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Optimization of Water Networks at Graha Jangli Indah Semarang Using EPANET

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Abstract: After the pipe boreholes damage in Graha Jangli Indah Semarang in September 2017, the Graha Jangli Indah Water Management was replaced with 2 boreholes. It should be seen after replacing the wellbore whether the performance of the pipeline network at Graha Jangli Indah can meet the pressure requirements reaching each customer's home. The simulation using the EPANET program can be concluded that the performance of water assessment based on water pressure in Graha Jangli Indah has very good performance because EPANET results and observations in the field have results not much different where the average water pressure in the field is 8.17 meters while the results water pressure in simulation I is 8.32 meters. Water pressure which is at a value of 8.17 and 8.32 meters is above the minimum value Minister of Public Works Regulation No.18 / PRT / M / 2007 (Ministry of Public Works of the Republic of Indonesia, 2007) which requires water pressure of 0.5 atm / 5 meters at the furthest pressure point.

Keywords: epanet, performance, network

1. Introduction

1.1. Background

Graha Jangli Indah is a housing complex located in Jangli Kelurahan, Tembalang District, Semarang City. In August 2017 at Graha Jangli Estate there was a break in the wellbore pipe at the Sumur A Location according to Figure 1. The event of the breakdown of the bore well resulted in a break in the flow of clean water to 85 households in Graha Jangli Indah for one month. The well pipe at location A has broken because the land in Graha Jangli has a type of clay, so the soil will move when it enters the rainy season. It is worth noting that from 2010 to 2017 Graha Jangli Indah relies on fulfilling its clean water needs from its own artesian well because it does not receive clean water service from PDAM Tirta Moedal, Semarang City, which is 2.8 kilometers from the main route of PDAM Jalan Teuku Umar Jatingaleh, where the area there is a clean water network of PDAM Tirta Moedal. For well and reservoir conditions can be seen in Figure 2.

Figure 1

Figure 2

The drop in the artesian well resulted in negative and positive things towards the residents of Graha Jangli Indah.. Where the negative consequences are:
a. Residents has not received clean water for one month
b. Residents has to pay more monthly water fees to subscribe to tank water
c. Residents must save on the use of clean water for daily needs
d. Residents must evacuate to relatives or parents' homes to take a bath or wash clothes
While the positive consequences are:
a. Residents worked together both in energy and funds to make better artesian wells
b. The emergence of the desire of citizens to make the Water Management Graha Jangli Indah in charge of managing the management of clean water Graha Jangli Indah
c. Residents took the initiative to install water meters in each house and collect monthly water fee contributions according to water usage
d. Residents are trying to find the source of the second artesian well to overcome the rupture at the first artesian well by seeking assistance from the government through the Semarang City Water Service.

The artesian water network at Graha Jangli Indah still uses artesian well sources in Gang IV (Sumur A Location) with a depth of 75 meters and 4m3 water reservoirs. In Graha Jangli Indah there is no water meter in each of the residents' houses. Residents pay a fixed fee of Rp. 30,000.00 per month. Every day the water only flows from 05.00 - 08.00 and at 16.00 - 22.00. The pump system is still turned on manually by the RT administrator. With these conditions there are several problems, namely:

1. The use of water is not monitored because there is no water meter
2. If there is a water leak at the customer the source of the water cannot be known
3. Electricity expenses for uncontrolled pump costs
4. The capacity of the water reservoir is very less
5. If the water manager does not start the pump, the water reservoir will run out
6. Lots of water arrears due to the payment of water in the monthly RT social gathering, so that residents can be in arrears by not participating in the household arisan
7. Mossy water because it uses a white water reservoir
8. If there is damage, the response time and repair time is quite long because it is waiting for the RT administrator to make repairs.


Figure 3

Agreement with residents make a joint contribution for each house Rp. 1,000,000.00 to make new artesian wells. The new well has a depth of 85 meters using a new reservoir of $4m^3$, and has used an automatic pumping system. In addition, another new artesian well was made at An Nur Musholla in the main alley (Location Well B) with a depth of 75 meters and using a $4m^3$ water reservoir. The artesian well was aids from the Semarang Water Service.

A picture of well A that has been repaired can be seen in Figure 3 while well B can be seen in Figure 4. After that incident the RT Management agreed to make the Graha Jangli Indah Water Management to manage the water in Graha Jangli Indah. Graha Jangli Indah Graha Water Management is a community involvement in improving drinking water service services or often called Community Based Drinking Water Supply (PAMBM). Community Based Drinking Water Supply is a drinking water supply system that is initiated, selected, built and funded by the community and / or with the assistance of other parties, managed sustainably by the community based on the agreement of the relevant drinking water user group (PUSKIM, 2012).

Figure 4

1.2. Formulation of the Problem

Graha Jangli Indah Water Management which is one of the PAMBM, community organizations that aim to provide water in Graha Jangli Indah must adhere to the principles of the organization where indicators of success are:

a. The community can enjoy drinking water more easily and cheaper than the previous conditions with better quality, quantity and continuity;

b. The formation of community groups capable of carrying out the development of drinking water supply systems independently and sustainably.

From the above background there needs to be research whether after replacing the two wells the water needs at Graha Jangli Indah have been properly fulfilled

2. Literature Review

In simulating network pipe optimization at Graha Jangli Indah.using EPANET software. EPANET is a program created by Lewis A. Rossman. EPANET software is a hydraulic simulation software and water quality behavior in water distribution systems. Where the first version 1.1 came out in 1994, while the second version 2.0 came out in 2000 where version 2.0 has undergone many updates. In addition, in 1999 Lewis A. Rossman released the API Programmer Toolkit that allows each programmer to develop EPANET software according to their individual needs. So much software development from EPANET, some of the software is

1. Pipe 2000 by KYPipe, LLC
2. H20MAP Water, H2ONET, Infowater by Innovyze Inc
3. WATERCAD, WaterGEMS by Bentleys Haestad Methods
4. GISWater by the Giswater Association

EPANET software provides an integrated environment for editing data networks, hydraulic simulations, water quality simulations and viewing the results in various formats. The modeling system provides information such as flows in each pipe, pressure in each pipe connection, amount of water contamination, chlorine concentration, water age and various other scenarios

EPANET is a computer program that describes hydraulic simulations and trends in water quality flow in the pipeline. The network itself consists from Pipes, Nodes (pipe connection points), pumps, valves, and tanks water or reservoir. EPANET is exploring the flow of water in each pipe, water pressure conditions at each point and material concentration conditions chemical flow in the pipe during the period jetting. In addition, water age and source tracking can also be simulated. EPANET is designed as a tool to achieve andrealize understanding of movement and destiny drinking water content in the distribution network. Also got itused for various analyzes of various network applications distribution. For example for making designs, calibrations hydraulic model, chlorine residual analysis, and customer analysis. EPANET can help in managing strategies for realize the quality of water in a system. All of it covers :

- Alternative uses of sources in various sources in one system
- Alternative pumping in scheduling tank filling / emptying.
- The use of treatment, for example chlorination in the tank storage
- Targeting of pipe cleaning and replacement.

Running under Windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots. Complete facilities and accurate hydraulic modeling is one of the effective steps in making a model about drainage and water quality. EPANET is a tool aids hydraulic analysis contained therein capabilities such as:

- Unlimited analytical skills network placement
- Calculation of the roughness of the pipe using Hazen-Williams equation, Darcy Weisbach, or Chezy-Manning
- Also includes minor head losses for bends, fittings, etc.
- Modeling of a constant pump speed or variable
- Calculate the pump energy and cost
- Modeling for variations in the type of valve included shitoff, check, pressure regulating, and flow control valve
- Available storage tanks with various shapes(such as a diameter that varies with height)
- Allows the inclusion of needs categories (demand) doubles at a node, each with a pattern alone which depends on time variations.
- Pressure models that depend on expenditure flow from the emitter (Sprinkler head)
- Can be operated with a basic system on the tank simple or time control, and on time control more complex.

2.1 Physical Components

EPANET models a water distribution system as a collection a line connecting the nodes. The line describe the pipes, pumps and control valves. Node describe joints, tanks, and reservoirs. Picture on below illustrates how nodes and lines can be connected to one another to form a network.

Junction

A junction is a point on the network where lines meet and where water enters or leaves network. Basic input needed for connection (junction) is:

- Elevation on all references (usually face average sea water)
- Water needs
- Current water quality

Computational results for connections (junction) on all simulation time period is

- Hydraulic Head (internal energy per unit weight of fluid)
- Pressure
- Water Quality

A connection can also:

- Contains varied water requirements with respect to time
- Has a double water demand category
- Has a negative price requirement that indicates water enters the network
- Being a source of water quality where there is content entering the network
- Has a discharge hole (or sprinkler) that is make the flow rate depends on pressure.

Reservoir

A reservoir is a node that represents a source external flow continuously to the network. Used to describe like lakes, rivers, aquifers ground, and connections from other systems. Reservoirs are also used point of water quality source. The main input for the reservoir is the hydraulic head (comparable with elevation of the water surface if not a reservo irnpressurized) and water quality initials for water quality analysis. Because a reservoir is a limiting point intissue, pressure and water quality cannot be affected by what happens in the network. But the pressure can made to vary with the time marked by the pattern.

Tank

Tank needs a node with capacity data, where the volume of stored water can vary by time during emulation

- Base elevation (where water level is zero)
- Diameter (or shape if not cylindrical)
- Maximum and minimum water levels at the start.
- Initial water quality.

Outputs based on time are:

- Hydraulic Pressure (water level)
- Water quality

The tank requires maximum and minimum levels for operate. EPANET will stop the water that comes out if the tank has a drinking water lever, so does the tank has a maximum water level.

Pipes

The pipe is the link that carries water from one point to another other points in the network. EPANET assumes that all pipes are full of water every time. Direction flow is from the point with the highest hydraulic pressure.

Inputs for pipes are:

- Start and end node data
- Diameter
- Length
- Coefficient coefficient (to explain missing press)
- Status (open, closed, or there is a check valve)

Complete pipeline status parameters containing shutoff (gate) valve, and check (non-return) valve (only drain) water in one direction.

Input Water quality for pipes containing:

- Bulk Reaction Coefficient
- Wall Reaction Coefficient

The calculation of output for the pipeline includes:

- Flow rate
- Speed
- Headloss
- Darcy-Weisbach friction factor
- Average reaction rate (along the pipe)
- Average water quality (along the pipe)

Pipeline hydraulic pressure loss due to pipe drainage because the pipe friction factor can be calculated using three Different formulas, namely:

- Hazen-Williams formula
- Darcy-Weisbach's formula
- The Chezy-Manning formula

The Hazen-Williams formula is a common formula used in the United States. The formula can't be used for liquids other than water and only for flow turbulent. The Darcy-Weisbach formula is widely used theoretical. Can be applied to all fluid conditions. The Chezy-Manning formula is widely used for flow on open channel.

Each formula uses an equation to calculate losing pressure between the beginning and end of a pipes, namely:

$hL = Aq^B$
Where hL = headloss (in units of length), q = flow rate (Volume / time), A = Resistance coefficient, and B = Factor stream exponent.

3. Research Methodology

To do network optimization using EPANET method, various data are needed. Such as pipe scheme data, pipe length and pipe type. In addition to the comparative data required field research in the form of taking data pressure at the specified sampling location. By using the EPANET 2.0 program, it can be seen the results of a simulation of high water pressure and high head water on the pipe in Graha Jangli Indah. Analysis with the EPANET 2.0 program is to assess whether the simulation results from the EPANET program by entering the field data obtained such as the pipeline scheme, elevation, pipe length, pipe size and water demand, whether the results of research in the field should be different or the same as the results EPANET 2.0 program simulation. It is expected that from this analysis the results of observations in the field will not be much different from the results of the EPANET 2.0 simulation program.

3.1 Water Pressure Sampling

Sampling for the purposes of water pressure data collection, using a cluster sampling system / sampling area. Where the sample is taken as many as the number of gangs in Graha Jangli Indah, so because there are 6 gangs in the taken 12 sample points. The research location is in accordance with Figure 5.

Figure 5

Measurement of water pressure on customers using a manometer that is connected directly to the water tap using a plastic hose. For measuring samples using a manometer / gauge water pressure Wiebrock brand with a dial size of 2.5 ", a manometer with a size of 4 kg / cm^2 is used where during peak hours it is estimated that the pressure is approximately 1 atm / 10 meter. Pressure measurements are carried out on the same sample and the same time as the discharge readings on the meter, carried out 6 times a day for 1 week. Samples taken from 12 customers are the same as the samples from the customer's discharge meter according to Figure 3.2. For 1 week 5 times will be taken namely: 06.00, 10.00, 14.00, 18.00 and 22.00.

3.2 Topographic Data & Network Schematic

For topographic data use the Garmin 64s GPS. From this GPS device you will get the height of each alley in Graha Jangli Indah. From the GPS position data and altitude at each point will be entered into the Global Mapper software to get a contour map in Graha Jangli Indah. So we can get the length of each pipe from the specified node. For pipe sizes, pipe schemes and pump wells capabilities were obtained from an interview with the Graha jangli Indah Water Management.

4. Results and Discussion

4.1 Water Pressure Sampling

For the effectiveness and smooth use and use of water, the Water Management of Graha Jangli Indah divides the water use area in Graha Jangli Indah into two water. The image of the area can be seen in Figure 6. They are : TA Area, Old water source in alley IV with tower A for 100 water customers and TB area new water source in musholla with tower B for 35 water customers.

Figure 6

The amount of water pressure from each data collection location can be seen at table 1.

Table 1 Water Pressure (in atm)

No	Region Time	TB 1	TB 2	TB 3	TB 4	TB 5	TA 6
1	06:00	1,01	1,02	0,96	0,79	0,77	0,57
2	10:00	1,01	0,99	0,94	1,01	1,04	0,90
3	14.00	1,11	1,03	0,94	1,07	1,08	1,10

4	18.00	1,05	1,02	0,96	1,11	1,14	1,09
5	22.00	1,00	1,00	0,95	1,04	1,09	1,10
No	**Region Time**	**TB 7**	**TA 8**	**TA 9**	**TA 10**	**TA 11**	**TA 12**
1	06:00	0,97	0,64	0,58	0,34	0,38	0,33
2	10:00	0,99	0,83	0,85	0,42	0,42	0,42
3	14.00	0,96	0,89	0,89	0,43	0,42	0,40
4	18.00	0,94	0,86	0,94	0,36	0,36	0,35
5	22.00	0,97	0,99	0,95	0,42	0,44	0,40

4.2 Pipe Schematic and Water Demand

In the calculation of water demand in each node is calculated from the needs of each house in the scope of the node. For the calculation of Q Demand in each node using the assumption that each family consists of 4 people, for water consumption needs of 170 liters / person / day using the size of a large city with a population of 500,000 - 1 million people. For a list of the Q Demand requirements for each node, see Table 2.

Table 2 Q Demand

Node	Q Demand (LPM)	Node	Q Demand (LPM)
1.1	0,0000	3.1	0,0000
1.2	0,4722	3.2	0,0000
1.3	0,4722	3.3	0,0000
1.4	0,4722	3.4	4,7222
1.5	2,3611	3.5	3,3056
1.6	0,0000	3.6	3,3056
1.7	0,9444	4.1	0,0000
1.8	0,0000	4.2	0,0000
1.9	4,7222	4.3	0,0000
1.10	0,0000	4.4	1,4167
1.11	0,9444	4.5	0,9444
1.12	2,3611	4.6	1,8889
1.13	1,4167	4.7	0,4722
1.14	0,4722	4.8	1,4167
1.15	1,4167	4.9	0,9444
2.1	0,0000	4.10	0,9444
2.2	4,2500	4.11	1,4167
2.3	3,3056	4.12	0,0000
2.4	2,8333	4.13	0,4722

Node	Q Demand (LPM)	Node	Q Demand (LPM)
2.5	0,0000	4.14	0,4722
2.6	4,7222	4.15	0,4722
		4.16	0,4722

For the calculation of EPANET 2.0 there are several values that we specify, namely:

1. To simulate the condition of the deep well bore, we made a reservoir with a water level of 24 meters DPL for TA wells and 25 meters DPL for TB wells.
2. The power of the submersible pump is according to the respective power curve of the factory. For TA well pumps using Grundfos 1.5PK submersible pumps with SQ type 3-95 rated flow 3 m3 / hour while TB well pumps use Grundfos submersible pumps 1.5PK with type SQ 3-80 rated flow 3 m3 / hour.
3. The dimensions of the water tank in TA and TB use a 4 cubic meter tank. For the height data input according to the elevation of the TA tank 109.16 meters DPL and TB tank 104.26 meters DPL. The tank diameter is 1.65 meters, the maximum height of the tank is 2.1 meters, the height of the water in the initial tank is 1.5 meters.
4. The diameter of the main pipe is 1.25 "= 31.75 millimeters, for pipes to customers 0.75" = 19.05 millimeters with the roughness of the PVC pipe is 110.
5. For the node and pipe schemes according to Figure 4.10 and Figure 7.

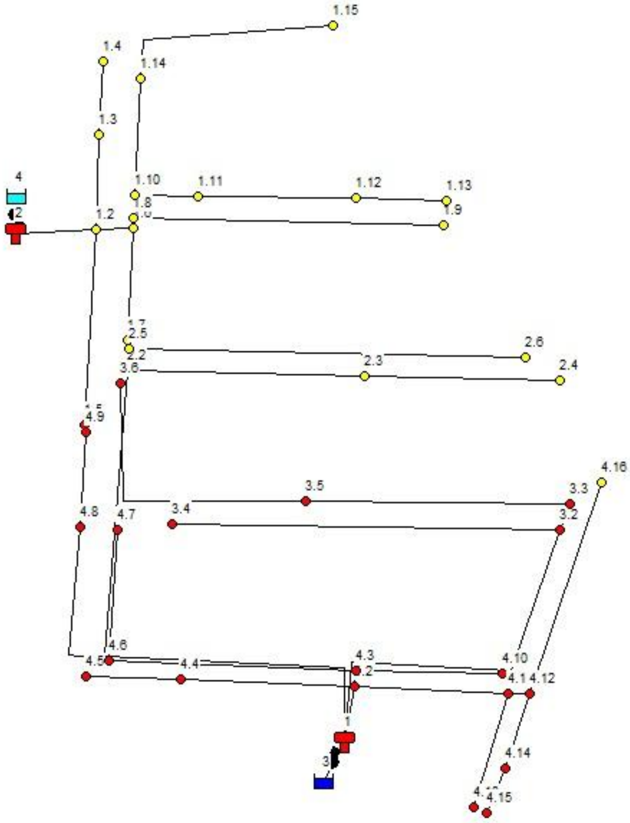

Figure 7

4.3 EPANET Simulation Results

Simulation results can be seen in table 3, where compared to the results of water pressure research in the field and the results of water pressure in the EPANET program. Results are compared at 12 node points in the field and 12 node points in the simulation.

Table 3 Epanet Comparison

Sample Location	Node	Water Pressure Sampling		EPANET Result (meter)
		atm	meter	
1	1.12	1,04	10,36	10,33
2	1.14	1,01	10,13	9,57
3	1.11	0,95	9,51	9,93
4	1.9	1,00	10,05	10,61
5	1.7	1,02	10,24	6,90
6	2.3	0,95	9,53	11,66
7	1.3	0,97	9,67	9,68
8	4.8	0,84	8,42	7,47
9	3.5	0,84	8,41	9,18
10	4.4	0,39	3,94	4,88
11	4.10	0,40	4,02	5,56
12	4.14	0,38	3,80	4,58
		Mean	8,17	8,32

To see the results of the comparison of the results of research in the field and the results in EPANET 2.0, the Square Square Mean Error (RSME) value of each simulation will be calculated. Root Square Mean Error is a frequently used measure of the difference between the values predicted by the model or estimator and the values observed in the field.

Table 4 RSME

Location	Node	Sampling (meter)	EPANET (meter)	Difference (meter)	RSME
1	1.12	10.36	10.33	0.03	1.35
2	1.14	10.13	9.57	0.56	
3	1.11	9.51	9.93	-0.42	
4	1.9	10.05	10.61	-0.56	
5	1.7	10.24	6.9	3.34	
6	2.3	9.53	11.66	-2.13	
7	1.3	9.67	9.68	-0.01	
8	4.8	8.42	7.47	0.95	
9	3.5	8.41	9.18	-0.77	
10	4.4	3.94	4.88	-0.94	
11	4.10	4.02	5.56	-1.54	
12	4.14	3.80	4.58	-0.78	

5. Conclusions

From the results of EPANET it can be concluded that the results of the EPANET pressure with the results of the water pressure research in the field are not much different. For region I, nodes 1.12, 1.14, 1.11 and 1.9 of EPANET pressure results are not much different from the results of pressure research in the field. For node 1.7 there is a significant pressure difference of around 3 meters. For water area 2 in node 2.3 there is a difference in value of about 2 meters higher than the results of the simulation of water pressure with the results of water pressure research in the field. For water areas 3 and 4 the value of the simulation results for the water pressure is also about 1 meter higher than the results of the research in the field.

From EPANET it can be concluded that the performance of water assessment in Graha Jangli Indah has

very good performance because EPANET results and field observations have not much different results where the average water pressure in the field is 8.17 meters while the water pressure results in simulation I is 8.32 meters.
From the Root Square Mean Error value in table 4 above, it can be seen that the RSME value in EPANET is close to 1. That means the smaller the RSME value the closer the simulation value / prediction value is to the value observed in the field.

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