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Application of minimum spanning tree algorithm to improve water distribution in Modibbo Adama University Yola

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Abstract:

Modibbo Adama University (MAU) used underground water as a source of water, it mainly used drilled boreholes to supply water to different areas in the university. However, in recent years it experiences inadequacies in supply to some of it storage facilities, this might be due poor distribution network to connect the supply boreholes and storage facilities. The study used minimum spanning tree algorithm to developed a water Distribution network for MAU. The coverage area is main campus of the university along Mubi road in Grei Local Government. The minimum spanning tree algorithm was used to realize the aim of the study, the developed network is reliable to meets water supply demand of the study area. A combined total length of 2.72 km was in existence, which connected only six industrial boreholes. The symmetric matrix which represents all possible distance connecting the eleven industrial boreholes was determined and used to develop the network. The result shows that a total length of 3.339KM is required to connect the eleven Industrial boreholes. The optimum network connecting servicing boreholes and distribution storage reservoirs was realized. Similarly, it was also discovered that the industrial boreholes alone have an average discharge yield of 189360 L/h. Considering world standard for the demand per capita of one hundred liters per day (100L/day) the yield is capable of meeting the growing population if properly manage. It was clearly shown that the process reduces the pipes length especially when compared existing network, where the pipes were installed without any proper procedures. Therefore, it is recommended that, this research work should be implemented to reduce to water shortest and university should have ideal network pattern for effective water distribution.

Keywords: *Distribution, Nodes, Spanning tree, Water network*

1. Introduction

Modibbo Adama University is underground water as a source of water, it mainly used drilled boreholes supply water to different areas in the university. However, in recent years it experiences inadequacies in supply to some of its storage facilities, this might be due poor distribution network to connect the supply boreholes and storage facilities. [1] revealed that the practice of water distribution for end-use has been in existence for a long time. Starting from the first ever laid pipes about 3500 years ago in Crete, to today's modern sophisticated and complex hydraulic models like the water system called the "Big Apple" in USA, it is clear to note that Water systems has experienced a great transformation across the world.

[2] mentioned that China floated the largest Water distribution system ever due to her severe water challenges.[3] designed the water distribution network with using EPANET software, the network is laid according to old day's requirement and is not suitable to the future needs and demands. The network was proposed according to the master plan keeping in view the ease and accessibility of the network with roadside and straight as it will help the laying out easy and less complicated. To design network in Chirala Municipality in Prakasam District of Andhra Pradesh, Bolognesi, *et al.* [4], proposes a new modal named „genetic heritage evolution" by stochastic transmission GHEST, a multi population evolutionary strategy like algorithm applied to the design of water distribution network. In computer science, Prims algorithm is an algorithm that finds a minimum spanning tree for a connected weighted undirected graph. This means it finds a subset of the edges that forms a tree that includes every vertex, where the total weight of all the edges in the tree is minimized. Prims algorithm is an example of a greedy algorithm.

The algorithm was developed in 1930 by Czech mathematician Vojtech Jarnik and later independently by computer scientist Robert C. Prim in 1957 and rediscovered by Edsger Dijkstra in 1959. Therefore, it is also sometimes called the DJP algorithm» the Jarnik algorithm, or the Prim-Jarnik algorithm [5].

[6] presents a mathematical simulation of canal operation for optimizing water allocation within a multiple crop rotation canal. [7] presented an overview of the multi-objective shortest path problem (MSPP) and a review of essential and recent issues regarding the methods to its solution. The paper further explored a multi-objective evolutionary algorithm as applied to the MSPP and describes its behavior in terms of diversity of solutions, computational complexity, and optimality of solutions, Results show that the evolutionary algorithm can find diverse solutions to the MSPP in polynomial time (based on several network instances) and can be an alternative when other methods are trapped by the tractability problem. As in the case of the single-objective shortest path problem, the multi-objective shortest path problem has been studied extensively by various researchers in the fields of optimization, route planning for traffic, transport design. Effective understanding of water and sanitation supply in developing States such as Edo State is a useful tool in addressing uneven distribution of these utilities [8]. This research study focuses on the evaluation of water and sanitation supply the state using baseline and demand responsiveness approaches to capture data on water d sanitation supplies in all the 18 local government areas in the State. The output of the analysis revealed that 62% representing 1,346,649, population could not access portable water, while 38% corresponding to 813,199 could fairly access portable water in 1993. [9] works on examines the nature of potable water supply and demand in Jema'a Local Government Area of Kaduna State. A total of 220 questionnaires were administered to households in five wards within the study area, although only 200 of these questionnaires were used for the purpose of analysis. Findings revealed that at some times and locations, the value of water can be very high due to scarcity, but at other times and locations it can be very low or even free due to relatively plentiful supplies.

[10] studies the challenges facing water supply for residents of Osiele in Ogun State, and recommend ways of improving it. [11], studied about the use of EPANET in the design of NDA water distribution network. This network consists of pipes, nodes, pumps, valves and storage tanks in reservoirs. EPANET tracks the flow, pressure height of water in each pipe, tank, etc. [12], deals with importance of flexible WDS design under uncertain future water demand. Zebedee [13] reported that inadequate supply of portable drinking water has been a problem to the residents of Jimeta metropolis, especially those residing in the following Wards: Jambutu, Wuro-Jabbe, Kofare and Saminaka which has been an ongoing problem as at the time of this research work dated March, 2014. Based on the findings of this studies the major problem has been the lack of piped water distribution network spanning the areas mentioned above. The objective of his study is to provide an Optimal Minimum Spanning Tree Protocol for Pipe Water Distribution Network in Jimeta Metropolis. The minimum spanning tree protocol has been demonstrated in this study which spanned the entire 16 Wards of the study area with minimum total pipes length of 29.65Km as against 47.482Km (excluding the transmission lines and service pipes). The results obtained justify the need to apply this kind of algorithm for efficiency and profitability. According to [13] inadequate supply of portable drinking water has been a problem to the residents of Jimeta Metropolis and optimal minimum spanning tree protocol has demonstrated to distribute water at minimum pipe length. Minimum Spanning Tree can be applied in many areas including transportation, communication, networking, and project management because of' its universality. It is one of the most intractable problems in Operations Research; consequently, it has become a popular playground for the latest optimization! techniques including virtually all local search paradigms. [14] Proposed an evolving network model which exhibits community structure. The network model was based on the inter-community; preferential attachment and mechanisms. The degree of distributions, of this network model, is analyzed based on a mean field method. Theoretical results and numerical simulations indicate that this network model has community structure and scale-free properties.

2. Material and Method

2.1 Study Area

MAU was established in 1981 and kicked off with about 214 students in 1982/1983 academics session. As of today, the university has about Twenty thousand (20,000) students and One thousand six hundred staff both academic and non-academic. The main campus is located along Yola-Grei-Mubi Road about 13 km away from Jimeta a State Capital of Adamawa State on Latitude 9.34702^0 north.

2.2 Types and Source of Data

For the purpose of this study the data used are of two types: the primary data which was obtained from the field and interview, and secondary data collected from the works department, academic planning unit and survey and geoinformatics Laboratory, all in MAU, Yola.

2.3 Population forecasting

By Geometrical increase method the population after 3 decades will be calculated as Present population of the area (P), Decennial population growth (Ig) = 13.39%

$$rg = Ig/100 = 0.1339$$

Design period (n) = 3 decades

$$Future\ population\ (Pn) = P\ (1 + rg)\ n \quad (1)$$

2.4 Minimal Spanning Tree Algorithm

The minimal spanning tree algorithm deals with linking the nodes of a network, directly or indirectly, using the shortest length of connecting branches. A spanning tree is a connected network that includes all the nodes in the network with no loops. In a minimal spanning tree problem, the desire is to determine the spanning tree that results the smallest sum of the connecting arcs. Thus, the minimal spanning tree deals with finding the most efficient connection among all the nodes in the network.

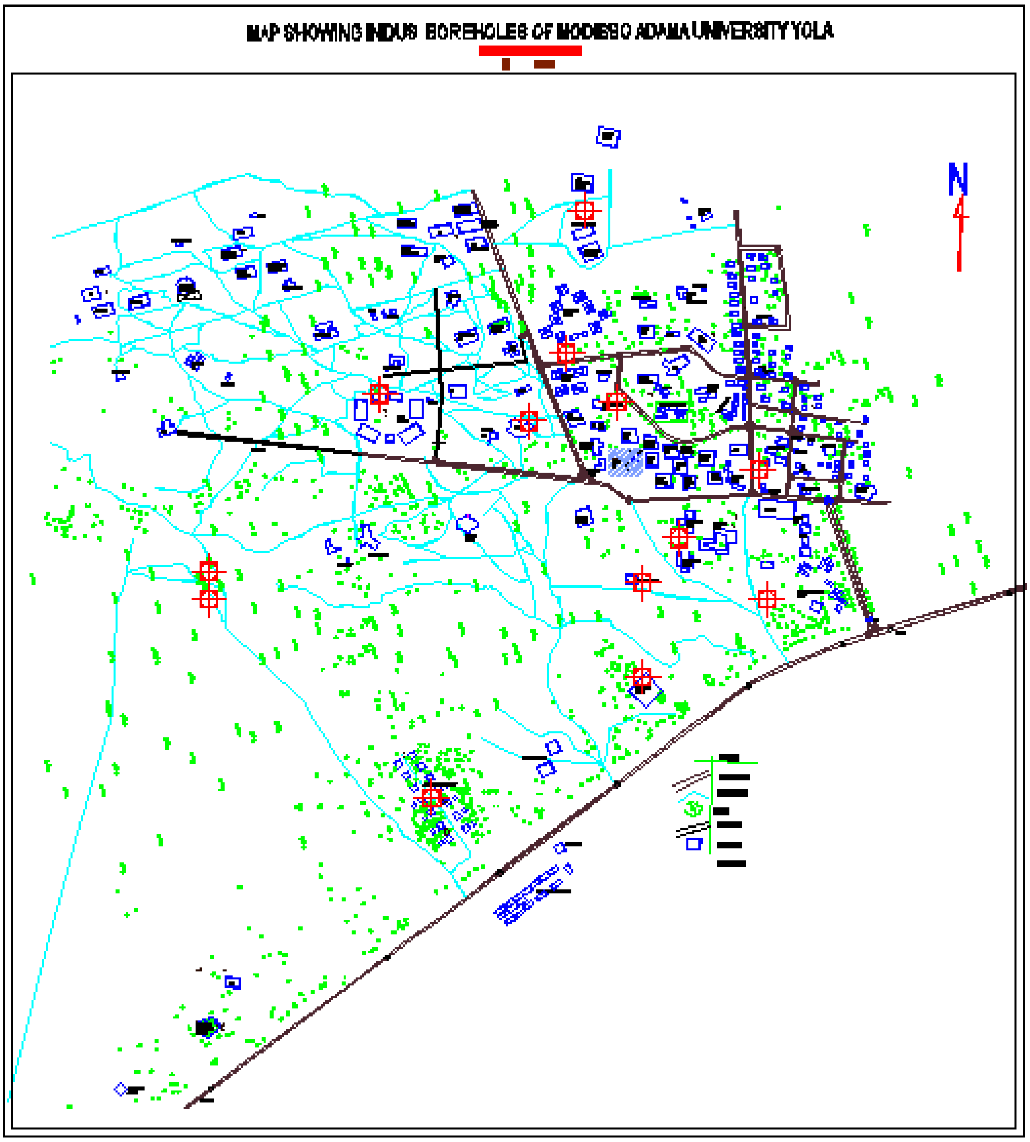

Figure 1: Map of the Study Area

The objective is to construct a connected network that is loops free. In solving the minimum span problem, it is assumed that there are enough proposed branches to ensure the existence of a solution [15]

The steps of the procedure are given as follows:

C_k = Set of modes that have been permanently connected at iteration k of the algorithm

$\bar{c}_k$ = set of nodes as yet to e connected permanently

Step 0. Set C_0 = and $\bar{c}0 = N$

Step 1. Start with any node, I, in the unconnected $\bar{c}_0$ and $C_1 = \{i\}$, which automatically renders $\bar{c}_1 = N - \{i\}$

Set k = 2

General step k. selects a node j*, in the unconnected set $\bar{c}_{k-1}$ that yields the shortest branch to a node in the connected set $\bar{c}_{k-1}$. Link j* permanently to $_{k-1}$ and remove it from $\bar{c}_{k-1}$ that is,

$$Ck = Ck - 1 + \{j *\}, \quad \bar{c}_k = \bar{c}_{k-1} - \{j *\} \quad (2)$$

If the set of unconnected nodes $\bar{c}_k$, is empty, stop. Otherwise, set k = k + 1 and repeat the step [5].

3. Results

The study identifies Seventeen (17) water storage facilities at various locations within the study area. Location of each storage facility was identified and recorded using a surveying tool called GPS. Furthermore, these storage facilities were categorized into two: Servicing tanks and Distribution tanks, among which eight were categorized as Distributions tank and are presented in table 2. The study revealed that there are about thirty-nine functional boreholes, out of which eleven of them were industrial boreholes (servicing boreholes). For this study the boreholes with pump capacity of five horse power (5 HP) and above were classified as industrial boreholes (servicing boreholes) as presented in table 1. Similarly, it was also discovered that the industrial boreholes alone have an average discharge rate or yield of 189360 L/h. considering world standard for the demand per capita of

(100L/day) the yield is capable of meeting the growing population if properly manage.

Table 2 representing the numbers of distribution storage tanks in the study area. Also, their GPS Coordinate was taking and place on the map, this helps the researcher in identifying services area of the network. Similar it was discovered that some of the storage facilities were mainly serves by nonindustrial boreholes. Therefore, if the storage tanks are properly connected with the developed network, the water demand will be met.

Also, Table 3, is a symmetric matrix represent all possible distance connecting all the nodes. The nodes were numbered one to eleven each number is representing a particular industrial borehole in the study area as presented in Table 1. From the matrix Table node 6 to 1 and node 9 to 2 gives the longest distance of one thousand three hundred and fifty meters and node 8 to seven gives shortest this distance of one hundred and sixty-two meters. The table was used to developed the network. The results were presented in tables and figures.

Table 1: Industrial Borehole in Study Area

	Borehole name	GPS Co-ordinate		Pump	Yeild	Pipe Diameter
		Northing	Easting	Power (HP)	L/S	Inch
1	Nata'ala	1033791	0224215	7.5	5	3" into 4"
2	Professors Quarters	1033088	0224907	5.5	3.7	2" into 2"
3	Academic Publishing Centre	1033464	0225564	7.5	6.7	3" into 3"
4	Land Scape	1033704	0225950	15	10	3" into 6"
5	Senate Building	1033895	0225679	5.5	3.7	2" into 2"
6	CEMIT	1034106	0225924	5.5	3.7	2" into 2"
7	Nana/Usman na Goggo Hostel	1034317	0225483	5.5	3.7	3" into 3"
8	Kabiru Umar Hostel	1034469	0225328	5.5	3.7	2" into 2"
9	New Posgraduate Female Hostel	1034914	0225383	5.5	3.7	2" into 2"
10	SMIT	1034258	0225211	5.5	3.7	2" into 2"
11	Faculty of Agric	1034342	0224746	7.5	5	2" into 2"

Table 2: Distribution Storage Tank in Study Area

S/N	Location	GPS Northing	Co-ordinate Easting
A	Architecture	1034448	0225101
B	CEMIT	1034107	0225946
C	Nana/Usman *na Goggo* Hostel	1034306	0225576
D	Old Food Science Department	1034128	0225639
E	Faculty of Agriculture	1034342	0224746
F	New Undergraduate and Postgraduate Hostel	1034794	0225447
G	Faculty of Education	1034809	0225300

Table 3: Distance Matrix (m)

Route	1	2	3	4	5	6	7	8	9	10	11
1	0	756	1026	1242	1134	1350	999	1026	1242	810	594
2	756	0	540	864	918	1053	972	1080	1350	864	918
3	1026	540	0	324	324	1080	621	729	1080	621	864
4	1242	864	324	0	243	270	540	702	972	675	999
5	1132	918	324	243	0	243	324	486	756	432	783
6	1350	1053	1080	270	243	0	351	513	756	567	864
7	999	972	621	540	324	351	0	162	432	216	540
8	1026	1080	729	702	486	513	162	0	324	216	432
9	1242	1350	1080	972	756	756	432	342	0	513	594
10	810	864	621	675	432	567	216	216	513	0	351
11	594	918	864	999	783	864	540	432	594	351	0

Table 4: Distances connected servicing boreholes and distributions tanks

S/N	A	B	C	D	E	F	G
1	1080	1350	999	1080	594	1242	702
2	1134	1053	972	999	918	1350	1215
3	486	1080	621	486	864	1080	1215
4	486	270	540	459	999	972	1242
5	594	243	324	162	783	756	1134
6	648	0	351	216	864	756	1107
7	270	352	0	132	540	432	810
8	162	513	162	297	432	324	648
9	324	756	432	594	594	0	621
10	216	756	216	459	351	513	540
11	297	864	540	675	0	594	243

The minimum spanning tree protocol has been used in this study to realize the objective and the algorithm was found efficient and easy to operations. Figure 2 is the old distribution network system which was not efficient to serve the needs of university main campus. The result from this study as in Figure 3 shows a combined total length of 2.72 km was in existence which connected some of the Industrial boreholes. This shows that there is no optimality or any standard procedures follow in existing network. However, the old network connected only six industrial boreholes out eleven. The route path through (1,7), (2,3), (3,5), (5,6) and (4,6), which gave distance of 2.72 km.

The developed networks come with minimum length that covered the eleven industrial boreholes as presented in Figure 4. The optimum network gives a total length of 3.339 KM. comparing these with the old network; we will conclude that the network is reliable with only a difference of 0.639KM. Similarly, Figure 5 was general network connection of servicing borehole and distribution storage facilities. This revealed the alternatives servicing borehole to each distribution storage facilities. Also Figures 4 and 6 present the optimal network for the water distribution system.

4. Discussion

The network starts with connecting industrial boreholes. The distance from each node was measured as in Table 3. The main aim of using minimum spanning tree algorithm is to find the minimum length connecting one node to another. If the least length between boreholes can be identified, the cost of networking can be reduced thus minimizing number of pipes and maximizing water supply. The use minimum spanning tree algorithm, in this case, was clearly shown to be advantageous since it assisted in reducing the total length of the pipes needed. However, using of random means to establish the route, lead to wastage of pipes by even more than 180% when compared to what minimum spanning tree algorithm. The distribution system proposed is intended to be strong efficient and durable that can serve the needs of university main campus.

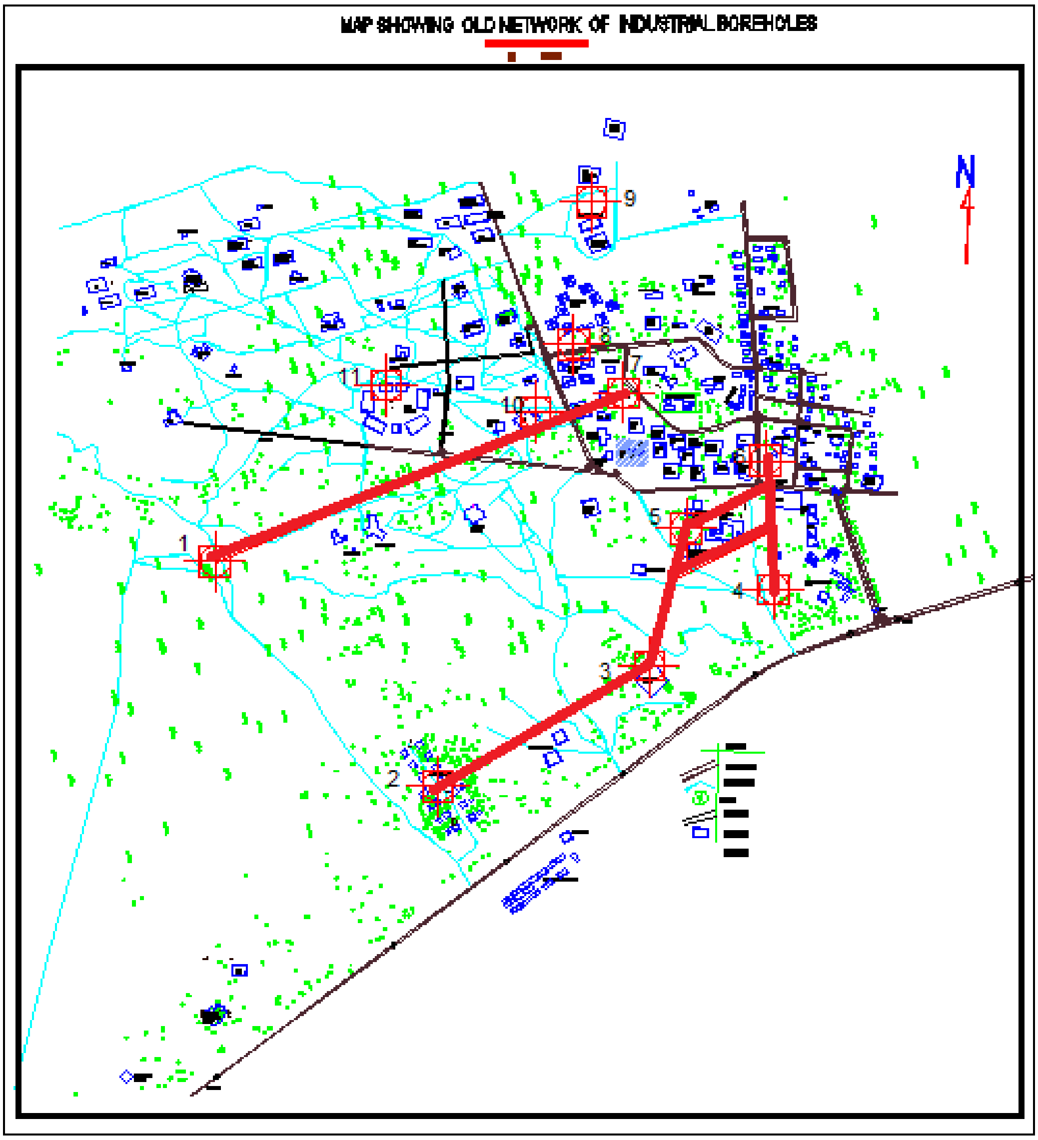

Figure 2; Existing network (Old network of industrial borehole)

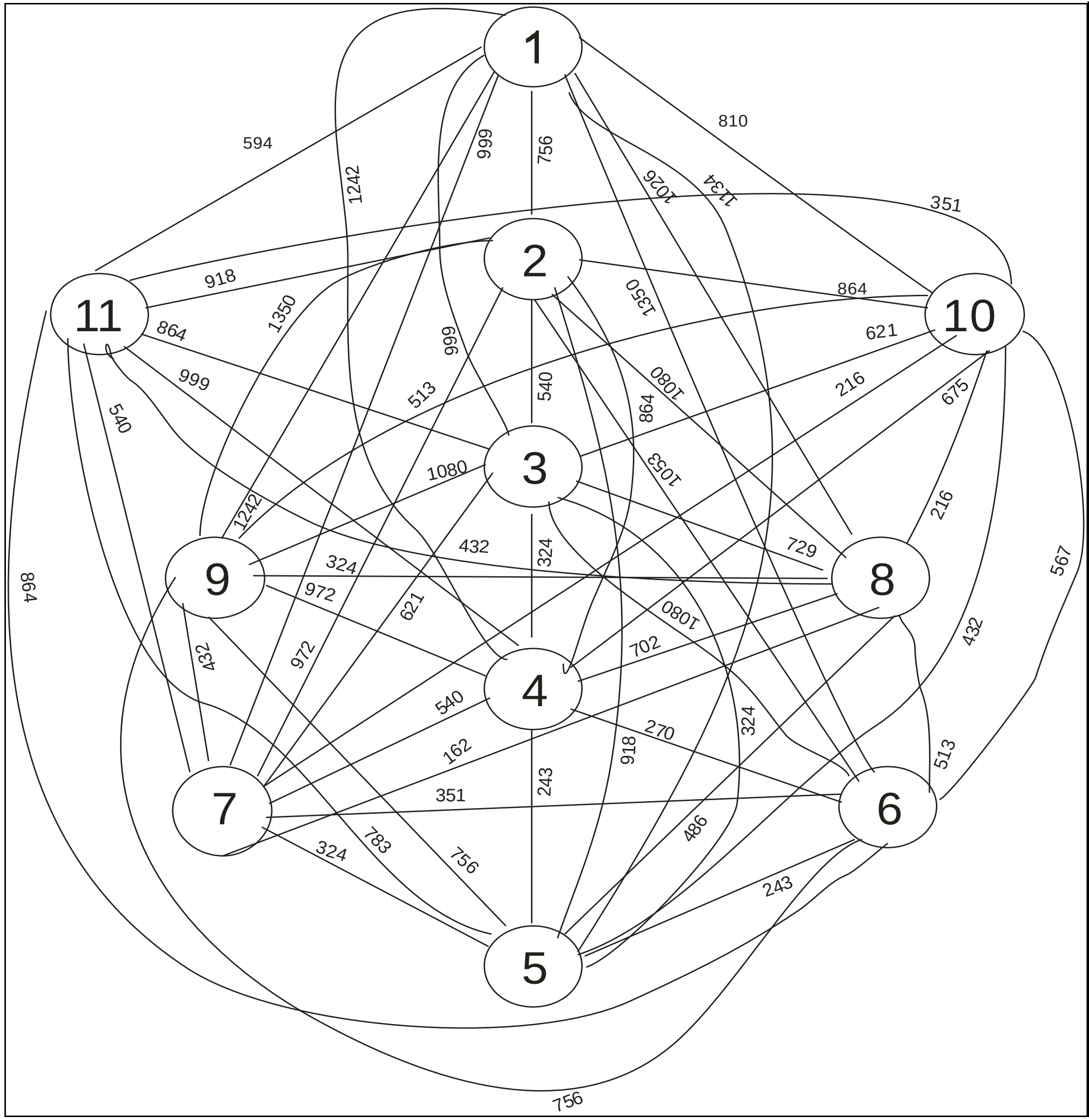

Figure 3: Developed network connecting servicing borehole, the possible links and their distances

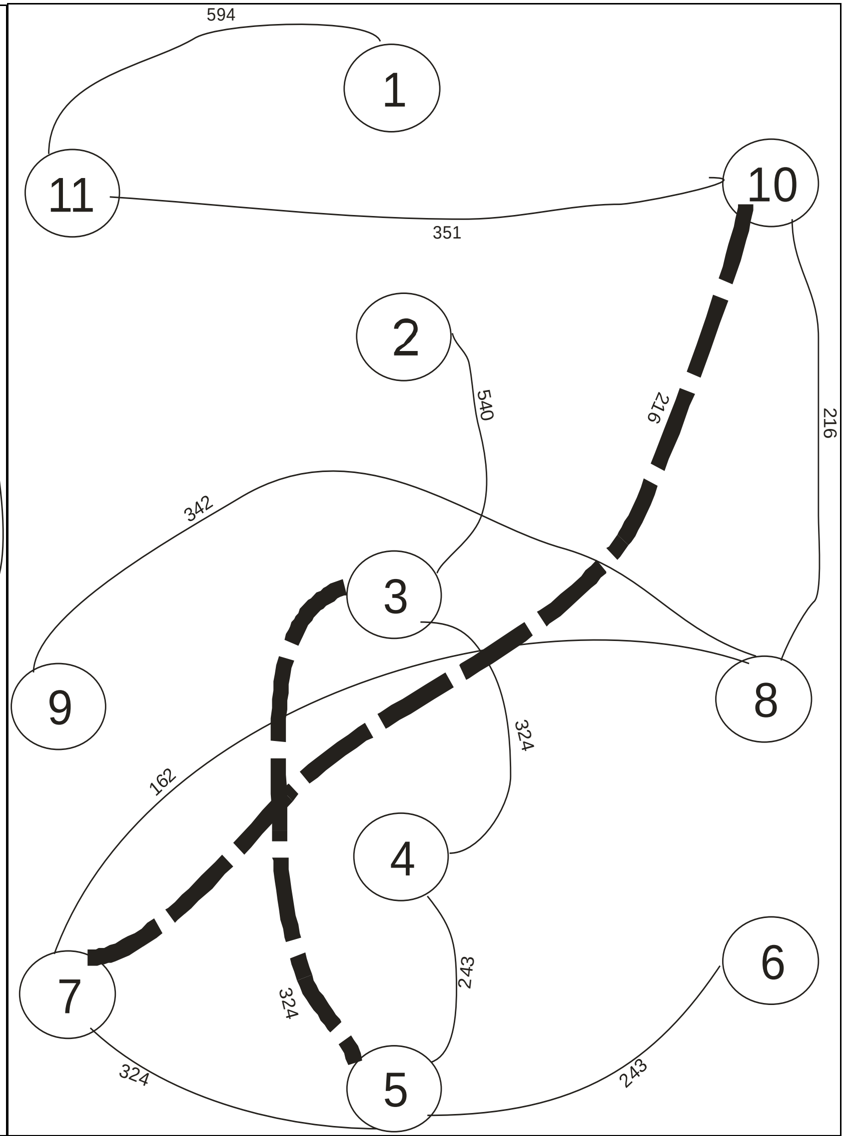

Figure 4: Developed minimum spanning tree network for the study area showing optimized links

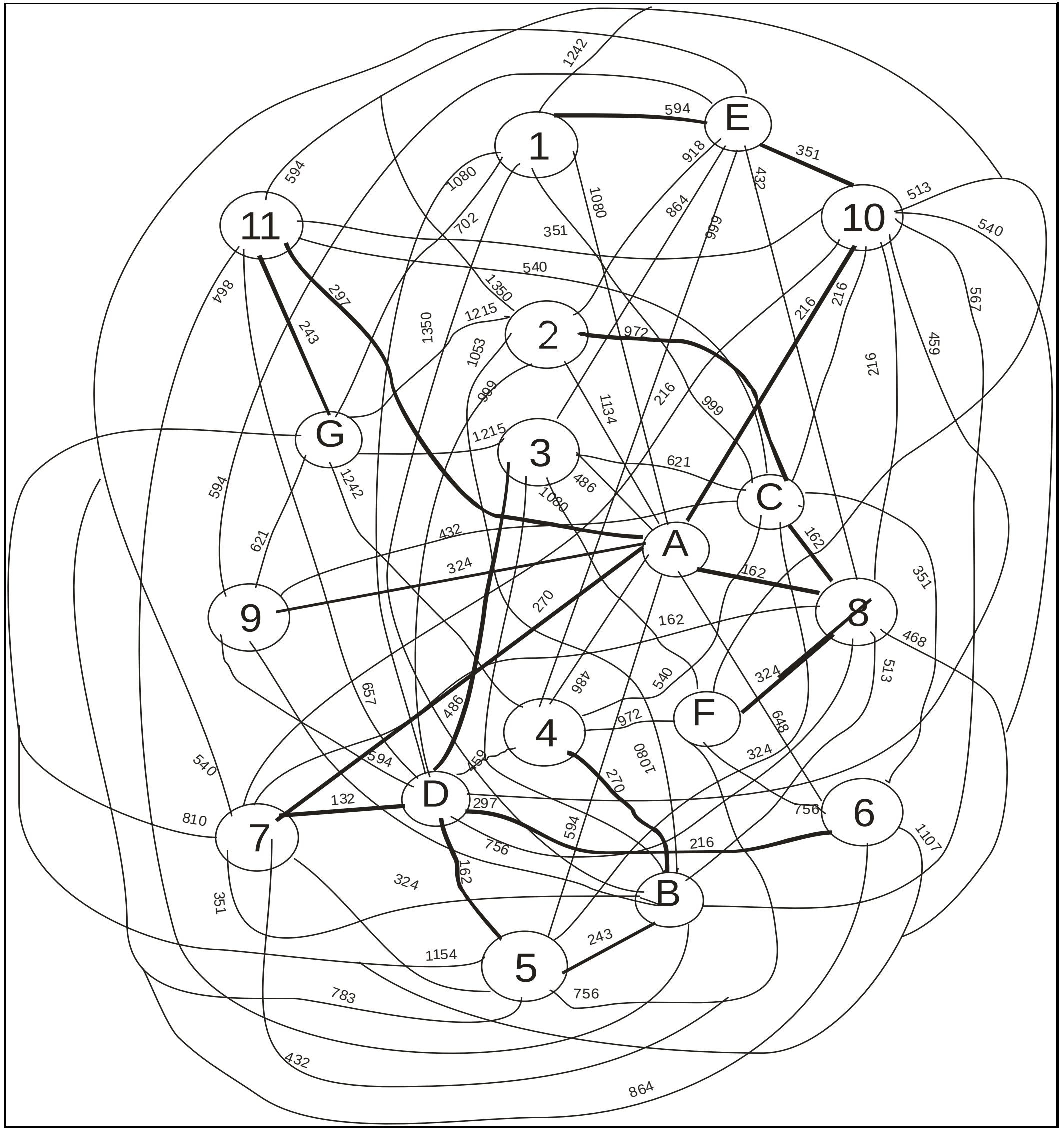

Figure 5: Developed network connecting distribution tanks and servicing boreholes

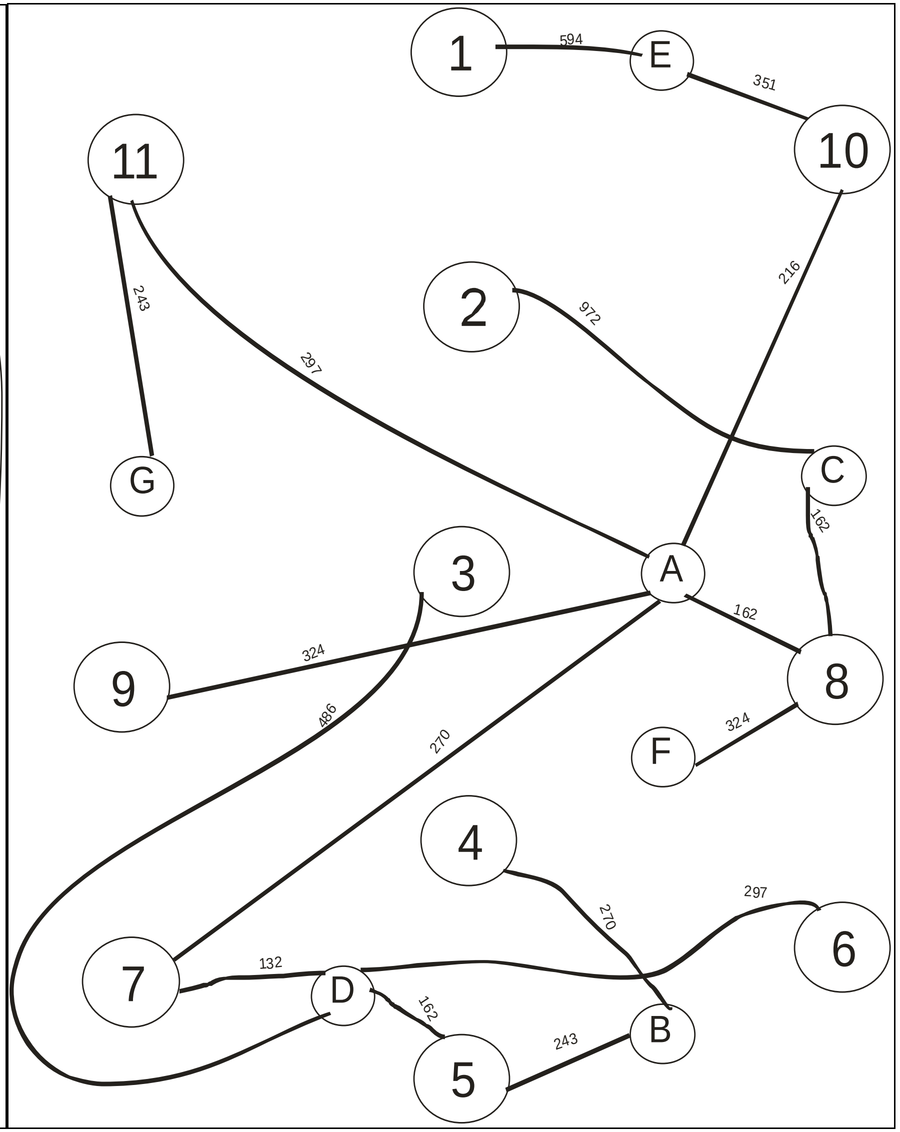

Figure 6: Developed minimum spanning tree network connecting industrial boreholes and storage tanks

The result from this study shows a combined total length of 3.339 KM is required to connect the main line of Industrial boreholes. This demonstrates a remarkable improvement compared with old network connecting only six industrial boreholes out eleven. The symmetric matrix obtained represent all possible distance connecting all the nodes. The nodes were numbered one to eleven; each number is representing a particular industrial borehole in the study area as presented in table1. Also, GPS Coordinate of the storage facilities was taking and place on the map, this helps the researcher in identifying services area of the network. Similarly, it was discovered that some of the storage facilities were mainly serves by non-industrial boreholes in their proximity. Therefore, if properly connected with the developed network in figure 6, the water demand upon the storage tank will be met.

The pump capacity was very important for the developed network, this is to know that the capacity at which the borehole's operate and average power required by each borehole within production time. Furthermore, the cost of production in terms of power consumption can be easily identify and the scheduled for production hour to optimize power consumption can be easily done. Yields or discharge rate is also of paramount important for efficiency and effectiveness for the network this is because the demand on service areas depends on its consumption rate. Therefore, demand rate and supply rate were proportional, that means the borehole yield has been in consideration to meets the demand of each service area. One of the major factors to be considered for effectiveness of the water distribution network was the water pressure. For the developed network the sizes of the pumping pipes and distribution pipes was measured, this is because the velocity of the water flowing in a pipe depends on the pipe diameter this is to shows that if the pumping pipe and distribution pipe are of the same diameter it means that no pressure scale up for the network. Therefore, for pressure scale up the output diameter should be less than the input diameter; this can be applied where necessary in the developed network depends of topography of the layout.

The main success of this research was the effective's distribution network was developed using minimum spanning tree algorithm. Also, the study revealed the number of functional boreholes, servicing tanks and distribution tanks. The research further revealed the co-ordinate of the borehole and storage facilities in the study area. Location of each storage facility was identified and recorded. Also out of thirty-nine functional boreholes, eight were industrial boreholes. The finding of the research revealed the Industrial boreholes have an averages discharge rate of 189360 L/h. The minimum spanning tree algorithm was used to realize the aim of the study and developed networks were found feasible to meet its purpose. The minimum lengths are selected while avoiding forming cycles in the process. The lengthy were obtained progressively. Figure 4 and 6 represent the final minimum spanning tree, optimum network based on the least length possible. The total length of pipes needed was 3.339 to connect the eleven industrial boreholes in the university.

5. Conclusion

During the study it was discovered that the existing network has no any procedure adopted for water distribution network. The research further identified the co-ordinate of the borehole and storage facilities in the study area. Location of each storage facility was identified and recorded. Also out of thirty-nine functional boreholes, eight were found to be industrial boreholes. The researchers found it suitable to used minimum spanning tree algorithm in developing the network. Distribution system developed was intended to be strong efficient and durable that can serve the water needs of university main campus. The result from this study shows a combined total length of 3.339KM is required to connect the Industrial boreholes.

Conclusively water supply problem affects almost everybody in study area, therefore the significant of the conducted research was to develop a distribution network that will mitigate the existing problem. Therefore, the developed network if adopted it will improve the water distribution and storage capacity in MAU, Yola main campus. Further research should be conducted in cost and water supply optimization

References

[1] Walski, T. M., Chase, D. V., Savic, D. A., Grayman, W., Beckwith, S., and Koelle, E. (2003). Advanced water distribution modeling and management, Civil and Environmental Engineering Mechanics Faculty publication. http://ecommons.udayton.edu/cee_fac_pub/18

[2] Kuo, L. and Quarts, J. (2014). China has launched the largest water-pipeline project in history. *The Atlantic*, 8(4), 1–18.

[3] Ramana, G. V., Sudheer, C. V., and Rajasekhar, B. (2015). Network analysis of water distribution system in rural areas using EPANET. *Procedia Engineering*, 119, 496-505.

[4] Bolognesi, A., Bragalli, C., Marchi, A., and Artina, S. (2002). Design and analysis of water distribution system, *Journal of Infrastructure Systems*, 21(2), 234-238.

[5] Taha, H. A., (2007) "Operation Research an Introduction" 8th edition, Pearson Education, Inc. India

[6] Ahmed, E. E., (2010). Water Allocation and Optimization of Minor Canal Operation, Agriculture and Biology, *Journal of North America*. 2(1):33-41

[7] Pangilinan, J. A. and Jansens, K. J., (2007). Evolutionary Algorithms for Multi-objectives shortest path problem, *International Journal of Mathematics, Computational, Physical Electrical and Computation Engineering*, 1(1) pp 7-12

[8] Idogho, P. O., Yahaya, O. and Dagona, A. G., (2013). Modelling water Sanitation Relationship in Edo State, Nigeria, *Advance in Scientific and Engineering Research*, 2(1), 10-17.

[9] Abaje, I. B., Ati, O. F. and Ishaya, S., (2009). Nature of Potable Water Supply and Demand in Jema'a Local Government Areea of Kaduna State,

Nigeria, *Research Journal of Environmental and Earth Sciences,* 1(1), 16-21.

[10] Ojo, O. M., (2014). Availability and Use of Domestic Water in Osiele Area of Ogun State, Nigeria, *Research Journal in Engineering and Applied Sciences*, 3(2) 104-107

[11] Saminu, A., Abubakar, N. and Sagir, L., (2013). Design of NDA water distribution network using EPANET. *International Journal of Emerging Science and Engineering (IJESE)*, 1(9), 5-9.

[12] Basupi, I. and Kapelan, Z., (2015). Evaluating flexibility in water distribution system design under future demand uncertainty. *Journal of Infrastructure Systems*, 21(2), 04014034.

[13] Zebedee, A. A., (2014) Optimal Minimum Spanning Tree Protocol for Pipe Water Distribution Network for Jimeta Metropolis Adamawa State" A thesis Submitted to the Department of Statistics and Operations Research Modibbo Adama University Yola. Unpublished

[14] Eckoson, N., (2016) Application of Minimum Spanning Tree for Pipe Water Distribution Network in Numan Metropolitan, Adamawa State, A thesis Submitted to the Department of Statistics and Operations Research Modibbo Adama University Yola. Unpublished

[15] Li, C. and Maini P. K., (2005). An evolving Network Model with Community Structure. *Journal of Physics A: Mathematical and General Science*, 38(45), 9741-9749.