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Optimization of water flow on Regency Municipality Waterworks-network of Jonggat Central Lombok Regency using Ford Fulkerson Algorithm and Dinic Algorithm

Lilis Sriwahyuni[a], Marwan[b], Zata Yumni Awanis[c]

[a]Department of matematics FMIPA University of Mataram, Mataram, 83125, Indonesia. Email: lilissriwahyuni0405@gmail.com

[b]Department of matematics FMIPA University of Mataram, Mataram, 83125, Indonesia. Email: Marwan.math@unram.ac.id

[c]Department of matematics FMIPA University of Mataram, Mataram, 83125, Indonesia. Email: zata.yumni@unram.ac.id

A B S T R A C T

Clean water is essential for humans which must be fulfilled for humans survival. The population of human in Jonggat, Central Lombok, from one year to the next which causes the use of clean water getting increase too. The necessity of rising clean water is not in line with the availability of water supply, therefore the RMW (Regency Municipality Waterworks) manages existing water resource. Will be distributed to consumers. The purpose of this research is to determine the optimal solution in the distribution of clean water in Jonggat using Ford Fulkerson and Dinic algorithms. Both Ford Fulkerson and Dinic algorithms are methods used to calculate the maximum flow in a network. As results, the computations of Ford Fulkerson and Dinic algorithms in Phyton software show the maximum current is 133 liters/second and 133.49 liters/second, respectively. Meanwhile, the average water flow is delivered by RMW is 95 liters/second. It means, the amount of flow in clean water distribution by RMW can be added. It's for facilitating the flow of water that reaches consumers with the additional flow that cannot exceed 133.49 liters/second.

Keywords: *Dinic algorithm, Ford Fulkerson algorithm, Maximum flow, Network flow*

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* Corresponding author.

Alamat e-mail: lilissriwahyuni0405@gmail.com

INTRODUCTION

Clean water is the main need for human which must be fulfilled for humans survival. The quality of people's live depends on the quality of the water they consume, so clean water is very important for social and economic development.

The population of human in Jonggat, Central Lombok have increased from year to year which causes the use of clean water is also increasing. The increasing need for clean water is not in line with the availability of water in nature such as water resources, rivers, and others are starting to be disturbed due to soil pollution and land pollution, therefore the government gives authority to Regional Drinking Water Company (RMW) to manages the existing water resources which will be distributed to consumers. RMW Tirta Ardhia Rinjani Central Lombok using pipe system to distribute clean water. One of mathematics method can be used to analyze the problem is Graph Theory. Graph teory been around since 1736 which have many implementation in life (Munir, 2012). The clean water distribution problem can be modeled using maximum flow problem.

There are 5 algorithms that can be used to solve flow network problems. The five algorithms include Ford-Fulkerson algorithm, Edmonds and Karp algorithm, Dinic algorithm, MPM algorithm (Malhotra, Pramodh Kumar & Maheswari), and Goldberg-Tarjan algorithm (Thulasiraman & Swamy, 1992). This study uses two algorithms to solve maximum current are Ford Fulkerson and Dinic Algorithms. According to the several studies, Ford Fulkerson algorithm is the most efficient algorithm in solving the maximum current problem, so many studies use this algorithm. Moligane (2003), Dinic's Algorithm is more efficient than Ford Fulkerson's Algorithm. Therefore, researchers are interested using these two methods in optimizing the distribution of clean water in Jonggat.

Ford Fulkerson algorithm first discovered by L.R. Ford, Jr dan D.R. Fulkerson in 1956 which is used to calculate the maximum flow in a network (Khairani & Sirait, 2015). Dinic algorithm first discovered by Dinic in 1970 which is used to calculate the maximum flow in a network using transportation network N, residual network, layered network and blocking flow (Yudhianto, 2003).

RESEARCH METHODS

The data used is secondary data, the data obtained from RMW Tirta Ardhia Rinjani Central Lombok. Find the maximum flow in the distribution of clean water in Jonggat use Ford Fulkerson and Dinic algorithms. Both algorithms are solved using python software.

The steps in this research are as follows:

1. Literature study. This research begins with study literature on maximum flow, network flow, Ford Fulkerson algorithm, Dinic algorithm and others. Study literature are searched on several sources such as books, journals and previous research.
2. Data collection. Data obtained in RMW Tirta Ardhia Rinjani Central Lombok, the data is in the form of a clean water distribution scheme in Jonggat, Central Lombok which was obtained from RMW Tirta Ardhia Rinjani Central Lombok.
3. Determine the maximum flow value that can flow from the reservoir to the destination using Ford Fulkerson algorithm and Dinic algorithm.
4. Conlusions are obtained based on research results.

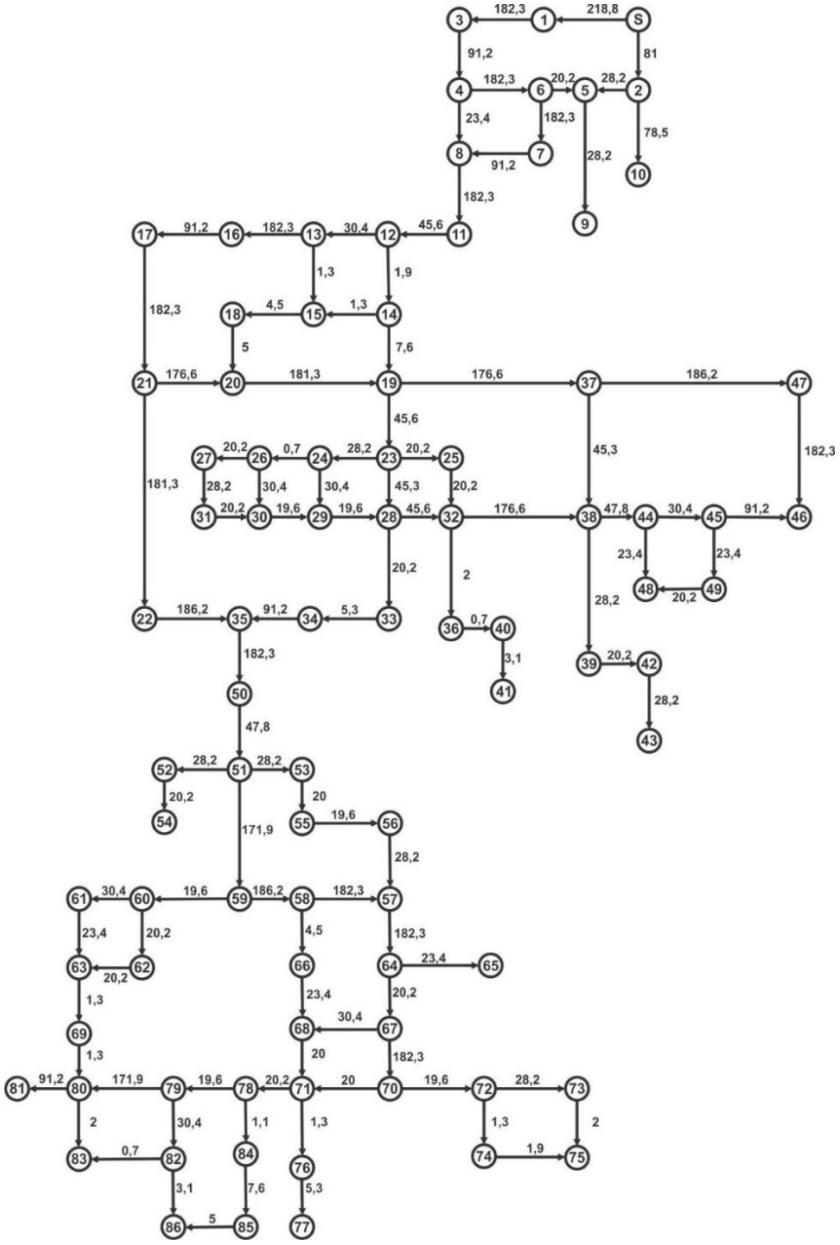

Figure 1. Distribution network scheme of clean water in Jonggat

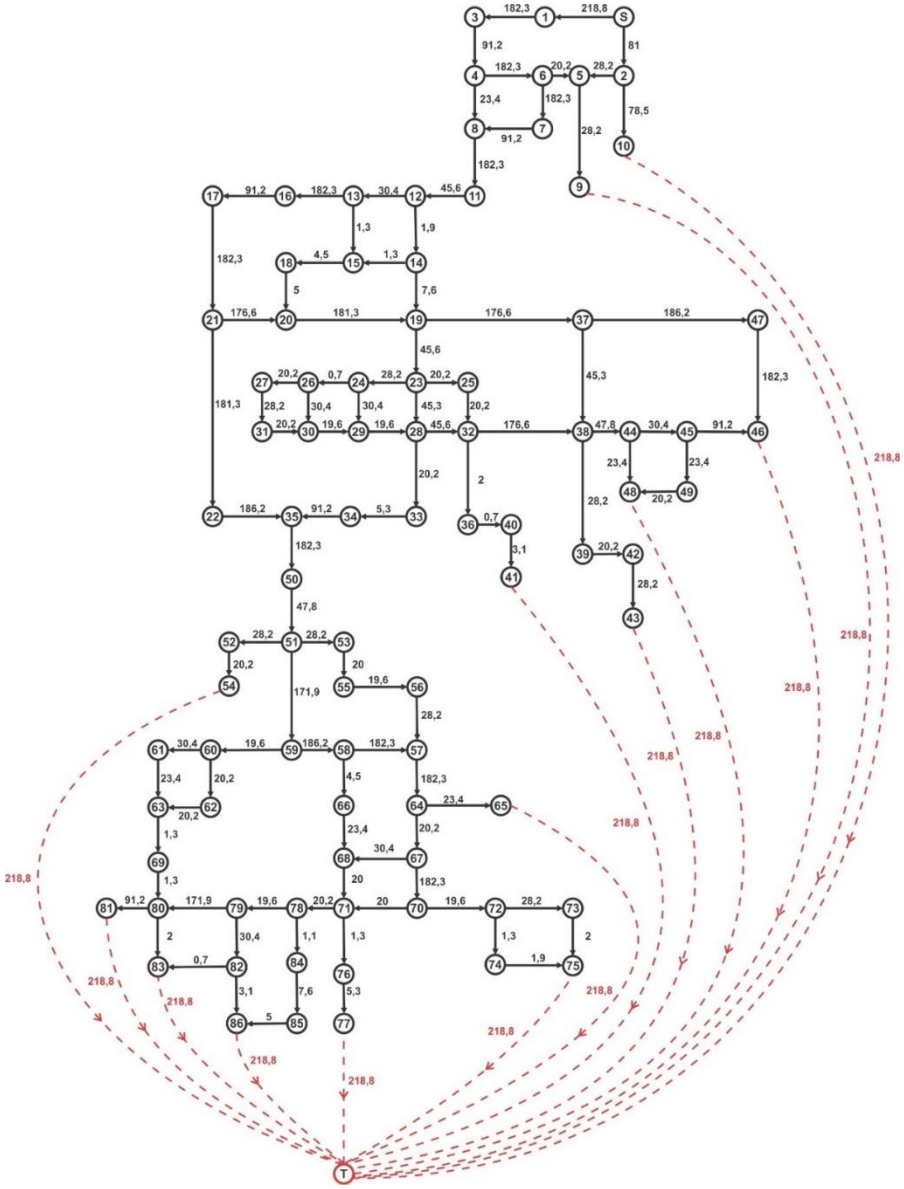

Figure 2. Distribution network scheme of clean water in Jonggat after adding supersink

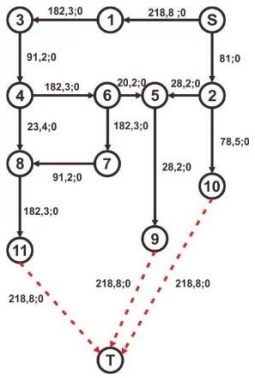

Figure 3. Part graph of the clean water distribution scheme in Jonggat in Figure 1

In Figure 3, researchers determine the maximum current using Ford Fulkerson and Dinic Algorithms. first of all define the augmenting path.

The following bellow are the augmenting path from Figure 3.

1. S-1-3-4-8-11-T
2. S-1-3-4-6-7-8-11-T
3. S-1-3-4-6-5-9-T
4. S-2-5-9-T
5. S-2-10-T

Iteration 1:S-1-3-4-8-11-T
Node S is labeled $[-, \infty]$

Node 1 is labeled $[S;\ \min\{\infty, 218{,}8 - 0\}] = [S; 218{,}8]$

Node 3 is labeled $[1;\ \min\{218{,}8\ , 182{,}3 - 0\}] = [1; 182{,}3]$

Node 4 is labeled $[3;\ \min\{182{,}3\ , 91{,}2 - 0\}] = [3; 91{,}2]$

Node 8 is labeled $[4;\ \min\{91{,}2\ , 23{,}4 - 0\}] = [4; 23{,}4]$

Node 11 is labeled $[8;\ \min\{23{,}4\ , 182{,}3 - 0\}] = [8; 23{,}4]$

Node T is labeled $[11;\ \min\{23{,}4\ , 218{,}8 - 0\}] = [11; 23{,}4]$

Node T has labeled, add flow 23,4

$f(S, 1) = 0 + 23{,}4 = 23{,}4$

$f(1{,}3) = 0 + 23{,}4 = 23{,}4$

$f(3{,}4) = 0 + 23{,}4 = 23{,}4$

$f(4{,}8) = 0 + 23{,}4 = 23{,}4$

$f(8{,}11) = 0 + 23{,}4 = 23{,}4$ (maximum flow)

$f(11, T) = 0 + 23{,}4 = 23{,}4$

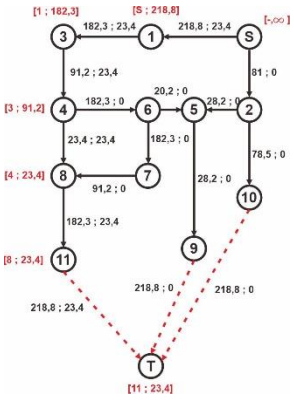

Figure 4. result iteration 1:S-1-3-4-8-11-T

And then do the next iteration until there are no more paths that can be passed. So the maximum current is 172.2 liters/second.

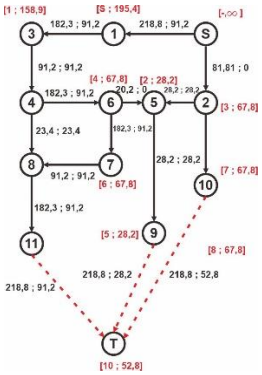

Figure 5. maximum flow use Ford Fulkerson Algorithm

Determine the maximum current using Dinic's Algorithm. The Dinic algorithm is as below. (Yudhianto, 2003).

1. Start with flow 0, $f(e) = 0$, for each edge e of G.

2.Construction of the residual network $G_f = (V, E_f)$ relative to the flow f in G.

3. Construction of layered network G_L relative to the flow f in G.

4. Determine blocking flow g in layered network to obtain the maximum flow. Update the flow on the graph. If there is a path that can still be passed then return to Step 2.

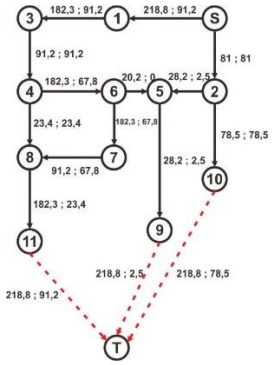

Figure 6. maximum flow with Dinic algorithm

Using the Dinic Algorithm, a maximum flow is 172.2 liters/second. So the conclusion that using the Ford Fulkerson and Dinic Algorithms, the maximum flow is 172.2 liters/second.

RESULT AND DISCUSSION

In this study, the author wants to determine the maximum flow in the distribution of clean water in Jonggat using Ford Fulkerson algorithm & Dinic algorithm and compare the results of the two algorithms. Data obtained from RMW Tirta Ardhia Rinjani Central Lombok are distribution schema of clean water pipe network and maximum flow of each pipe. There are 88 vertices and 106 edges to be analyzed. The scheme of the RMW pipe network used can be seen in Figure 1. The average water flow is delivered by RMW is 95 liters/second, this amount is said to be still lacking because many consumers are short of water.

Maximum flow is a problem that start from source to sink. So, it will add a supersink connected by the edges with the actual destination vertices, where the weight of this side must be greater than or equal to the weight of the largest side in the network to avoid excess capacity that exists on of the trajectory. The biggest weight is 218.8 liters/second. So, the weight used in connected edges to the supersink is 218.8 liters/second. So, that the distribution network after adding the red dashed line and we called supersink can be seen in Figure 2. In Figure 2 we will find maximum flow using Python software. Based on the results of research using Python software on the Ford Fulkerson algorithm, the maximum flow is 133 liters/second, while using the Dinic algorithm, the maximum flow is 133.49 liters/second. Ford Fulkerson Algorithm is more accurate than Dinic Algorithm because the Dinic Algorithm has an error value of 0.49.

CONCLUSIONS

The maximum flow that RMW can flow in Jonggat using Ford Fulkerson algorithm is 133 liters/second while using Dinic algorithm is 133.49 liters/second. Increasing the amount of water flow in the distribution of clean water will have a better effect in fulfilling consumer needs if compared with the flow provided by RMW of 95 liters/second, so that the results obtained become a reference for providing flow in the network to better fulfill consumer needs and avoid pipe damage caused by excess capacity of the pipe in the network. Dinic algorithm is more effective than Ford Fulkerson algorithm because the results obtained are largest and more accurate.

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