Effect of Pipe Diameter and Point Height on Clean Water Capacity and Velocity in Epanet-Based Loop Model Gravity Pipe System

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Abstrak
Efficient distribution of clean water is an important challenge in water resource management during peak hour demand. The purpose of this study is to evaluate the effect of pipe diameter and elevation on water capacity and velocity using Epanet software. This study uses an experimental design with a Loop design approach for the distribution and control of clean water using epanet.
The independent variables of this study include the diameter and elevation of the pipeline and the dependent variable is the capacity and water velocity of each pipe point, measured during peak service hours. Energy is provided 5 mka as a single variable. There were 45 sample points with repeated measurements five times at each point using a flow meter and analyzed using ANOVA. The results showed that a larger pipe diameter increased water capacity and velocity, while an increase in elevation decreased the pressure and flow velocity.
In conclusion, pipe diameter and point elevation have a significant effect on water capacity and velocity. pipe diameter and elevation of each piping node are key factors in the design of an efficient water distribution system, and the use of Epanet simulation tools can help in more effective planning.

Keywords**:** diameter, elevation, capacity, planet.

INTRODUCTION.

Efficient and effective distribution of clean water is one of the important aspects of water resource management. The problem of clean water distribution often arises, especially during peak times when all consumers of different elevations require the same need for clean water, where the speed and capacity of water tend to decrease at points far from the source. This study aims to evaluate how pipe diameter and elevation affect the capacity and velocity of clean water in a loop-based distribution system analyzed using Epanet software. The results of this study are expected to make an important contribution to better planning and management of clean water distribution infrastructure, especially in facing the challenge of water demand during peak service hours.
Pipe diameter and point elevation are two critical factors in a water distribution system. Larger pipe diameters tend to reduce friction losses and increase water flow capacity (Aydın, A., & Çelik, Y. 2021).
In contrast, point elevation has a significant influence on water pressure, where an increase in elevation is usually associated with a decrease in pressure ((Reddy, M. J., & Elango, K. 2020). The combination of these two factors is often a major concern in the design and analysis of clean water distribution systems.

METODE AND MATERIAL

The type of research carried out was experimental design. This method uses a Real Experiment. This research is the result of original research into the engineering of a loop model of clean water distribution piping and was carried out at different junction height points.

The independent variable is the height of the intersection (0.30; 0.50; and 0.75) meters. Pipe diameter (1.0; 1.25 and 1.5) inches, and pipe length (100, 200, and 300) meters. Energy supplying the average water pressure of 5 meters of water column, mka (as a single variable).

The brief procedure for this research method includes: a). Loop model piping system design, b). Preparation of research tools and materials; c). Measuring the elevation point of the entire intersection using Thedoloit; d). Determine the location of the piping; e). Overall model engineering process in the field; f). Test the model with the epanet system at each intersection, g). Thorough feasibility test of the piping system (including the feasibility of measuring instruments and the feasibility of the piping system), h). Test the feasibility of water capacity and water speed at each intersection. i) measuring the water capacity and water speed of all junctions and recording them into basic data (Excel), j) enter the basic data summary into Epanet 2.0 after converting it to international units, k) read the data entry results in epanet and, then the reading results of the water capacity and water speed of each junction are checked against the objective criteria in Table 1. Overall data processing uses the Epanet model. Check the water capacity and water speed at each intersection and the pipe network as a whole. The reading results for each junction use a ratio scale.

Dependent variables: water capacity and speed of water flowing at each intersection. Determination of repetitions uses the Federer formula, with five repetitions. The operational definitions of variables and objective criteria in research can be explained as in Table 1. The location of this research was carried out in the Mamboro village area, North Palu sub district, Palu City, Central Sulawesi Province. Data was collected from 45 sample points with repeated measurements five times at each point using a flow meter to ensure accuracy. Data analysis was carried out using Epanet to determine the influence of independent variables on dependent variables. The test was carried out using empirical data collected from 45 sample points that varied in terms of pipe diameter and elevation. This data was analyzed using variance analysis (ANOVA) to identify the significant influence of each variable.

Between-Subjects Factors: Data shows that the sample consists of various categories of node elevation and pipe diameter. The largest number of samples is in the Low category with a Small pipe diameter (N = 45), and the category with the smallest number of samples is in the High elevation with a Small pipe diameter (N = 1). The average speed of water varies based on the category of elevation and pipe diameter. The highest velocity is recorded at nodes with High elevation and Small pipe diameters (13.96 m/s) and in general, larger pipe diameters tend to increase the average velocity of water at various elevation levels.

Table 1: Operational Definitions of Variables and Objective Criteria in Research.

No	Variable	Operational Definition	Measuring instrument	Objective Criteria
1	Water Capacity (Q)	Water flow flowing in pipes in units (Liters/minute or GPM, gallons per minute)	Flow Meters	0,6 to 3,0 Liters/minute
2	Water Speed (V)	The rate of water flowing in a piping system in units of distance per time (Feet/Meters)	Flow meters	0,3 to 4,5 Meters/second
3	Junction	Junction height measured in distance units (Feet)	Theodolite	0,3 to 0,75 Meters
4	Pipa diameter	The cross-sectional area of the pipe used as a medium for carrying water or the water contact area in the unit (inches/mm).	Micrometer	0.5, 1.25 and 1.5 Inches
5	Long pipe	Length of pipe path through which water reaches each junction in units (feet)	Meter roller	100 to 300 Meters
6	Loop system	The pipe network model is a circular model (loop) that is interconnected at the ends with each other	Piping model	On system
7	System performance	The ability of the water distribution system to produce effective water capacity and water speed at service peaks.	Flow meter	V ≥ 0,3 meters/second (≥ 0,016 feet/second) is an effective criterian. V< 0,3 meters/second or (≤ 0,0164 feet/second) not effective. Q ≥ 0,6 Liters/minute (≥ 2,27 GPM) is Efective. Q < 0,6 liter/minute (<2.27 GPM) not Efective.

RESULTS

The results of the analysis show that both the pipe diameter and the point height significantly affect the capacity and velocity of clean water in the pipeline network. Pipes with larger diameters tend to have higher water flow capacity and more stable flow velocities, especially at points farther away from the water source. Similarly, the increase in the height of the water distribution point is directly proportional to the decrease in the speed of the water flow at that point, especially during peak service hours.

Base on result of Table 2 it can be explained, link Id is the pipe sequence number, pipe diameter (inches), length is the length of the pipe (feet), roughness of the pipe (no dimensions), capacity PGM and water speed FPM. Based on the Epanet 2.0 run results in Table 2, it can be explained that, running results using Epanet, for the junction network at the furthest point on all junction 1 to 54, the water speed is between 2.21 feet/second to 29.43 feet/second.

Based on the results of statistical tests using Anova, it can be interpreted from the findings. Results of the anova test, for the Velocity variable, the value of Sig. = 0.576 shows that it is significant in the error variance between groups, so that the assumption of variance homogeneity is met. For the variable Water capacity, the value of Sig. = 0.360 also shows significant variance in error between groups, which also meets the assumption of variance homogeneity.

The results of the anova test, for the Velocity variable, the value of Sig. = 0.576 shows that it is not significant in the error variance between groups, so the assumption of variance homogeneity is met. For the variable Water capacity, the value of Sig. = 0.360 also shows significant variance in error between groups, which also satisfies the assumption of variance homogeneity.

Table 2: Results of Running the Loop System Using Epanet

LinkID	Length	Diameter	Roughness	Flow	Velocity
	ft	in		GPM	fps
Pipe 2	3.28	1	110	4.75	3.94
Pipe 3	3.28	1	110	5.01	2.05
Pipe 4	3.28	1	110	4.54	4.85
Pipe 5	9.8	1.5	110	31.61	5.74
Pipe 6	44.94	1.5	110	25.43	4.62
Pipe 7	43.30	1.5	110	20.68	3.75
Pipe 9	9.84	1.25	110	13.25	3.46
Pipe 10	4.92	1.25	110	9.25	5.42
Pipe 11	4.92	1.25	110	4.55	4.19
Pipe 12	16.40	1.25	110	16.87	4.41
Pipe 13	6.56	1.25	110	22.25	5.82
Pipe 14	10.7	1.25	110	26.15	6.84
Pipe 16	10.7	1	110	43.85	17.91
Pipe 17	1.64	1	110	39.68	16.21
Pipe 18	25.16	1	110	30.69	12.54
Pipe 19	15.32	1	110	26.36	10.77
Pipe 20	35.00	1	110	15.01	6.13
Pipe 21	38.28	1	110	12.11	4.95
Pipe 22	19.68	1	110	7.78	3.18

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Based on statistical tests for water velocity: Pipe diameter and node elevation both have a significant effect on water velocity (Sig. = 0.000). The interaction between the two was also significant (Sig. = 0.034), but its contribution was relatively small compared to the main effect. Water capacity: The diameter of the pipe has a great effect on the water capacity (Sig. = 0.000), as well as the elevation of the node (Sig. = 0.008). The interaction between the two was also significant, although small (Sig. = 0.039).

Analysis using Epanet showed that both the pipe diameter and the point height significantly affected the water capacity and velocity at all measured points. Larger pipe diameters and optimal height differences increase flow rates and water capacity, especially at the farthest distribution points. The results of the analysis show that pipe diameter and elevation have a significant influence on water speed and capacity.

The running results of the water speed in the system have met the standards. Facts in the field, after checking when the system is operating, at the furthest points such as pipe lines, the water speed is still within real limits, and is effective where the water speed during peak hours of water use at the junction shows the ability of the water distribution system to reach the farthest point optimistically. These factors have been able to meet water needs at peak hours when clean water services are needed at the same time and at different distribution heights. Based on the running loop system using Epanet 2.0 as in Figure 1, junctions can be analyzed at each elevation and all networks show blue nodes. At 0.01 feet per second. This means that at this level the numbers meet the minimum speed criteria in the clean water distribution system in SPAM.

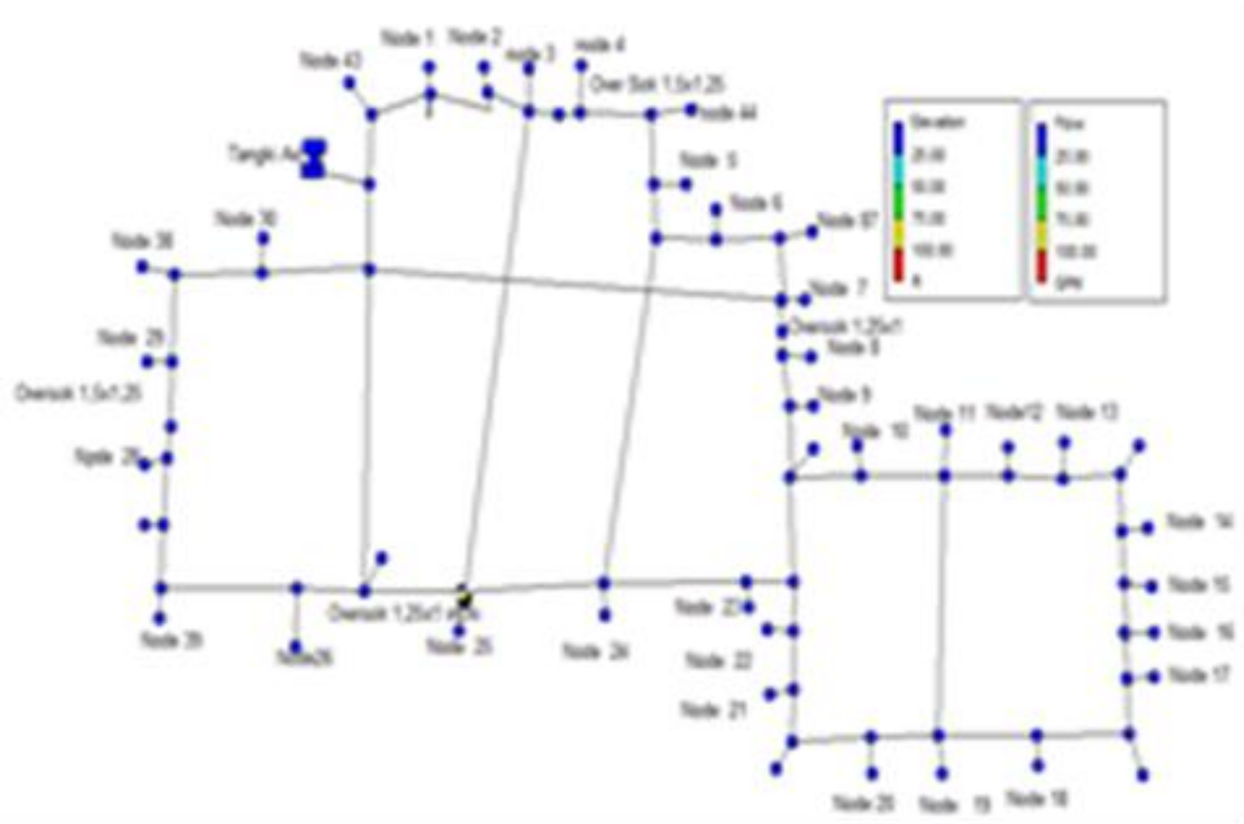

Figure 1 : Run the Junction Eelevation and Water Flow Results Using Efanet.

Larger pipe diameters consistently increase the average velocity of water at various elevation levels. For example, at low elevations, a larger pipe diameter results in a higher average velocity compared to a smaller diameter.
Likewise at medium and high elevations, larger pipe diameters contribute to increased water flow velocities. For water capacity, the results show a similar pattern. The larger pipe diameter not only increases the speed of water flow but also the water capacity throughout the distribution points. Elevation also plays an important role, where significant elevation differences between distribution points lead to variations in the water capacity produced.

DISCUSSION.
These findings indicate that pipe design and distribution height are critical factors in ensuring efficient and effective clean water distribution. Larger pipe diameters can reduce flowresistance and increase distribution capacity, while point height settings can help manage water flow speeds to achieve maximum efficiency.
The results of this research can be the basis for designing a better water distribution system in the future. Larger pipe diameters reduce friction losses, while precise height management ensures consistent pressure, increasing water velocity and capacity during peak hours of water distribution. These findings are consistent with recent studies that emphasize the importance of optimizing these variables to improve the performance of water distribution systems (He & Yuan, 2019; Izadi, Yazdandoost, & Ranjbar, 2020). The larger pipe diameter reduces flow resistance, which in turn increases the flow rate and reduces pressure loss along the pipe (Farley, M., & Trow, S. 2019). This is especially important in water distribution systems where low flow rates can lead to deterioration in water quality due to stagnation and long residence times (Hajibagheri, M. et al. 2020). Elevation, has a direct effect on water pressure. In a gravitational system, water tends to flow from higher altitudes to lower altitudes, and this difference in altitude creates pressure that drives the flow of water (Mays, L. W. 2021). However, as the elevation increases, the pressure tends to decrease, which can reduce the speed and capacity of the water flow if there are no proper pressure control measures. The interaction between pipe diameter and elevation was also significant, although the effect was smaller compared to the main effect of each variable. This interaction suggests that the effect of pipe diameter on water velocity and capacity can vary depending on the elevation of the distribution point. For example, at higher elevations, an increase in pipe diameter may not always result in a proportional increase in flow velocity due to lower pressure (Sarbu, I., & Borza, I. 2019).
Based on the results of this study, the use of Epanet as a simulation tool provides advantages in analyzing the complexity of water distribution networks. Epanet makes it possible to simulate different scenarios and identify critical points in the distribution system that require special attention (Rossman, L. A. 2020). The use of Epanet software in research also supports the validation of empirical results with more accurate and realistic simulations
The larger pipe diameter significantly reduces the resistance of the water flow, which ultimately increases the flow rate and capacity of the water. The flow resistance, which is produced by the friction between the water and the pipe wall, is inversely proportional to the diameter of the pipe; The larger the diameter, the lower the resistance. This is because, in pipes of larger diameters, the water has more room to move, which reduces direct contact with the pipe walls and, therefore, reduces friction (Bratby, J. 2021).
The results of the study from Farley and Trow (2019), confirm that a larger pipe diameter not only reduces pressure loss but also allows for a more even distribution of water throughout the network, especially at distribution points far from the source. This is crucial in maintaining the stability of water pressure throughout the network, especially in the face of peak demand.

Low flow velocity due to small pipe diameters can lead to a decrease in water quality, especially through the phenomenon of stagnation. Stagnation occurs when water moves too slowly or even not at all in the pipe, which can lead to sediment accumulation, microbial growth, and a decline in the chemical quality of the water (Hajibagheri, M. et al., 2020).

In this context, the use of larger pipe diameters is one of the effective solutions to avoid water quality problems that often arise in dense or complex distribution systems. However, the use of pipes with larger diameters also has economic implications. Pipes with large diameters tend to be more expensive, both in terms of material purchase and installation costs. Therefore, in planning a water distribution system, it is necessary to conduct a comprehensive cost-benefit analysis to determine the optimal pipe diameter, which not only meets technical needs but is also economical (Abd El-Bary, Y. 2021).

Elevation is another factor that plays an important role in the distribution of water. In a gravity distribution system, water flows from an area of higher elevation to an area of lower altitude, with the pressure resulting from that elevation difference. This pressure, known as "head pressure", is the main driver of water flow in the distribution system (Mays, L. W. 2021). However, as the elevation of the distribution point increases, the pressure tends to decrease as the potential energy of the water decreases. This decrease in pressure can reduce the speed and capacity of water flow, especially in areas with much higher elevations than water sources. In this situation, there needs to be an effective pressure management strategy, such as the use of auxiliary pumps or buffer tanks, to ensure that the water flow remains stable and meets the needs at all distribution points (Schmitt, T. G., & Thomas, M. 2021). The interaction between pipe diameter and elevation adds a dimension of complexity in water distribution system planning. For example, although a larger pipe diameter tends to increase the speed of water flow, this effect can be minimized if the elevation of the distribution point is high. At high elevations, the water pressure is lower, which means that even with larger pipe diameters, the flow rate may not reach its maximum potential (Sarbu, I., & Borza, I. 2019). Conversely, at low elevations, the use of pipes with larger diameters can provide more optimal results because higher natural pressures allow for faster and more stable water flow. Therefore, in the design of distribution networks, it is important to consider the combination of pipe diameter and elevation to optimize system performance (Mu, T. et al. 2021). Simulations using Epanet also allow the identification of critical points in the distribution network where water flow problems may arise. With these simulations, planners can identify areas that require technical intervention, such as the installation of additional pumps or the use of pipes with larger diameters to ensure even distribution of water (Lee, S. J., & Lee, J. K. 2021). In this study, the results of the Epanet simulation support the empirical findings, where pipe diameter and elevation significantly affect the speed and capacity of water flow. Validation of these results with simulations provides greater confidence in the accuracy and reliability of the findings, and provides a solid basis for the development of more effective management strategies in water distribution systems. The findings of this study have far-reaching implications for the planning and management of water distribution infrastructure. First, it is important for planners to consider the combination of pipe diameter and elevation in the design of the water distribution system. The choice of the right pipe diameter should be based not only on technical considerations, but also on an economic analysis that considers the long-term costs and benefits. Second, in areas with high elevation, there is a need for effective pressure management strategies to ensure that water flow remains stable and water capacity remains adequate. This may include the use of additional pumps, buffer tanks, or even redesign of the distribution network to reduce extreme elevation differences (Izadi, A., Yazdandoost, F., & Ranjbar, R. 2020). Third, simulation using software such as Epanet should be an integral part of the planning and design process. With simulation, planners can test various scenarios and determine the best solution before implementation, which can save cost and time and reduce the risk of system failure (Ren, W., Wang, X., & Yuan, X. 2020).

CONCLUSION

Conclusion This study concludes that pipe diameter and elevation have a significant influence on water capacity and velocity in the clean water distribution system. Larger pipe diameters consistently improve system performance, especially at distribution points far from the source

Elevation also plays an important role, where significant elevation differences can affect pressure and, ultimately, the speed and capacity of water flow. These findings provide valuable insights for the planning and management of water distribution systems, particularly in addressing peak demand challenges and improving overall system efficiency.

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