Design of Water Distribution by Using Umbulan Water in West Surabaya

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Abstract. Umbulan spring water would be used as raw water for clean water production by Surabaya City. Umbulan water would be sold in bulk for Rp3,300.00/m³ in 2019. The price would rise by 5.53% annually. The difference between Umbulan water price and PDAM Kota Surabaya tap water rates encouraged PDAM Kota Surabaya to plan using Umbulan water source. In its design, PDAM Kota Surabaya would make a special area that would use only Umbulan water as tap water. To maintain its quality, Umbulan water must be distributed separately from PDAM Water. There are two alternative plans to distribute Umbulan water. The first alternative was by isolating the distribution pipes in the planned area. The second alternative was by using new food-grade pipes without isolating the existing pipe. These two alternatives affect water flow pattern in West Surabaya. Customers in the planned area still doubted the quality of Umbulan water. However, customers in that area were willing to pay a higher rate as long as it would not increase more than Rp50,000.00 monthly. By using Umbulan water and not rising tap water’s rates, PDAM Kota Surabaya would not experience any deficit until 2023. But, if PDAM Kota Surabaya increased tap water’s rate, PDAM Surabaya would not get any deficit until 2030.

1. Introduction

Surabaya is one of the metropolitan cities in Indonesia. According to registration data, the population of Surabaya in 2016 was 3,016,653. The population of Surabaya rose 0.63% from 2000 to 2010. The population of Surabaya is raising from time to time [2]. To fulfill water needs, Surabaya Government has a company called PDAM Kota Surabaya. In 2016, PDAM Kota Surabaya could supply 97% of the customers in its service area with 2% of customer growth rate [4]. Since the population of Surabaya is growing, PDAM Kota Surabaya plans to increase water production. To increase water production, PDAM Kota Surabaya will use Umbulan Water Spring as their raw water.

Umbulan water spring is located in Desa Umbulan, Kecamatan Winongan, Kabupaten Pasuruan. This spring produce 5000 L/s flow in which 4000 L/s will be used as raw water for five cities in East Java. PDAM Kota Surabaya will get 1000 L/s from this spring [7].

By using Umbulan Water, Surabaya will build two offtake units in two different locations. These two offtake units will be built in South Surabaya (Ketegan) and West Surabaya (Alas Malang). On planning, these two offtake units will be equipped with a reservoir and pump to distribute Umbulan Water to customer. Each offtake unit will have 500L/s of capacity [7].

When using Umbulan water, PDAM Kota Surabaya has to pay East Java Government. Umbulan Water will be sold in bulk at Rp3,300.00/m³ by East Java Government. The price will be raised by 5.53% annually. So as not to incur a loss, PDAM Kota Surabaya has to be able to sell water above its
purchasing price. The average PDAM Kota Surabaya water selling price, Rp2,876.00/m³ [4], is lower than Umbulan Water price from East Java government. With this price gap, the new water price has to be planned accordingly.

PDAM Kota Surabaya has made Umbulan water usage scenarios, including its pricing scenarios. From interviewing PDAM Kota Surabaya operational and distribution staff, it was found out that Umbulan Water in Alas Malang offtake unit will be used separately from PDAM Kota Surabaya water. Umbulan Water in Alas Malang offtake will be distributed in West Surabaya. Customers in the area who uses Umbulan Water will pay a higher price. In contrast, Umbulan Water in Ketegan offtake unit will be distributed directly into water distribution system. Customer in the area using Umbulan Water from Ketegan offtake unit will not be charged higher than usual.

This research takes West Surabaya as a place for a case study. West Surabaya in this study is an area near Alas Malang offtake unit that will be served by Umbulan water. This study area consists of District of Sambikerep and District of Lakarsantri. To know the impact of the new distribution design, other areas nearby these two districts will be analyzed later.

2. Material and Methods

2.1. Data Collection

Data needed in this design were primary and secondary data. Primary data include community response in Umbulan water usage and field data e.g. elevation and field condition. Secondary data include water usage data by PDAM Kota Surabaya, existing water distribution piping map, existing water pump and booster pump operational data and location, and distribution zone map. Community response in Umbulan water usage was collected using a questionnaire. Water usage data was collected randomly based on PDAM Kota Surabaya water usage report in the last six months. The numbers of samples used in community response and water usage data collection are according to [5]. The equation:

\[ n = \frac{Np(1-p)}{(N-1)D+p(1-p)} \]  

is used to get the numbers of samples needed where \( n \) is the number of samples needed, \( N \) is the number of houses in surveyed area, \( p \) is the ratio of sample (usually 0.5). \( D \) is the sum of the equation

\[ D = \frac{b^2}{t^2} \]

where \( B \) is the error rate of each sample. \( T \) is the level of trust that is correlated with the degree of flashiness. The value of \( B \) and \( T \) depend on area category in the surveyed area. Area category is determined by the total population in that area. Area categories according to total population can be seen in table 1. The values of \( B \) and \( T \) can be seen in table 2.

| Area Category | Total Population | Number of Houses |
|---------------|------------------|------------------|
| Metropolis    | >1,000,000       | >200,000         |
| Urban         | 500,000 - 1,000,000 | 100,000 - 200,000 |
| Suburban      | 100,000 - 500,000 | 20,000 - 100,000 |
| Small City    | 10,000 - 100,000  | 2,000 - 20,000   |
| Village       | 3,000 - 10,000   | 600 - 2,000      |
Table 2. The value of $B$ and $T$ according to area category.

| No. | Area Category | Level of Trust ($T$) | Error Rate ($B$) |
|-----|---------------|----------------------|------------------|
| 1   | Metropolis    | 95%                  | 2%               |
| 2   | Urban         | 95%                  | 3%               |
| 3   | Suburban      | 95%                  | 5%               |
| 4   | Small City    | 95%                  | 6%               |
| 5   | Village       | 95%                  | 9%               |

By referring to equation (1) and (2), the number of samples used in this survey was 63.

2.2. Analysis of Water Distribution Design

The design of Umbulan water distribution referred to the applicable standards in Indonesia [6]. The steps of water distribution planning started from analyzing water demand, planning tapping locations, analyzing water flow in pipeline, designing water distribution pipe in the planning area, and analyzing the impact on existing pipeline in West Surabaya.

A computer software was used to analyze water flow in pipes. Location and elevation of tapping spot, water demand of each tapping spot, pipeline, length of pipes, type of pipes and roughness coefficient of the pipes used are needed to analyze water flow by using computer software. The results of computer software computation are in the forms of directions of water flow, water discharge in pipe, water velocity, headloss and head in certain spots.

2.3. Analysis of Community Response

Community response to Umbulan Water usage was analyzed to find out the social impact of Umbulan Water usage. In general, communities in Surabaya were not used to consuming tap water directly. Umbulan water has a high quality and is directly drinkable. By design, Umbulan water would be able to be consumed directly from water tap. With this condition, community response was analyzed to know the willingness of the communities to use tap water as drinking water. Due to the gap of Umbulan water price and PDAM Kota Surabaya water price, an analysis of community response in price raise was also needed.

Data used in analyzing community response was collected using a questionnaire. The questionnaire contained general questions for communities in area of design to find out their willingness to use tap water as drinking water. In the questionnaire there were questions on the reasons why communities would not be willing to use tap water as drinking water. The number of samples used in this questionnaire referred to equations (1) and (2). Total samples needed were 63.

3. Results and Discussion

3.1. Analysis of Water Demand

Domestic water demand and non-domestic water demand were analyzed. Domestic water demand was analyzed by using PDAM Kota Surabaya Customer Record within six months. Customer data used in this analysis were acquired from customers who lived in the area of design. From 63 samples, the average domestic water demand was 26.25 m$^3$/month or 180,833,732.48 L/day. Assuming one house was inhabited by 5 people, the average of domestic water demand per capita was 175.05 L/person/day. The value of domestic water demand in one district could be obtained by multiplying the average domestic water demand per capita per day with total population in a certain district. The value of domestic water demand in each district can be seen in Table 3.

Non-domestic water demand was analyzed by multiplying each public facility water demand with total public facility in the design area. The standard used to determine public facility water demand referred to applicable National Indonesian Standard (SNI) [3], [5]. From the result of the calculation, the value of non-domestic water demand was 737,920 L/day. Detail of non-domestic water demand can be seen in Table 3.
By knowing the value of domestic water demand and non-domestic water demand, the value of water demand in each district could be obtained. The value of total water demand in each district could be obtained by adding up domestic water demand and non-domestic water demand. Total water demand in each district can be seen in Table 3.

**Table 3. Total water demand in each district**

| District     | Qa Domestic (L/day) | Q Non-domestic (L/day) | Total Water Demand |
|--------------|---------------------|------------------------|--------------------|
|              | Public Facility     | Per Public Facility    | Total Q Non-domestic |
| Lakarsantri | 7918284             | 72140                  | 380740             | 8299024 |
| Worship Place| 57200               |                        |                    |        |
| Medical Facility | 249600         |                        |                    |        |
| Market       | 1800                |                        |                    |        |
| Sambikerep  | 10165448            | 74350                  | 357180             | 10522628 |
| Worship Place| 36630               |                        |                    |        |
| Medical Facility | 244400          |                        |                    |        |
| Market       | 1800                |                        |                    |        |

\*Q – Water demand

The value of water demand in each sub-service zone can be found by comparing the area of sub-service zone with the total area of a certain district [1]. This area comparison is multiplied by the total water demand in a certain district. The size of sub-service zone area can be seen in Table 4.

**Table 4. Size of each sub-service district area**

| Sambikerep | Sub-service Zone | Inhabited Area (m²) | Lakarsantri | Sub-service Zone | Inhabited Area (m²) |
|------------|------------------|--------------------|-------------|------------------|--------------------|
| 538        | 803842           | 539                | 439136      |
| 535        | 2186971          | 534                | 1207335     |
| 537        | 1914768          | 541                | 1724957     |
| 516        | 1516562          | 540                | 2125858     |
| 536        | 159246           | 538                | 495587      |
| 533        | 528826           | 535                | 569060      |
| 532        | 467511           | 537                | 1155045     |
| 520        | 1082739          | 516                | 1402181     |

From area comparison, total water demand in each sub-service zone can be seen in Table 5.
| Sub-service Zona | Water Demand (L/day) | Sub-service Zona | Water Demand (L/day) |
|------------------|----------------------|------------------|----------------------|
| 539              | 506720,5             | 537              | 3167666,3            |
| 534              | 1393147,9            | 516              | 3071250,3            |
| 541              | 1990433,6            | 536              | 152599,94            |
| 540              | 2453034,6            | 532              | 506755,69            |
| 538              | 1342153,5            | 533              | 447999,64            |
| 535              | 2752339              | 520              | 1037551,4            |

3.2. Analysis of Water Distribution Design
To maintain the quality of Umbulan water, a water distribution system needed to be redesigned. Besides to maintain the quality of Umbulan water, a change in the water flow pattern in primary piping would make redesigning the water distribution system necessary. Previously, water would come from Karangpilang water treatment plan, from South to North, 5426 meters away in the design area. New flow, with Umbulan water, would come from offtake unit in Alas Malang. Umbulan water would flow from North to South. This flow change can trigger resuspension inside the pipe. This new flow would reduce the head in the system. To maintain the head after Umbulan water flowing in, a 30m head 500L/second flow water pump would be required.

Two design alternatives could be used to distribute Umbulan water. The first alternative would be by isolating existing pipes and change pipes in some location. The second alternative would be by installing new piping to distribute Umbulan water. This new piping would only distribute Umbulan water, while the old piping would still be used to distribute PDAM Kota Surabaya tap water to other areas outside the design area. These two alternatives were designed by using computer software. Computer software was used to get the water flow pattern in the design area. The results of the calculation were the value of head at some points, the velocity of water in pipes and the value of head loss in pipes.

In the first alternative, some pipes would need to be changed with larger diameter pipes to maintain head at some points. Pipes that need to be changed in this alternative would be steel pipe with 450mm diameter and 4521m length, to be replaced with 500mm diameter HDPE pipe. When isolating the existing water distribution system, the water flow pattern in West Surabaya would be affected. This could be caused by isolating primary pipe in design area used to carry water from Karangpilang water treatment plan to West Surabaya.

In the second alternative, installing new pipes would be required. New pipes used in this alternative would be HDPE. HDPE pipes would be used in this alternative due to its high quality and low roughness scale. Existing primary pipes would not be closed or taken. The existing primary pipeline would be operated to distribute water outside the design area. Since they would still be operating existing primary pipes, the head at some points in West Surabaya would rise. Rising head at some points would be due to increasing load in the existing primary pipe. Less load on pipes would cause less head loss in pipe.

The value of head in the first alternative can be seen in Figure 1. In general, the value of head in all spots would be more than 20m. The value of head in the second alternative can be seen in Figure 2. In general, the value of head in the second alternative would be more than 20m.
Figure 1. Head in the design area on first alternative design.

Figure 2. Head in the design area on second alternative design.
Both alternatives would affect water flow in the whole Surabaya City piping. In this research, only water flow changes in West Surabaya were analyzed. Existing head in West Surabaya can be seen in Figure 3. The first alternative sees a decrease of head at some points. Some locations in West Surabaya would have negative pressure levels when the first alternative was applied. This negative head would occur due to increasing head loss in the primary pipeline. Load accumulation in other primary pipes outside the isolated area would increase head loss value. To maintain head in those areas, some pumps were to be installed at some points. There would be one pipeline bypassed to another pipeline to decrease water flow distant. Lessened water flow distant would result in less head loss value. Figure 4 shows decreasing head by isolating pipe. While Figure 5 shows increasing head after adding pumps and bypassing a pipeline.

![Figure 3. Existing head value in West Surabaya.](image-url)
Figure 4. Head levels in West Surabaya after isolating pipe in the design area.

Figure 5. Head in West Surabaya after isolating pipe, adding pumps and bypassing a pipeline.
In contrast with the first alternative, the second alternative would use new pipes, which would rise head levels in West Surabaya. At some points, the value of head increase would reach 5 to 10 meters. Figure 6 shows head levels in West Surabaya after the second alternative is applied. Increasing head value would occur by decreasing head loss value. Less load in water distribution system would result in less head loss in the pipes.

![Figure 6. Head in West Surabaya after second alternative is applied.](image)

3.3. Analysis of Community Response

Community responses were analyzed by using the results of interview. The community was interviewed by using a questionnaire with a total of 63 samples. The 63 respondents were interviewed randomly regardless of whether they were customers of PDAM Kota Surabaya or not. From 63 people, 61 people were customers of PDAM Kota Surabaya, while two people were not. In general, customers of PDAM Kota Surabaya paid Rp50,000.00 – Rp100,000.00 monthly for tap water. In the results of the interview, 62 people consumed bottled water daily. From all of the samples, no one used tap water as drinking water. In general, members of the community spent Rp100,000.00 – Rp200,000.00 on bottled water monthly.

While doing the interview, the quality of Umbulan water was explained to each respondent. After getting explanation, 25 people were willing to consume Umbulan water as drinking water. But 28 people were still doubtful about consuming Umbulan water as drinking water and the remaining 11 people were not willing to consume Umbulan water as drinking water. In general, people who were doubtful and not willing to use Umbulan water as drinking water said that they doubted the performance of PDAM Kota Surabaya.

Responding to tap water increase rate, the community agreed with the policy. 51 people agreed on the increasing tap water rate, provided that the quality would also become better. In general, 31 people agreed to pay a higher rate, provided the expense would not rise more than Rp50,000.00 from existing monthly expense.
Therefore, from the results of the community survey, members of the community in the design area were still not willing to consume Umbulan water as drinking water. But, should tap water rate increase, the community in the design area was willing to pay a maximum of Rp50,000.00 more than existing monthly expense on tap water. To increase the willingness of consuming Umbulan water as drinking water, PDAM Kota Surabaya needs to do more counseling with the community in the design area. PDAM Kota Surabaya can work together with the Public Health Department to show the drinkable quality of Umbulan water.

3.4. Analysis of Umbulan Water Operational Profit and Loss

The analysis of Umbulan water operational profit and loss was done by comparing the income and outcome of PDAM Kota Surabaya when operating with Umbulan Water. The calculation was done in two conditions. The first condition would be no increasing tap water customer expense. The second condition would an increase in tap water expense as much as Rp50,000.00 in total. The tap water rate would be increased gradually by 10% every two years. In general, the profit and loss of Umbulan water operations were calculated in the following way.

Income in 2019 was calculated by multiplying the number of house connection in 2019 with the average of annual spend on tap water per house connection. The number of house connection in 2019 was 64604. In the first year, with or without increased tap water rate, the total average expense on tap water per house connection would be Rp84,631.25. By multiplying those numbers, the total average income per month in 2019 can be found. In order to get the total income in 2019, the result of total average income per month should be multiplied by 12. From that calculation, in 2019 there was income as much as Rp5,467,516,275.00 for either with increased tap water rate or without increased tap water rate.

The 2019 numbers were calculated by multiplying Umbulan water rate per cubic meter with total water bought for PDAM Kota Surabaya usage. In 2019, Umbulan water price was Rp3,330.00 per cubic meter. PDAM Kota Surabaya would buy Umbulan water in bulk at the same number, 500L/second. Therefore, the outcome in 2019 was Rp4,924,800,000.00. By finding the difference between income and outcome, the operational profit and loss can be obtained. In 2019, the total operational profit without raising tap water price would be Rp1,151,837,275.00. If PDAM Kota Surabaya raised tap water price by averagely Rp50,000.00 per house connection, the total operational profit in 2019 would be Rp4,382,037,275.00.

Umbulan water rate would be raised by PDAB Provinsi Jawa Timur as much as 5.53% annually [7]. Therefore, Umbulan water price in 2020 would be Rp3,330.00 + (Rp3,330.00 × 5.53%) = Rp3,513.98. In the second condition, tap water rate would be increased 10% every two years. Tap water rate in 2021 can be calculated by using the same steps in rising Umbulan water rate. The calculation of profit and loss from 2020 to 2030 can be done by using the same steps as before.

Figure 7 shows profit and loss of Umbulan Water operations from 2019 to 2030. Without rising tap water price, PDAM Kota Surabaya would incur a deficit in 2024. But if PDAM Kota Surabaya raised tap water price by averagely Rp50,000.00 per house connection per month, PDAM Kota Surabaya would not incur any deficit until 2030.
Figure 7. Umbulan water operations profit and loss from 2019 to 2030.

4. Conclusion
From this research it can be concluded that by using Umbulan Water in West Surabaya there would be several impacts on PDAM Kota Surabaya. PDAM Kota Surabaya needs to reengineer water distribution system in West Surabaya. There are two alternatives that can be used for designing water distribution system. The first alternative is by isolating existing pipeline and the second alternative is by making new pipeline. Both alternatives affect water flow in West Surabaya. PDAM Kota Surabaya needs to increase tap water rate so as not incur any deficit. By raising averagely 10% of tap water rate every two years, PDAM Kota Surabaya will not incur any deficit until 2030. Although the quality of Umbulan water is good, the members of community inside the design area still had doubts about the tap water quality and were not willing to consume tap water directly as drinking water. The main reason was the community’s doubt on the performance of PDAM Kota Surabaya.

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