Inputting tracking results and existing pipe network systems
      - Determining the starting point of water extraction (initial node)
      - Creating existing pipe routes and optimization plans
   b) Measuring water usage fluctuations over 24 hours. Water usage fluctuations are measured on existing transmission pipes. These fluctuations are used to determine peak hour requirements and factors and to understand the flow rate during the 24 hours in the existing area.
   c) Calculating Base Demand for Each Node/Junction Calculate the load for each node by examining the average water usage data in the last 3 months from the Customer Meter Stand Data (DSML) or Billed Account Data (DRD) in each block or existing service area.
   d) Measuring Residual Pressure at Several Points in the Existing Distribution Network Measure residual pressure by taking samples at several points representing the existing pipe network comprehensively. This data is used to determine the actual residual pressure in the field, which will be used as a comparison with the results of EPANET 2.0 hydraulic simulations.
   e) Inputting Data into EPANET 2.0 Software Data obtained [12], such as elevation at each node, pipe length, existing pipe diameter, pipe roughness coefficient, loss coefficients for each pipe segment (minor losses & major losses), base demand, and demand patterns, are inputted into EPANET 2.0 for simulation.
   f) Performing Analysis by Simulating it in the EPANET 2.0 Software Analyze the existing network conditions and network optimization by simulating the data in the EPANET 2.0 software.
   g) Reviewing to Draw Conclusions from the Conducted Simulations.

3. Result and Discussion

3.1. Planning Data

3.1.1 Population Data

The following is the population data for the evaluated region.

Table 1. Population of the Evaluated Area

No.	Village / Sub District	District	People
1	Kupen	Pringsurat	5.469
2	Kebumen	Pringsurat	4.180
3	Pringsurat	Pringsurat	2.594
4	Nguwet	Kranggan	3.042
		Total	15.285

Source: BPS, 2022

3.1.2 Topography and Ground Elevation

The following is the topography and ground elevation.

JICE Journal Innovation of Civil Engineering

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

Figure 2. Topography of the Existing Network

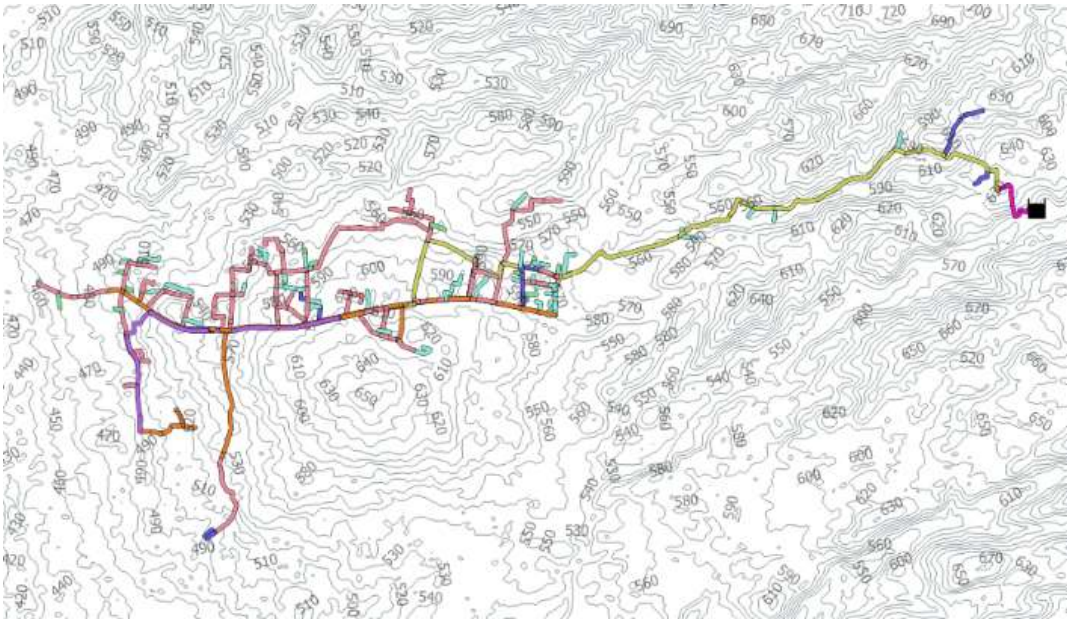

Figure 3. Contour Map of the Existing Network.

3.2.3 Data Rekening Ditagih (DRD) / Billing Account Data

Data rekening ditagih or Billed Account Data (DRD) is obtained from the Customer Service section of the Tirta Agung Drinking Water Perumda for the last 3 months (September, October, November). The following is the DRD report data:

JICE Journal Innovation of Civil Engineering

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
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Table 2. Billed Account Data (DRD) for the Pringsurat Unit

No.	Service	Number of Customers	Water Usage (M^3/month)	Average Water Usage (M^3/month)	Average Water Usage (L/People/Day)
	SEPTEMBER				
	Domestic				
1	Non Commerce A	16	1,146.00	71.63	596.88
2	Non Commerce B	5,328	101,034.00	18.96	158.02
3	Non Commerce C	222	6,423.00	28.93	241.10
4	Non Commerce A (Ip)	32	2,126.00	66.44	553.65
5	Non Commerce B (Ip)	20	1,109.00	55.45	462.08
		5,618	**111,838**	**48.28**	**402.35**
	Non Domestic				
1	Common				
2	Exclusive	136	6,996.00	51.44	428.68
3	Small Commerce	320	9,114.00	28.48	237.34
4	Medium Commerce	43	2,471.00	57.47	478.88
5	Large Commerce	46	10,470.00	227.61	1,896.74
		545	**29,051**	**91.25**	**760.41**
	OCTOBER				
	Domestic				
1	Non Commerce A	16	795.00	49.69	414.06
2	Non Commerce B	5,324	101,732.00	19.11	159.23
3	Non Commerce C	223	6,458.00	28.96	241.33
4	Non Commerce A (Ip)	32	2,066.00	64.56	538.02
5	Non Commerce B (Ip)	19	531.00	27.95	232.89
		5,614	**111,582**	**38.05**	**317.11**
	Non Domestic				
1	Common				
2	Exclusive	135	6,310.00	46.74	389.51
3	Small Commerce	323	9,583.00	29.67	247.24
4	Medium Commerce	42	2,050.00	48.81	406.75
5	Large Commerce	46	12,647.00	274.93	2,291.12
		546	**30,59**	**100.04**	**833.65**
	NOVEMBER				
	Domestic				
1	Non Commerce A	16	985.00	61.56	513.02
2	Non Commerce B	5,364	103,783.00	19.35	161.23
3	Non Commerce C	225	6,763.00	30.06	250.48
4	Non Commerce A (Ip)	32	2,167.00	67.72	564.32
5	Non Commerce B (Ip)	20	509.00	25.45	212.08
		5,657	**114,207**	**40.83**	**340.23**
	Non Domestic				

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
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Publish: 27-06-2024 |

No.	Service	Number of Customers	Water Usage (M^3/month)	Average Water Usage (M^3/month)	Average Water Usage (L/People/Day)
1	Common				
2	Exclusive	138	6,434.00	46.62	388.53
3	Small Commerce	324	10,106.00	31.19	259.93
4	Medium Commerce	42	2,276.00	54.19	451.59
5	Large Commerce	47	12,547.00	266.96	2,224.65
		551	**31,363**	**99.74**	**831.17**

In Table 2, the Billed Account Data (DRD) for the Pringsurat Unit shows that domestic and non-domestic water consumption exhibits significant fluctuations that affect water distribution. This analysis highlights the importance of integrating new technologies for more accurate management and prediction of water needs. Advanced technologies can help minimize water losses and ensure more effective distribution.

a. Planning Result

Here is the topography and ground elevation.

1) Population Data Analysis (Population Projection)

Population data analysis is calculated using the geometric method. Below is an example calculation using the geometric method.

Table 3. Geometric Correlation Coefficients

Year	Total Population	X	Ln Y	XY	X^2	Y^2
2017	769.843	2	13,5539	27,1079	4	183,7093
2018	765.594	3	13,5484	40,6452	9	183,5593
2019	791.264	4	13,5814	54,3255	16	184,4541
2020	790.174	5	13,5800	67,9000	25	184,4166
2021	794.403	6	13,5853	81,5121	36	184,5616
2022	799.764	7	13,5921	95,1445	49	184,7444
Total	**4.711.042**	**27**	**81,4412**	**366,6353**	**139**	**1.105,4454**
Correlation (r)						**0,8977**

Here is an example calculation of the population growth for Kupen Village, Pringsurat Subdistrict, until the year 2038:

P0 = 5,230 (Year 2022)
N = 16 (Projection for year n)
r = 1.11% (Average population growth rate of Pringsurat Subdistrict from BPS)
The calculation for the projected population for the year 2038 is as follows:
Pn = P0 (1+r)^n
= 5,230 (1 + 1.11%)^16
= 6,240 people

Below is the presentation of population projection data for the village until the year 2038:

Table 4. Population Growth Projection using The Geometric Method

JICE Journal Innovation of Civil Engineering

Vol. 5, No. 1, pp. 34-47, 2024
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No.	Village	Data	Population Projection (People)				
		2022	2023	2024	2028	2033	2038
1	Kupen	5,469	5,530	5,591	5,843	6,175	6,525
2	Kebumen	4,180	4,226	4,273	4,466	4,720	4,987
3	Pringsurat	2,594	2,623	2,652	2,772	2,929	3,095
4	Nguwet	3,042	3,076	3,110	3,250	3,435	3,630
	Total	**15,285**	**15,455**	**15,626**	**16,332**	**17,258**	**18,238**

2) Water Needs Analysis
   - Number of people per household connection: taken as 4 people per HC according to field conditions
   - Water needs for 1 person per day: taken as 170 Liter/day according to [2] in 2000 for Temanggung City
   - The percentage of customers in each village per year is calculated from theBilled Account Data (DRD) from 2015 to 2023 as follows:
     - Pringsurat Village = 4.5% per year
     - Kebumen Village = 3.5% per year
     - Kupen Village = 5% per year
     - Nguwet Village = 8% per year

   Below is the recapitulation of the calculation of clean water needs until the year 2038:

Table 5. Calculation of Water Needs for The Year 2038

No.	Village	Description	Unit	Projection Year			
				2023	2028	2033	2038
1	Kupen	Q average (Qr)	L/det	12.57	15.87	16.77	17.72
		Q H max	L/det	13.82	17.45	18.44	19.49
		Q peak	L/det	18.85	23.80	25.15	26.58
2	Kebumen	Q average (Qr)	L/det	8.19	10.78	12.82	13.54
		Q H max	L/det	9.01	11.85	14.10	14.90
		Q peak	L/det	12.28	16.16	19.22	20.31
3	Pringsurat	Q average (Qr)	L/det	2.25	4.07	6.09	8.33
		Q H max	L/det	2.47	4.48	6.70	9.16
		Q peak	L/det	3.37	6.10	9.13	12.49
4	Nguwet	Q average (Qr)	L/det	7.46	8.83	9.33	9.86
		Q H max	L/det	8.21	9.71	10.26	10.84
		Q peak	L/det	11.19	13.24	13.99	14.78
TOTAL		**Q average (Qr)**	**L/det**	**30.47**	**39.54**	**45.00**	**49.44**
		Q H max	**L/det**	**33.51**	**43.49**	**49.50**	**54.39**
		Q peak	**L/det**	**45.70**	**59.31**	**67.50**	**74.16**

Based on the calculation, the average clean water demand in 2038 is 49.44 Liter/sec. The available flow rate is 25 Liter/sec, and the peak-hour demand is 74.16 Liter/sec. Therefore, the needs

JICE Journal Innovation of Civil Engineering

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

for the four villages are not met for the next 15 years because the available flow rate from the source is less than the customer flow rate demand. The additional flow rate required to meet the demand in 2038 is 24.44 Liter/sec.

1) Fluctuation of water usage in the planning research area
This study conducted Ultrasonic Flow Meter measurements in the Barcoh area, Rejosari Village, Pringsurat Subdistrict. The installation took place for 24 hours, starting from 18:00 on September 21, 2023, until 18:00 on September 22, 2021. Measurements were only taken at one point on the transmission pipe after the pump.
Below is the table and graph showing the fluctuation of water usage from the Tuk Ngasinan source.

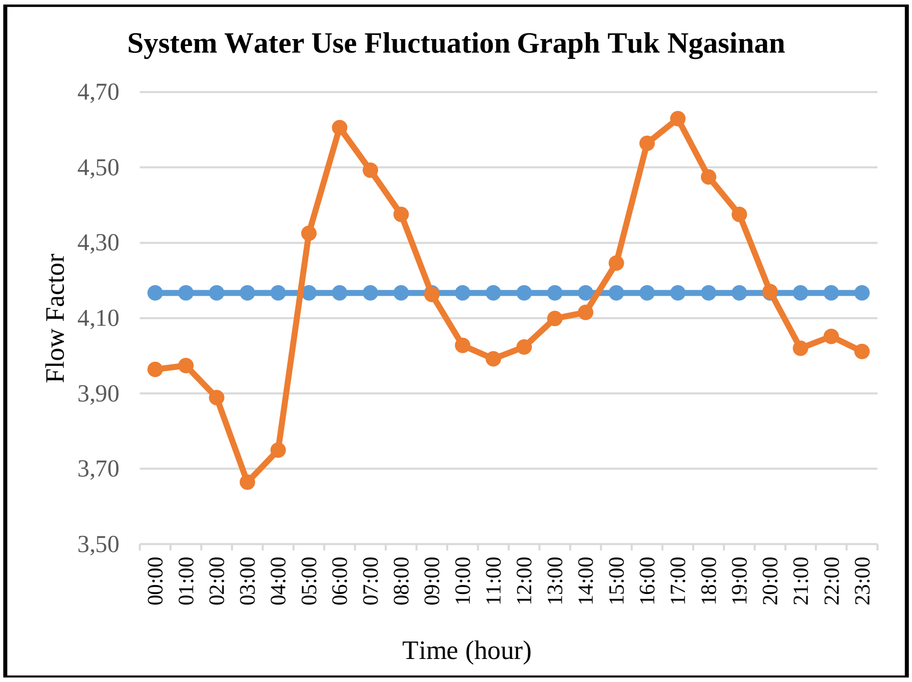

Figure 4. Graph of Water Usage Fluctuation in the Tuk Ngasinan System

Table 6. Fluctuation of Water Usage in Tuk Ngasinan

No.	Time	Usage				Factor Usage
		Debit (L/sec)	Debit (M^3/hour)	Average Debit (L/sec)	% Usage	
1	0:00	19.96	71.86	20.98	3.96	0.95
2	1:00	20.01	72.04	20.98	3.97	0.95
3	2:00	19.58	70.49	20.98	3.89	0.93
4	3:00	18.45	66.42	20.98	3.66	0.88
5	4:00	18.88	67.97	20.98	3.75	0.90
6	5:00	21.78	78.41	20.98	4.33	1.04
7	6:00	23.19	83.48	20.98	4.61	1.11
8	7:00	22.62	81.43	20.98	4.49	1.08
9	8:00	22.03	79.31	20.98	4.38	1.05
10	9:00	20.96	75.46	20.98	4.16	1.00

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

No.	Time	Usage				Factor Usage
		Debit (L/sec)	Debit (M^3/hour)	Average Debit (L/sec)	% Usage	
11	10:00	20.28	73.01	20.98	4.03	0.97
12	11:00	20.10	72.36	20.98	3.99	0.96
13	12:00	20.26	72.93	20.98	4.02	0.97
14	13:00	20.64	74.30	20.98	4.10	0.98
15	14:00	20.72	74.59	20.98	4.11	0.99
16	15:00	21.38	76.97	20.98	4.25	1.02
17	16:00	22.98	82.73	20.98	4.56	1.10
18	17:00	23.31	83.92	20.98	4.63	1.11
19	18:00	22.53	81.11	20.98	4.47	1.07
20	19:00	22.03	79.31	20.98	4.38	1.05
21	20:00	21.00	75.60	20.98	4.17	1.00
22	21:00	20.24	72.86	20.98	4.02	0.96
23	22:00	20.40	73.44	20.98	4.05	0.97
24	23:00	20.20	72.72	20.98	4.01	0.96
Total		503.53	1812.70	503.53	100.00	24.00
Q average		20.98	75.53			

2) Division of Servis Block Maps
The division of service block maps is only used to facilitate explanations and references to specific locations for analysis. This block division is based on areas that have interconnected networks and have almost the same flow conditions. The following is an image of the division of service block maps.

Figure 5. Division of Service Block Maps

b. Analysis and Discussion of the Existing Condition of the Tuk Ngasinan System with EPANET 2.0
Simulation In the analysis of the existing condition with this EPANET Simulation, the regulations of the [2] are used:

JICE Journal Innovation of Civil Engineering
Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

- Velocity = (0.3 – 3) m/second
- Residual pressure = (10-80) m
- Maximum unit headloss = 10 m/km

1) Residual Pressure Simulation result with the EPANET 2.0 program
   In the image below, you can see the results of pressure measurement using the EPANET 2.0 simulation by entering data obtained from secondary and primary data. Here are the residual pressure results during peak usage (at 06:00) with the EPANET 2.0 program:

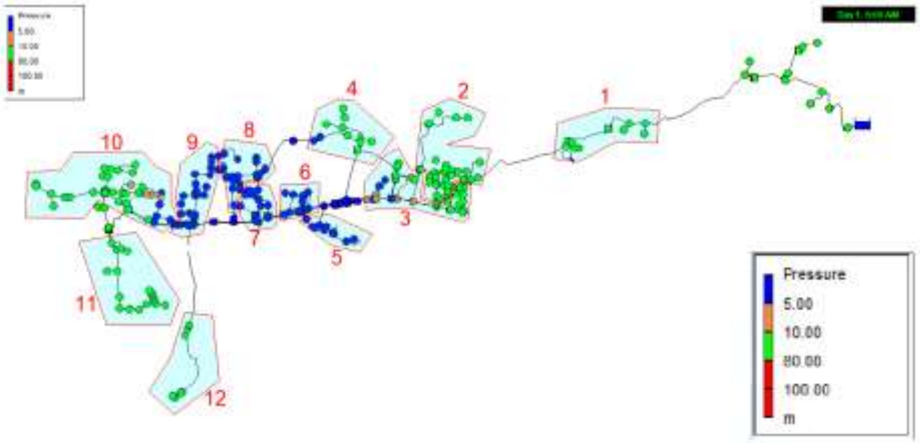

Figure 6. Residual pressure simulation results using the EPANET program during peak usage

And here are the residual pressure results during minimal usage (at 03:00) with the EPANET 2.0 program:

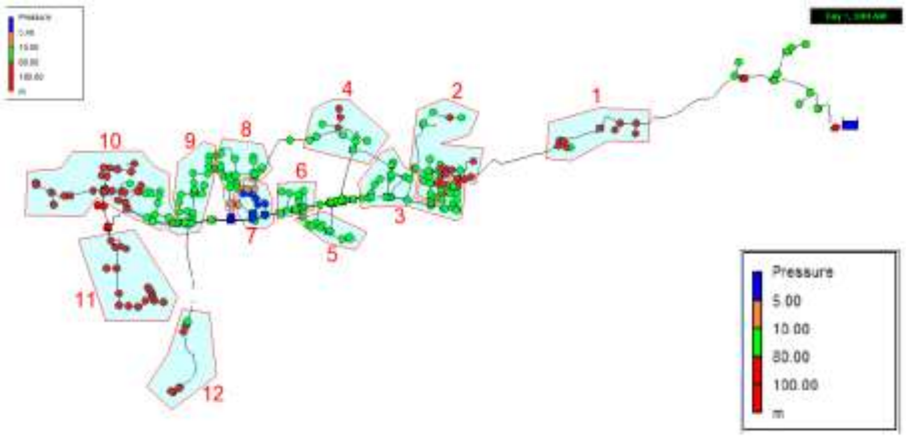

Figure 7. Residual pressure simulation results using the EPANET program during minimal usage

From the results of the EPANET 2.0 simulation, it can be seen that during peak usage, many areas have pressures below 10m, especially in blocks 5, 6, 7, 8, and 9. Areas with pressures below 10m may result in insufficient water conditions or even no water flow at all. This is caused by mismatched pipe dimensions, insufficient water flow, and also because some blocks have elevations that are too high, such as blocks 5 and 6. To increase pressure, the solution is to increase the existing flow rate, optimize the pipe diameter efficiency, and for high areas, consider installing booster pumps or creating reservoirs.

Meanwhile, during minimal usage, many areas have residual pressures exceeding the maximum criteria (more than 80m), especially in blocks 1, 2, 10, 11, and 12. Flow conditions with residual pressures exceeding 80m can lead to pipe breakage and increased pipe leakage, resulting in high leakage values. Therefore, in those blocks, pressure needs

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

to be regulated, such as by using Pressure Reducing Valves (PRV) or optimizing pipe diameter.

2) Simulation result of water flow velocity in pipes using the EPANET 2.0
Here are the results of the simulation of flow velocity in the pipes using the EPANET program at peak hours (06:00)::

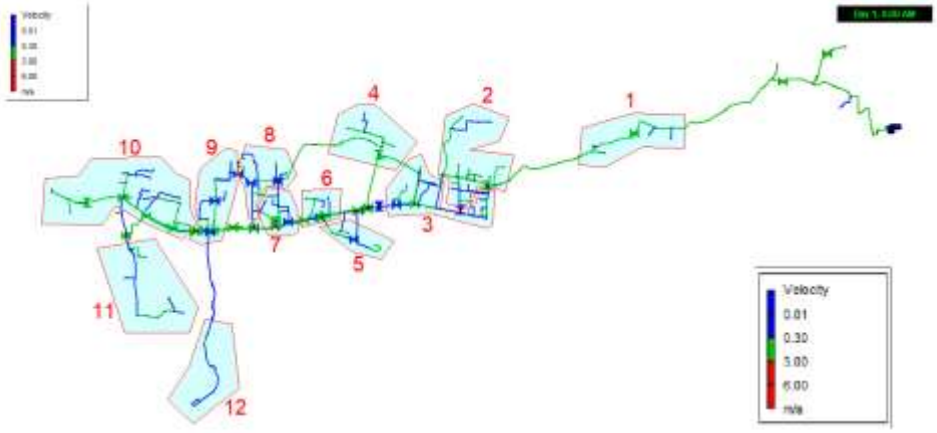

Figure 8. Water flow velocity in pipes during peak hours

From the simulation results, it can be seen that there are still many pipes with velocities below the minimum criteria of 0.3 m/s, and this condition is evenly distributed across all blocks. However, there are no simulation results that exceed the maximum speed criteria. Too low flow velocity can lead to sediment accumulation in pipes, causing various problems such as blockages and others. On the other hand, if the pipe velocity is too high, it can cause corrosion, leading to a reduction in the pipe's lifespan.

The low water velocity in some pipes is due to the small flow passing through the pipe and the pipe diameter being too large. This can be addressed by increasing the flow rate or by replacing the distribution pipes with smaller ones.

3) Simulation result of unit headloss in pipes using the EPANET program:

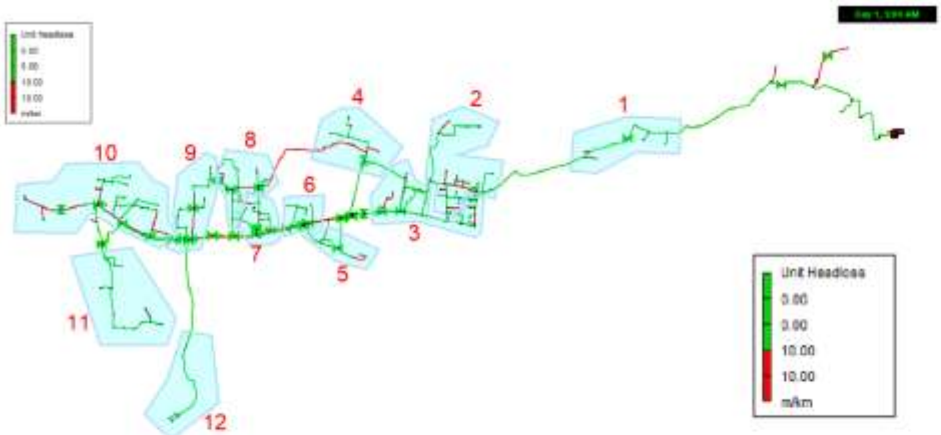

Figure 9. Unit Headloss Simulation Results

Head loss is the pressure drop in the fluid flowing inside the pipe. According to Ministerial Regulation No. 18/PRT/M/2007, the maximum value of unit headloss is 10m/km. In the EPANET simulation results, many pipes still have unit headloss above the criteria (more than 10m/km), marked by red lines on the pipes. This can happen due to factors such as the pipe diameter being too small, and increasing friction inside the pipe, resulting in a large amount of wasted energy. To overcome high headloss, one solution is

JICE Journal Innovation of Civil Engineering

Vol. 5, No. 1, pp. 34-47, 2024
Submit: 28-01-2024 |
Accepted: 26-05-2024 |
Publish: 27-06-2024 |

to increase the pipe size or to regulate the flow evenly using Flow Control Valves (FCV). Unit headloss is also influenced by the pipe's length; even if the headloss is small, if the pipe is too long, the headloss will also increase.

4) Tuk Ngasinan Network System Condition in 2038
Based on the water demand projection data in the previous subsection, network evaluation is projected from 2023 to 2038. The simulation presented aims to assess the Tuk Ngasinan distribution pipe system's capability to meet water demand until 2038.
The following depicts the existing conditions of the Tuk Ngasinan system during peak hours in 2038 using the EPANET simulation program:

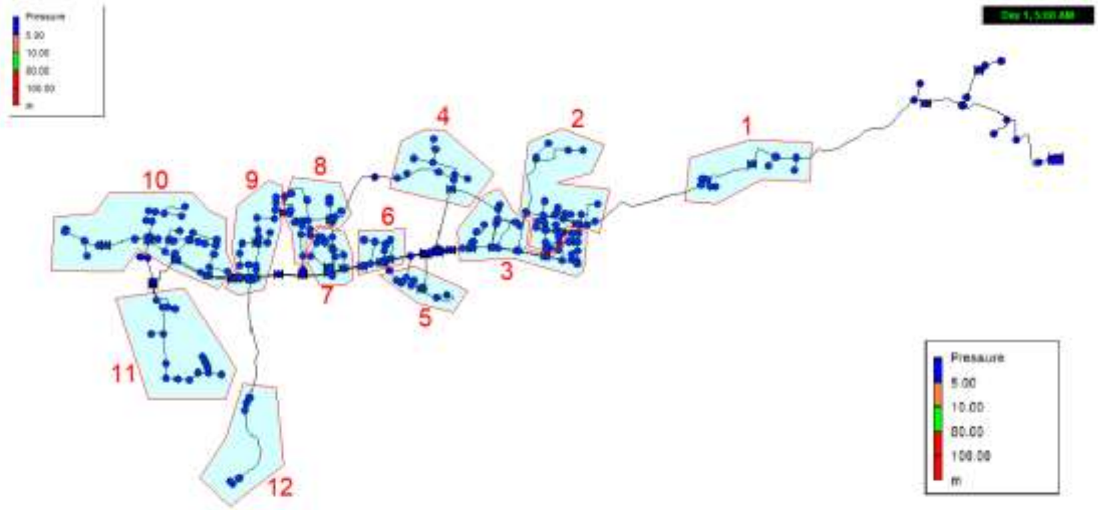

Figure 10. Existing Network Conditions of Tuk Ngasinan System in 2038

The simulation results above indicate that the existing network conditions of the Tuk Ngasinan system in 2038, across almost all blocks, show residual pressure below the specified pressure criteria, represented by blue-colored nodes. This is due to the daily average water demand in 2038 reaching 49.44 Liter/second, while the current available flow is only 25 Liter/second, resulting in a flow difference of 24.44 Liter/second. One way to address this issue is by increasing the flow. Therefore, to meet the water demand in 2038, Tirta Agung Water Company must provide a flow of at least 49.44 Liter/second.

4. Conclusion

The water demand projections highlight a significant shortfall in the available water supply. In 2023, the average daily demand was recorded at 30.47 liters/second, with the peak-hour demand reaching up to 45.70 liters/second. By 2038, these figures are expected to rise dramatically to an average daily demand of 49.44 liters/second and a peak-hour demand of 74.16 liters/second, while the existing flow remains at a mere 25 liters/second. This discrepancy points to a critical need for augmenting the water supply to at least 49.44 liters/second by 2038 to adequately meet the escalating demands. This situation underscores the necessity for advanced water management technologies that can enhance the efficiency of water distribution systems and help in accurately predicting future water needs.

The simulation results reveal that the hydraulic conditions within the Tuk Ngasinan network do not meet various performance criteria, including residual pressure, velocity, and unit headloss. Nearly all service blocks exhibited residual pressures below acceptable levels in 2038 forecasts, indicating widespread inefficiencies and potential service disruptions. These findings highlight the importance of integrating new technologies to improve the hydraulic performance of water distribution networks.

Vol. 5, No. 1, pp. 34-47, 2024
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The prevalent issues in the Tuk Ngasinan network, substandard residual pressure, inadequate flow velocity, and excessive unit headloss, especially during peak demand periods, suggest a systemic problem of outdated or improperly sized infrastructure. This not only leads to significant water losses but also jeopardizes the system's reliability and efficiency. The introduction of advanced technologies could provide crucial benefits such as real-time monitoring and automated adjustments to flow rates and pressures, thus minimizing energy loss and preventing infrastructure damage due to inconsistent pressure levels.

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