Analysis of The Increasing Need of Drinking Water as The Effect of High-rise Building Growth in Eastern Surabaya

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Abstract. Surabaya City, the capital of East Java, is one of the centers for business, trade, industries, and education in Indonesia. Surabaya is also a very important hub for the eastern part of Indonesia, making it a strategic location for property investors. Nowadays, Surabaya’s economic is hugely affected by its significant growth in properties, where skyscrapers, malls, plazas, apartments, office buildings, and hotels will continue to be built in the coming years. The amount of the aforementioned commercial buildings creates concern on drinking water supply management. In this study, the projection of drinking water need was determined by projecting inhabitants or users of high-rise buildings based on existing project data as well as interviews and field survey to people in charge. The study was directed towards 9 high-rise buildings in the eastern part of Surabaya, in particular in the districts of Gubeng, Tenggilis Mejoyo, Rungkut, and Gunung Anyar. The projection data were then analyzed and modeled using WaterCAD. Technical aspects discussed in this study include the amount of water, the network of water distribution system, and supply management. This study found that the total water need would range between 3-20 L/s depending on the number of inhabitants or user. The modelling predicted year to year situation on flows and pressures until 2025. In the last year of the modelling, the pressure obtained on the distribution system were in the range of -4 to 18 mH₂O, which is a critical range of pressure in those areas.

Keywords: Drinking water, distribution, high-rise building, Surabaya, WaterCAD.

1. Introduction
Surabaya is a metropolitan city with a population of more than 3 millions in 2016 [1]. Surabaya City has also become one of the centers for business, trades, industries, and education in Indonesia. As a province capital, it has also become a strategic location for both regional and nation-wide office buildings and industrial centers. Surabaya’s economic is hugely affected by its significant growth in properties, where skyscrapers, malls, plazas, apartments, office buildings, and hotels will continue to be built each year. In 2018, there was 347,333 m² total of office spaces in Surabaya and in 2018-2020 there would be another 124,347 m² to be built. 33,535 apartment flat units would also be available until 2021 or 8,384 new units each year, 164% higher than the previous 5 years average. Another 2,035 new units of hotel rooms will also be available in 2018 [2]. Population growth will surely cause a rise in daily clean and drinking water need. The rapid growth of current and future high-rise building projects is expected to influence clean water supply system. With that thought in mind, this study aims to figure out the drinking water distribution systems situation in the study area until 2025.
2. Methods

2.1 Ideas
Study ideas came from the significant growth of high-rise buildings in the recent few years, especially in the study area. This growth causes concern over existing distribution network of Surabaya Drinking Water Enterprise (PDAM), especially in the districts of Gubeng, Tenggilis Mejoyo, Rungkut, and Gunung Anyar, located in the eastern part of Surabaya. This problem prompted a need for a study about the influence of the rise of drinking water need from high-rise buildings on the existing drinking water distribution network. In this study, a high-rise building is defined as a building with more than 8 stories [3].

2.2 Literature review
In order to gain a general understanding of knowledge necessary for the study and make the process run more smoothly, references were studied prior to the study. References’ sources include journals, theses, books, papers, final projects, and other related academic literature. These literatures include hydraulics in drinking water distribution, high-rise buildings, water need, and WaterCAD V8i manual.

2.3 Data collection
Data collection is a necessary process to support the study. The data collected include primary and secondary data. Primary data includes data obtained directly through the source, which are the results of survey, interviews, opinions from both individuals and groups, object observation, and experiment results. Primary data collected in this study were:
1. The condition of high-rise buildings and their surrounding areas as well as high-rise building project location, obtained through field observation.
2. Data of high-rise buildings projects in the study area, obtained by direct survey to the manager of each building. Data includes building name, location and operational starting year; number, specification, and area of each stories; number, specification, and type of each unit; and water need projection.

Secondary data were obtained indirectly through sources such as books, archives, and other records from related sources or institutes. Secondary data collected in this study were:
1) Administration Map and Spatial Plan (RTRW) of Surabaya Municaipality, which shows general figure of land use in Surabaya as well as the development plan.
2) High-rise buildings list with Building Permit (IMB) to build and develop in Surabaya City. This data would determine the high-rise building that would be included in the study.
3) Technical data including revision of Drinking Water Supply Masterplan (RISPAM) of Surabaya, distribution network map, types and condition of network pipes and distribution pipes, distribution scheme, service zone map, production capacity, and water need. This data would assist the analysis of the existing distribution network.

2.4 Data processing
Data were processed based on the collected primary and secondary data. The processing started from high-rise building occupancy calculation to predict the water need. This calculation was based on the data from high-rise buildings management. Occupancy of the apartment and hotel buildings was determined based on the number and type of units, while for the malls and house-shops it was determined based on the area of building stories.

The next step was calculating the water need. Water need applied in this study was based on the peak hour water need. The calculation could be done based on the users, types and number of plumbing tools, the weight unit of plumbing tools, or the water use towards time [4]. However, the water need in this study was determined based on building capacity calculation with the assumption
that the water usage for each person was proportionate to the building use. Total water need would then be multiplied with occupancy rate per year based on building use to obtain the yearly water need until 2025.

2.5 Existing distribution networking modelling
Existing data obtained would then be imported towards WaterCAD V8i to model the distribution network condition. The modelling generated information on the pressure of pipe and junctions, water flows, and other technical data for analyzing the existing water distribution situation.

2.6 Modelling of Network Distribution Projection
Modeling of network distribution projection was done using processed data of the water need yearly. The water need data were imported to existing distribution network using WaterCAD based on each buildings and locations. The modelling of WaterCAD would indicate the change in pressure of pipe and junctions, water flow, and other technical data. These differences would be compared with the existing situation, to predict the influence of high-rise buildings growth towards the water distribution network.

3. Results and Discussion

3.1 Existing distribution networking modelling result
Modelling in this study used a steady state condition where the water distribution system (water flow, pressure, pump operational, valve, etc.) was calculated with the assumption that water need and other conditions would not change along with time [5]. Physical components in the distribution network and their status were adjusted to the distribution scenario from PDAM. In this existing network modelling, there were 4 reservoirs, namely Ngagel I, Ngagel II (1), Ngagel II (2), and Ngagel II (3) reservoir. The valves in use consisted of 2 types, i.e. 25 units of Throttle Control Valves (TCV) and 1 unit of Pressure Regulating Valve (PRV), respectively. There were 34 pumps throughout The Drinking Water Treatment Plants (IPAM) Ngagel in use in the study area. 526 pipes and 374 junctions were included.

Modelling result showed the pressure level in each junction in the network in a color coded form. The existing distribution network modelling showed that the pressure in the districts of Tenggilis Mejoyo, Rungkut, and Gunung Anyar were in a safe zone (more than 20 mH2O). On the other hand, in Gubeng District, the pressure in the existing junction varied, ranging from 5.1 – 14.9 mH2O.

The modelling result of existing condition would be used as a basis of comparison with the modelling results of the coming years. Later on, the changes in the distribution network would be presented every year until 2025 in the following Figure 1.
3.2 Projection of the water distribution network

The projected model of distribution network projection was made by modifying the pre-made existing distribution network. The first change was erasing the reservoir and pump in IPAM Ngagel I, Ngagel II, and Ngagel III. This erasure would simulate a condition of IPAM Ngagel where the unit had reached its maximal capacity and would not be able to add water supply for the study area. Therefore, pipes originating from IPAM Ngagel were cut and imported as negative value demand. A negative value in the junction indicated water injection into the system [5].

The second change was to add a reservoir into the network of pipes that contained water supply from IPAM Karangpilang III. Because IPAM Ngagel had reached its maximum production capacity, water supply addition could only be from IPAM Karangpilang III. The addition of a reservoir as well as a booster pump would be to increase pressure in the distribution network. For the modelling’s purpose, the pump was named “Karangpilang III”. The maximum capacity of the pump was planned to be 2,000 L/s, based on the maximum production capacity of IPAM Karangpilang III, and the head pump was determined based on excess pressure from modelling result in that certain point, which was 33.6 m. The pump curve can be seen in the following Figure 2.

Figure 2. Karangpilang III Pump Curve
The water need was added according to the operational year, for example, the building that would be operational in 2020 would have the water need of building year 1. For buildings that would have passed 5 years in modelling, the water needs for the next years were assumed to be constant. This was because after 5 years, the occupancy rate of buildings are known to be relatively constant. Pipe and junction additions were also done in this step to connect high-rise buildings with distribution networks. The pipe diameter of high-rise buildings was calculated based on the total water need of the buildings for 100% occupancy. Distribution pipe diameter was calculated using the following equation [6].

\[
\text{Diameter} \ (D) = \frac{4Q}{\pi V}
\]  

(1)

After calculating the pipe dimension, the applied pipe diameter would be chosen from the closest pipe diameter available in the market. The next step was testing the water velocity with the chosen diameter and ensuring it would be in the range of criteria (0.3 - 2.5 m/s) [7]. The result of pipe diameter and velocity test are presented in the following Table 1.

Pipes and junctions’ addition that would be connecting the high-rise buildings to the existing water distribution network is presented in the following Figure 3.

**Table 1. Result of Pipe Diameter and Velocity Test**

| Pipe ID      | Calculated Pipe Diameter (mm) | Pipe Diameter Used (mm) | Velocity Test (m/s) |
|--------------|-------------------------------|-------------------------|---------------------|
| Apartment A  | 163.21                        | 200                     | 0.67                |
| Apartment B  | 103.89                        | 125                     | 0.69                |
| Apartment C  | 128.64                        | 150                     | 0.74                |
| Apartment D  | 76.92                         | 100                     | 0.59                |
| Apartment E  | 44.37                         | 75                      | 0.35                |
| Apartment F  | 119.97                        | 125                     | 0.92                |
| Apartment G  | 144.13                        | 150                     | 0.92                |
| Apartment H & I | 102.24                    | 125                     | 0.67                |
3.3 Modelling of distribution network projection

Modelling of distribution network projection was done for each year. This modelling would add peak hour water need from high-rise buildings every year. The peak hour water need is the largest amount of water need in a certain hour in a whole day [8]. In this study, modelling was commenced without any influence from the surrounding population growth, which also meant that the changes in this modelling were only affected by the growth of high-rise buildings in the study area. The pressure in high-rise building junctions were presented in the following figures and tables. The pressure levels in the junctions are color coded; black for below 0 mH$_2$O, red for 0.1 - 5 mH$_2$O, yellow for 5.1 - 10 mH$_2$O, green for 10.1 - 15 mH$_2$O, light blue for 15.1 - 20 mH$_2$O and dark blue for beyond 20 mH$_2$O.
Table 2. Pressure in High-rise Buildings’ Junctions for Year 2018-2019

| Junction ID | Pressure 2018 (mH₂O) | Pressure 2019 (mH₂O) |
|-------------|-----------------------|-----------------------|
| Apartment A | 19.4                  | 17.8                  |
| Apartment B | 20.3                  | 18.9                  |
| Apartment C | 25.3                  | 23.6                  |
| Apartment D | 7.1                   | 5.3                   |
| Apartment E | 7.9                   | 6                     |
| Apartment F | 20.9                  | 17.5                  |
| Apartment G | 20.7                  | 18.2                  |
| Apartment H | 22                    | 20.9                  |
| Apartment I | 22                    | 20.9                  |

Figure 5. Modelling Result for Year 2020-2021

Table 3. Pressure in High-rise Buildings’ Junctions for Year 2020-2021

| Junction ID | Pressure 2020 (mH₂O) | Pressure 2021 (mH₂O) |
|-------------|-----------------------|-----------------------|
| Apartment A | 13.5                  | 10.8                  |
| Apartment B | 15.9                  | 13.1                  |
| Apartment C | 20.9                  | 19.3                  |
| Apartment D | 0.2                   | -2.7                  |
| Apartment E | 0.9                   | -1.9                  |
| Apartment F | 13.7                  | 10.9                  |
| Apartment G | 14.2                  | 11.8                  |
| Apartment H | 18.5                  | 17                    |
| Apartment I | 18.5                  | 17                    |
Table 4. Pressure in High-rise Buildings’ Junctions for Year 2022-2023

| Junction ID | Pressure 2022 (mH₂O) | Pressure 2023 (mH₂O) |
|-------------|-----------------------|-----------------------|
| Apartment A | 8.9                   | 7.7                   |
| Apartment B | 11.5                  | 10.5                  |
| Apartment C | 18.3                  | 17.8                  |
| Apartment D | -4.0                  | -4.9                  |
| Apartment E | -3.2                  | -4.1                  |
| Apartment F | 9.4                   | 8.2                   |
| Apartment G | 10.4                  | 9.3                   |
| Apartment H | 16                    | 15.5                  |
| Apartment I | 16                    | 15.5                  |

Figure 6. Modelling Result for Year 2022-2023

Figure 7. Modelling Result for Year 2024-2025
Table 5. Pressure in High-rise Buildings’ Junctions for Year 2024-2025

| Junction ID | Pressure 2024 (mH₂O) | Pressure 2025 (mH₂O) |
|-------------|-----------------------|----------------------|
| Apartment A | 7.1                   | 7                    |
| Apartment B | 10                    | 9.8                  |
| Apartment C | 17.6                  | 17.6                 |
| Apartment D | -5.2                  | -5.2                 |
| Apartment E | -4.4                  | -4.4                 |
| Apartment F | 7.9                   | 7.9                  |
| Apartment G | 8.9                   | 8.8                  |
| Apartment H | 15.2                  | 15.2                 |
| Apartment I | 15.2                  | 15.2                 |

The results of the modelling showed that the junctions for every high-rise building would experience pressure level decline every year, especially in the district of Gubeng. This would be caused by the lack of water boost from IPAM Ngagel due to its capacity limit. In the table above, 6 apartment buildings in the study area showed value below the criteria. The minimum pressure allowed inside of a pipe is 1 atm or equivalent to 10 mH₂O [9].

The growth of high-rise buildings in the Eastern Surabaya would have quite a significant influence on water supply. The most influenced district would be Gubeng which is the farthest from the water supply from Karangpilang III. In the end of year 2025, about half of the junctions in the Gubeng would suffer from negative value pressures. The rest would not meet the 1 atm pressure criteria which are shown with yellow color in the color-coded display of the modelling result (<= 10 mH₂O). Aside from Gubeng, water supply in some junctions in Tenggilis Mejoyo, Rungkut, and Gunung Anyar would also be influenced, where in the last year of projection (2025), the pressure in each district would range from -11.7 to 41.7 mH₂O in Gubeng; 5.1 to 20.2 mH₂O in Tenggilis Mejoyo; 5.1 to 21.3 mH₂O in Rungkut; and 5.1 to 29.6 mH₂O in Gunung Anyar, respectively.

Low pressure levels occurring in certain zones could be because their land elevation level were higher than other service zones [5]. In this study, Gubeng is an area with a relatively higher elevation than other districts, by about 1 - 5 m. In this situation, pipe diameter change and pump flow capacity could not provide a higher working pressure. If a zone did not have any water tanks, then upgrading the existing pump or replacing it with a new pump could be a possible option.

At the same time, there were 137 distribution pipes that would not meet minimum inside-pipe water velocity. The minimum water velocity allowed inside a distribution pipe is 0.3 m/s [9]. This could be caused by an inefficient flow system, affected by several factors like ineffective pipe design, insufficient water flow, and rise of water need higher than the initial pipe design capacity.

4. Conclusions
The modelling result in the end of the year 2025 showed that the district of Gubeng would suffer from a significant pressure level decline where the junction pressure levels were calculated at -11.7 to 41.7 mH₂O. In the other districts, the pressure levels would be in the range of 5.1 to 29.6 mH₂O. The model also showed that some apartment buildings would have pressure values lower than the criteria of 10 mH₂O. It showed that the booster pumps which pump the water for IPAM Karangpilang II would lack pressure.

References
[1] Badan Pusat Statistik Kota Surabaya 2017 Kota Surabaya dalam Angka 2017 (Surabaya: BPS)
[2] Salanto F 2018 Surabaya Property Market Report H1 2018 (Jakarta: Colliers International)
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