ASSESSMENT OF FLOW PRESSURE IN SELECTED ZONES OF ILORIN TOWNSHIP WATER SUPPLY NETWORK

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Abstract
In our societies today such as Ilorin metropolis, the study area, the objective water supply system has not been attained, thus calling for improvement in pipe distribution system to supply water to various consumers more effectively. In an attempt to improve the service, the Kwara State Government constructed additional service reservoirs at different locations within the metropolis; most of which receive water from Agba dam treatment plant. Pipe network analysis was then carried out based on the demand in the study area. 10 cases were considered using the location of the service reservoirs in relation to the study area and also on the actual production for distribution to the three zones within the study area. The pressure distribution at the nodes was determined for the ten cases. The maximum and the minimum nodal pressures obtained were compared with recommended values for satisfactory performance of a water supply pipe network.

Keywords
Pressure, water supply, pipe, treatment.

1.0 Introduction
One of the main objectives of water supply system is to provide safe potable water for domestic use, adequate quantity of water at sufficient pressure for fire protection and for industrial use. Haddadin (2001) opined that economics and social development, environment and public health hinge on water and the extent of its availability. There is no economic activity, whether in production of commodities or provision of services that can be accomplished or sustained without water. In addition to meeting the basic requirements of human, animal, and plant life, water is needed to create jobs and generate incomes to maintain acceptable living standards for individuals, families and society at large. It is also needed to preserve the environment and maintain acceptable personal and household hygiene standard.

A typical water supply system consists of source, treatment, pumping, storage and distribution system. Sources of water supply are ground and surface water. Large cities such as Ilorin generally use major rivers or lakes (surface water) to meet their demands, whereas many small and medium size towns use groundwater of adequate quality, which may preclude treatment other than chlorination as a way of disinfection. Wells can be located in several points within a municipality for water supply. Well pumps or low lift pumps from surface intake convey the raw water to the treatment plant, where the water is treated to make it suitable for public consumption. A large reservoir of treated water (clear water tank) provides reserve for the high demand period and equalizing of pumping rates. The high lift pumps deliver treated water under pressure through rising mains to the storage tank and then into distribution pipes.

An essential part of all water supply system is the distribution system. The water has to get to the consumer through the network of pipelines with a minimum specified residual pressure at sufficient quantity without degrading its quality from the sources or purification works. Among other components, this supply system also includes hydraulic elements such as pumping stations and storage reservoirs. A particular distribution pipe network can have many solutions for a given set of consumptions and pressure head values, depending on pumping station, location of elevated storage reservoirs, and topography of the area under consideration.

Oyegun (1983) highlighted the problem of water shortage in Ilorin metropolis, which he attributed to increase in water needs of consumers in Ilorin. In just a decade, water consumption increased in three folds for domestic use, but ten folds for industrial uses. The reason for the phenomenal increase in water requirement is the rapid growth rate in the population and industries in the metropolis. He further stated that emphasis in providing adequate water for Ilorin and environs should therefore focus on how to conserve excess water, increase exploitation of present available water resources and transport of excess to areas of need around the state capital. In an attempt to proffer solutions to the aforementioned important aspects, he suggested that additional service reservoirs are needed to supplement the existing ones. In his work, he did not attempt to evaluate the pressure distribution in the system based on the existing network configuration.

Sule, et al (1999) having studied the water situation in Kwara State suggested the need for a master plan. The rationale for a master plan for water supply is as a result of the increasing demand imposed on water resources, due to accelerated social and economic development and the failure of existing arrangement and facilities to cope with various requirements for domestic, commercial and industrial uses. To complicate the situation, the parties involved in the water sector continue to undertake fragmented projects, which cannot be systematically assessed at a centralized level, thereby leading to duplication of efforts. The primary objective of producing a master plan for water supply, therefore, is to provide the state government with the necessary tool for making decisions on the development of water supply for rural and urban areas.

Distribution reservoirs are located strategically for maximum benefits. Normally they are positioned near the centre of use (central portion of the distribution area), but in large metropolitan areas, a number of distribution reservoirs may be located at key points. Reservoirs providing service storage must be high enough to develop adequate pressures in the system they serve. A central location decreases friction losses by reducing the distance from supply point to the area served. Positioning the reservoir so that pressures may be approximately equalized is an additional consideration of importance (Okeola, 2000).

In this study, the variables considered are the sizes of pipes, pressure heads over the network, elevation and location of service reservoir and the capacity of pumping station. Therefore for optimum pressure distribution at the nodes within the pipe network distribution system, locations and possible combinations of two or more service reservoirs were considered. From the analyses, and for a particular network of pipelines, the residual pressures at nodes were determined in order to know the variations between minimum and maximum residual pressure. It should be noted that pressure requirement assessed by this work would be useful to determine this important aspect of distribution reservoir, i.e. capacity.

2.0 Basic Features and Data

2.1 Water Production

Water supply system of Ilorin is based on surface water drawn from Agba, Asa and Moro Rivers. These three rivers have dams constructed across them. They also have treatment plants to supply water to the metropolis and its environment. The dams have total reservoir capacity of about 46 million m^3/day with total treatment plant full capacity operation of about 82,276 m^3/day. Operations from these dams have yielded about 23,402 m^3/day in year 2002 against 62,003 m^3/day between 1997 and 1999 (Ayanshola, 2002). Table 1 shows the summary of the main features of the water works.

Actual production at Agba dam was measured by monitoring the pumping operation over a period of time. Three pumps connected in parallel were studied. One pump is used at a time while the remaining two are on standby. The study and analysis show that the pumping rates for the three pumps are 4.1 m^3/min, 3.9 m^3/min and 3.3 m^3/min respectively. On daily basis, the pumps will supply 5904 m^3, 5616 m^3 and 4752 m^3 respectively.

Table 1: Summary of the Main Features of the Water Works serving Ilorin

Storage Dam	Dam Reservoir Capacity (x 10^3 m^3)	Treatment Plant Capacity (x10^3 m^3/day)	Average Production (x 10^3 m^3/day)	
			1997 - 1999	2002
Asa	43,000.00	55.000	40.833	18.800
Agba	3,100.00	18.184	13.067	4.000
Sobi	3,000.00	9.092	8.133	0.602
Total	49,100.00	82.276	62.033	23.402

2.2 Service Reservoirs

Water pumped from Asa, Agba and Sobi clear water tanks are normally stored in distribution/service reservoirs where it is delivered by gravity to the various demand areas. Before 1999, seven service reservoirs were connected to the network. Another six overhead steel tanks were introduced in 2001 to enhance the distribution system. Table 2 shows the location and the capacities of all the 13 service reservoirs

2.3 Population

According to National Population Commission (1996), the population of Ilorin was estimated to be 606,533 in 1996 with a growth rate of 2.83 %. The geometric growth method was used to project the population for year 2004. This is giving (Raju, 1995) as:

$$P_n = P_o(1+r)^n \tag{1}$$

Where P_n = present population, P_o = initial population, r = growth rate and n = number of year.

The population of year 2004 was estimated to be 758,251 people residing in the metropolis, while 9 people per 1000 m^2 were estimated to be the population density in the area.

Table 2: Location and Capacities of Distribution Reservoirs in Ilorin Township

S/No	Reservoir type	Location	Source of Water	Capacity (m^3)	Remarks
1	Underground concrete Reservoir	GRA/Fate quarters)	Agba	4,600	In use
2	Easter ground level Reservoir	Tanke	Asa	10,000	In use
3	Western ground level Reservoir	Adewole Estate	Asa	10,000	In use
4	Overhead Concrete Reservoir	Unilorin Teaching Hospital	Asa	4,600	In use
5	Overhead Steel Reservoir	Olanrewaju Estate, Offa garage	Agba	227.30	Replaced
6	Overhead Steel Reservoir	Oke Sobi, Sobi road	Sobi	227.30	Replaced
7	Overhead Steel Reservoir	Central Mosque	Asa	227.30	Not in use
8	Steel Overhead Reservoir	Central Mosque	**Asa**	454.609	In use
9	Steel Overhead Reservoir	Sobi Road	Sobi	454.609	In use
10	Steel Overhead Reservoir	Unity-Taiwo junction	Agba	454.609	In use
11	Steel Overhead Reservoir	Olanrewaju Estate	Agba	454.609	In use
12	Steel Overhead Reservoir	Kwara Hotel	Agba	454.609	In use
13	Steel Overhead Reservoir	GRA/Fate	Agba	454.609	In use

2.4 Pipe Network System

The distribution system in the metropolis is primarily dictated by street patterns, topography, water demand and location of treatment and service reservoirs. This work will take account of main trunk lines, which transport water between separate sections of some important areas. It will also include some transmission lines, which links some important routes. Fig. 1

shows pipe layout and location of tanks for the study area. The study is limited to four reservoirs, and they are:

1. Underground Concrete Reservoir at GRA/Fate
2. Overhead Steel Reservoir at GRA/Fate
3. Overhead Steel Reservoir at Kwara Hotels
4. Overhead Steel Reservoir at Taiwo-Unity Junction.

Figure 1: Pipe Network Showing the Distribution Reservoirs (CIWAT Engineers Ltd, 2000)

Fig. 1 Pipe layout and location of tanks for the study area

The zones under study include zones 11, 12, 13, 14, 15, 16 and parts of zones 2, 9 and 17. The zones selected are the areas covered by supply from the treatment plan at Agba Water Works. Figure 2 is the skeletized pipeline layout for the metropolis showing the pipeline dimensions for the study area. The area considered has a total number of 19 pipes, 15 nodes and 5 loops as shown in Figure 2.

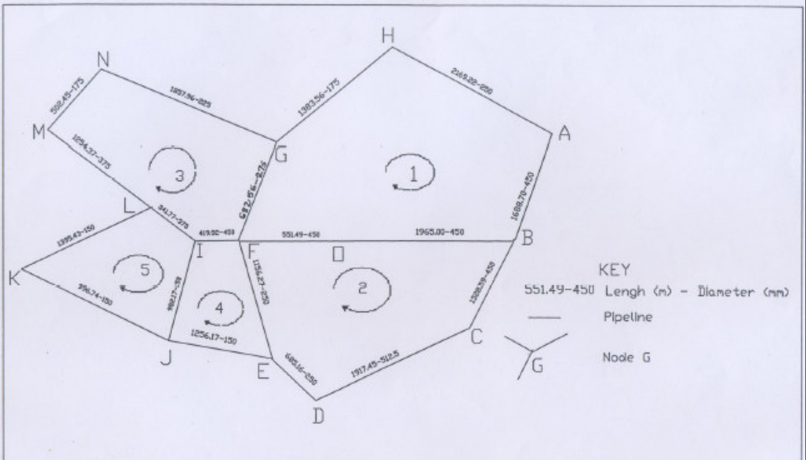


Figure 2: Skeletized Pipeline Layout Showing Pipe Dimensions for the Study Area

Fig. 2 Skeletized pipeline layout for the metropolis showing the pipeline dimensions

3. Estimation of Pipeline and Nodal Flows

Two forms of pipeline and nodal flows were generated. One was based on estimated consumption in the study area while; the other was based on the actual production from Agba Water Works.

3. 1 Estimation of Flow Based on Consumption

The area of each loops of the network considered were determined using the planimeter. A scaled pipe network map obtained from the Kwara State Water Corporation was used. Table 4 shows the area, population, pipe and total length for each loop. In order to determine consumption for each loop, average demand required and an average consumption of 120 l/c/d was used (Okeola, 2000). For the study area, 132.625 l/s has been estimated as consumption rate. Table 5 gives the summary of average demand and consumption for each loop. The assumed flows were then generated such that continuity is satisfied at each node, i.e. the flow to each junction must equal flow out of junction. There are seven cases considered for study, which are based on the location of the service reservoirs. Each of the cases considered are shown in Table 3 along with three other cases.

3.2 Estimation of flow based on the actual production

For this case, the actual production is used for the analysis and it is estimated as follows.

The total production is 5904 m^3/day

Average Demand = 120 l/c/d.

Hence this amount can serve the population of: $\frac{5904 \times 10^3}{120} = 49{,}200$ people.

Based on the fact that the actual production can serve only 49,200 people, the study area was divided into three areas to be served separately as follow:

1. Loop 1, with estimated total population of 45,810 people, which represents Case VIII.
2. Loop 2, with estimated total population of 21,420 people, which represents Case IX.
3. Loops 3, 4 and 5 with estimated total population of 28,260 people, which represents Case X.

Table 3: Various Cases Considered with Reservoirs and Loops used.

Case No	Reservoir(s) S/NO	Loop(s) Used
I	1	All
II	10, 12 and 13	All
III	13	All
IV	12	All
V	10	All
VI	13 and 10	All
VII	10 and 12	All
VIII	13	1
IX	12	2
X	12	3 and 4

Table 4: Areas, Zones, Population, Pipes and total length of the Pipes in each Loop.

Loop	Area (x 10^6 m^2)	Zones	Population	Pipes	Total Length (m)
1	5.09	13, 14, 15, 16 (part)	45,810	AB, BF, FG, GH, AH	8440.53
2	2.38	12	21,420	BC, CD, DE, EF, BF	7603.96
3	1.62	2, 17 (Part)	14,580	GF, FI, LI, LM, MN, GN	4924.72
4	1.61	9 (part), 17 (part)	5,490	EF, EJ, IJ, FI	3814.86
5	0.91	1 (part)	8,190	IJ, JK, KL, LI	3662.08
Total			95,490		

Table 5: Average Demand and Consumption for each Loop

Loop	Average Demand (l/s)	Peak Demand (l/s)	Total Pipe Length (m)	Consumption per Length (x 10^{-3} l/s/m)
1	63.63	127.26	8440.53	15.08
2	29.75	59.50	7603.96	7.82
3	20.25	40.50	4924.72	8.22
4	7.63	15.26	3814.86	4.00
5	11.38	22.76	3662.08	6.22

4. Results and Discussion

4.1 Results

The analyses of pipe network for each case of the study area was carried out so as to evaluate the pressure distribution using the Hardy-Cross method (Featherstone 1983) and software developed by Thermal Analysis Systems Co, UK down loaded from the website: http://www.engineering-software.com/pr/sku27543.htm. Table 6 shows the pressure head at nodes for the various cases considered. Figure 3 is the diagrammatic representation of the pressure head at nodes for the various cases considered. Figure 4 shows the percentage distribution while Figure 5 show the pressure map of the area.

4.2 Discussion of Results

The minimum residual pressure for pipe network systems pressure varies from one country to another. According to Bhardwaj, (2001) the recommended minimum pressure heads varies between 25 m and 28 m and maximum pressure heads vary between 70 m and 84 m. According to AWWA (1956), 15m to 70m pressure head value has been recommended, while 35 m and 140 m was recommended by Washington State University Uniform Design Standard (1998) as minimum and maximum pressure head respectively. A lower value of residual pressure looks to be economical since the distribution cost will be reduced and excess residual pressure above recommended value could lead to pipe busting. Before the introduction of new reservoirs, the minimum pressure head is 2.89 m while only one node has pressure head above 84 m. But with the new reservoirs the minimum pressure is -47.78 m as in case V while the maximum pressure head obtained is 104.97 m. Based on these results the areas with high pressure, need pressure reducing valves along the pipeline so as to reduce excessive pressure that might be generated. Adequate pressure can be achieved for the proposed network system by proper planning for positioning and sizing of service reservoir.

Table 7 shows the percentage nodal pressure variation for the various cases considered. From Figure 4 and Table 7, it can be noted that Case IV has highest percentage total number of nodes with pressure between 25 m and 84 m and Case V has the least percentage total number of nodes for the same pressure range. For the percentage number of nodes with pressure below 25 m, Case V has the highest value, while Cases III has the least value, while for the percentage number of nodes with pressure greater than 84 m; Cases II, IV, V, VIII, IX and X have none while Case III has the highest value.

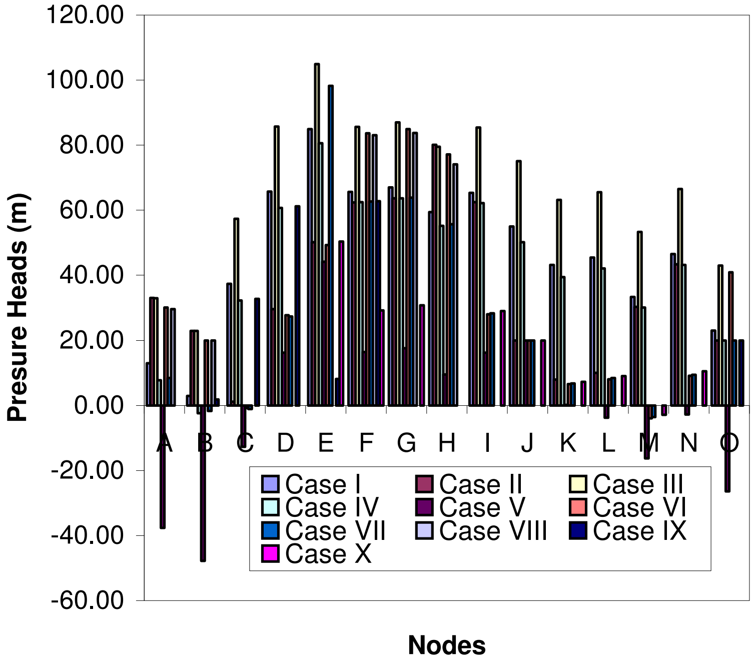


Figure 3: The diagramatic Representation of the Nodal Pressure Heads for the various Cases Considered

Node	Nodal Pressure (m)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
A	12.95	33.02	32.95	7.77	-37.65	30.13	8.40	29.57	-	-
B	2.89	22.89	22.89	-2.36	-47.78	20.00	-1.73	20.00	1.80	-
C	37.34	1.10	57.34	32.30	-12.69	-0.84	-1.16	-	32.72	-
D	65.73	29.56	85.73	60.76	16.19	27.72	27.37	-	61.18	-
E	84.97	50.20	104.97	80.63	44.15	49.28	98.28	-	8.14	50.41
F	65.64	62.43	85.64	62.50	16.38	83.67	62.71	83.03	62.78	29.19
G	66.98	63.63	86.98	63.63	17.58	84.94	63.91	83.74	-	30.81
H	59.49	80.13	79.49	55.25	9.53	77.16	55.72	74.14	-	-
I	65.39	62.53	85.39	62.18	16.20	28.02	28.37	-	-	29.01
J	55.05	20.00	75.05	50.15	20.00	20.00	20.00	-	-	20.00
K	43.19	7.92	63.19	39.41	0.18	6.59	6.80	-	-	7.22
L	45.50	10.03	65.50	42.15	-3.76	8.06	8.41	-	-	9.05
M	33.33	30.26	53.33	30.12	-16.24	-3.97	-3.62	-	-	-2.91
N	46.58	43.37	66.58	43.23	-2.75	9.14	9.42	-	-	10.48
O	23.00	20.00	43.00	20.00	-26.40	40.96	20.00	-	20.00	-

Table 6: Nodal Pressure for the Various Cases

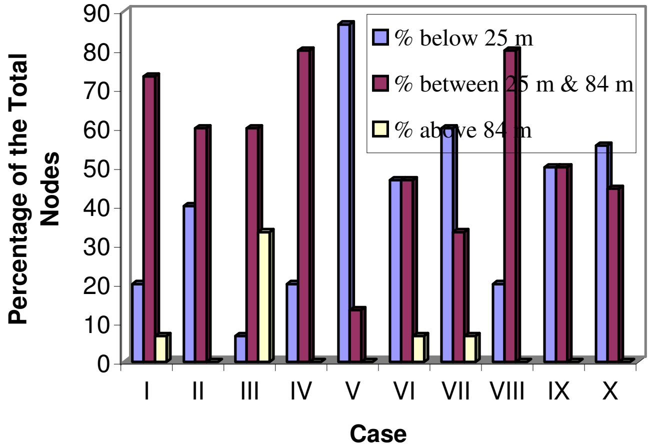


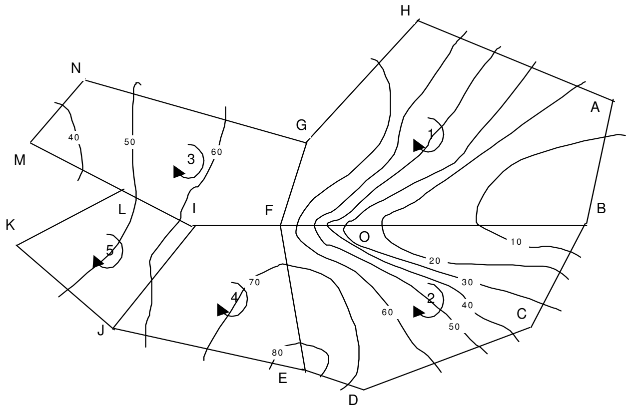
Figure 4: Diagram showing the Percentage Nodal Pressure Heads Variation for the various Cases

Table 7: Percentage Nodal Pressure Heads Variation for the various Cases

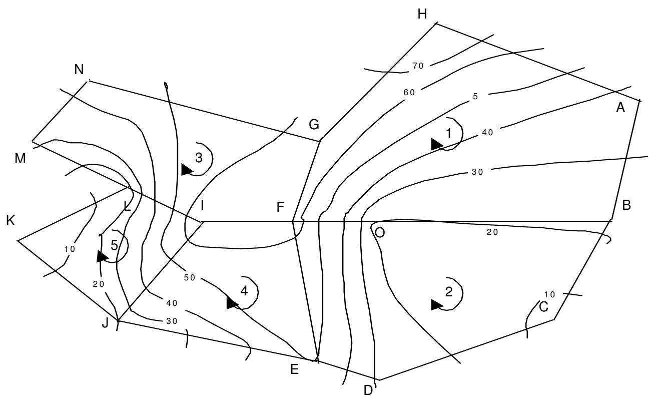
Case	Percentage Total Nodes with Pressure Heads Indicated		
	Below 25 (m)	Between 25 m and 84 (m)	Above 84 (m)
I	20	73	7
II	40	60	0
III	7	60	33
IV	20	80	0
V	87	13	0
VI	47	47	7
VII	60	33	7
VIII	20	80	0
IX	50	50	0
X	56	44	0

Based on these facts, using case IV to distribute water will be more effective, because it has the highest percentage number of nodes that fall between 25 m and 84 m. Also, about 20% of the total nodes have pressure below 25 m and none above 84 m, which will rule out the possibility of pipe bursting as a result of excessive pressure in the pipeline. Hence it can be said that Case IV has the optimal nodal pressure distribution. It should also be noted that for case I, the number of nodes that have pressure between 25 m and 84 m is over 70%, but bursting can still be experienced as a result of excessive pressure since about 7% of the total number of nodes has their pressure head above 84 m.

If the actual production is considered, it will be more desirable to use Case VIII, i.e. to use the actual production to serve loop 1 only with the reservoir located at Fate/GRA. The result generates an optimal nodal pressure distribution

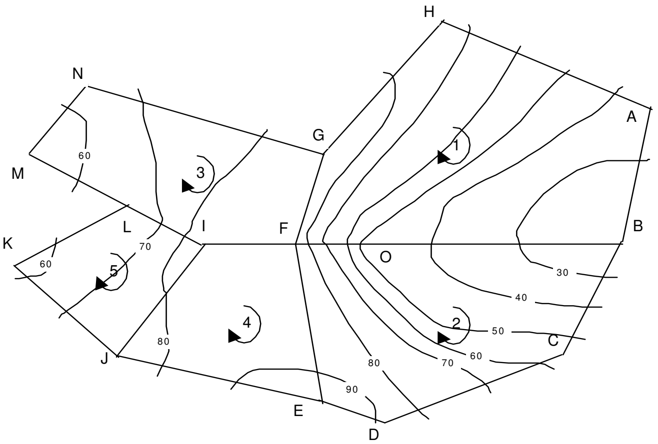


Nodal Pressure Distribution for Case I

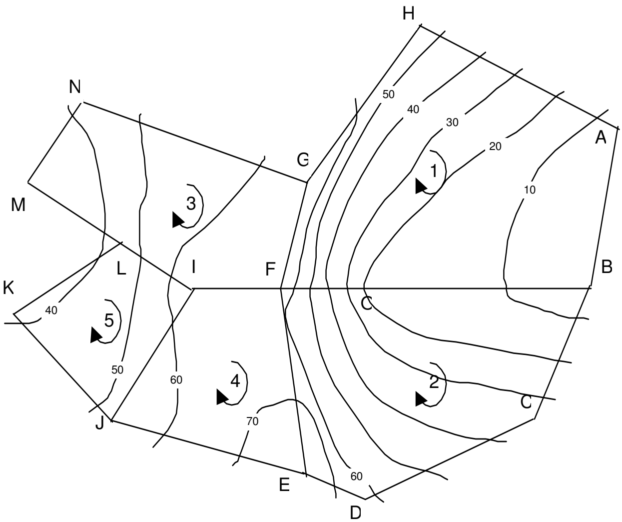


Nodal Pressure Distribution for Case II

Fig 5a Pressure contour maps for cases I and II

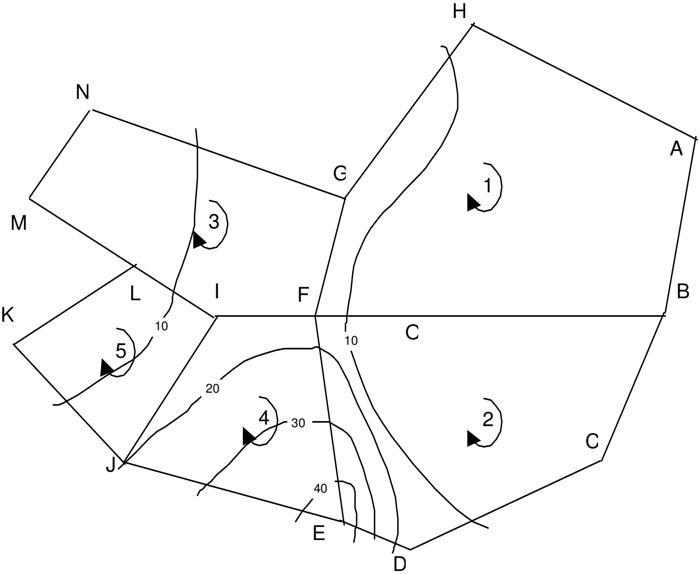


Nodal Pressure Distribution for Case III

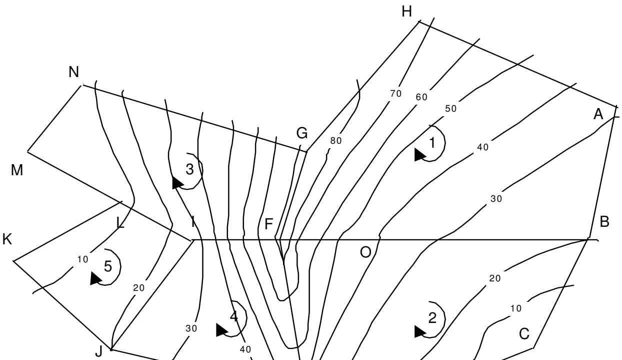


Nodal Pressure Distribution for Case IV

Fig 5b Pressure contour maps for cases III and IV

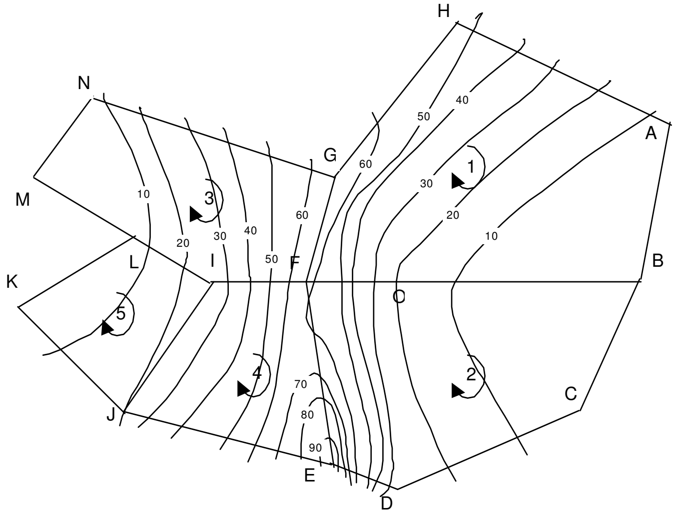


Nodal Pressure Distribution for Case V

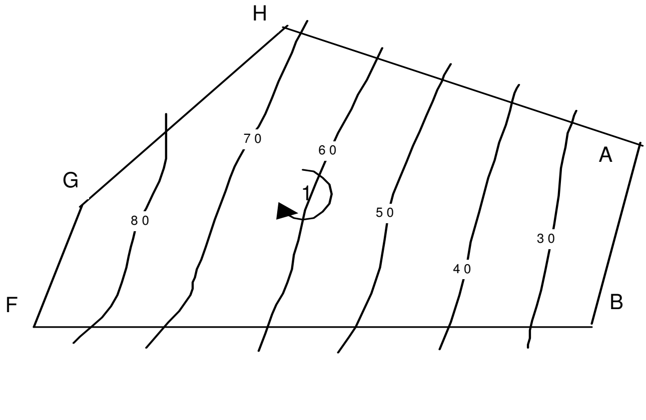


Nodal Pressure Distribution for Case VI

Fig 5c Pressure contour maps for cases V and VI

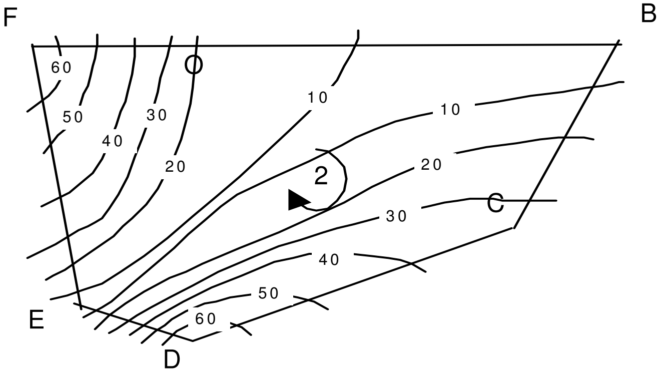


Nodal Pressure Distribution for Case VII

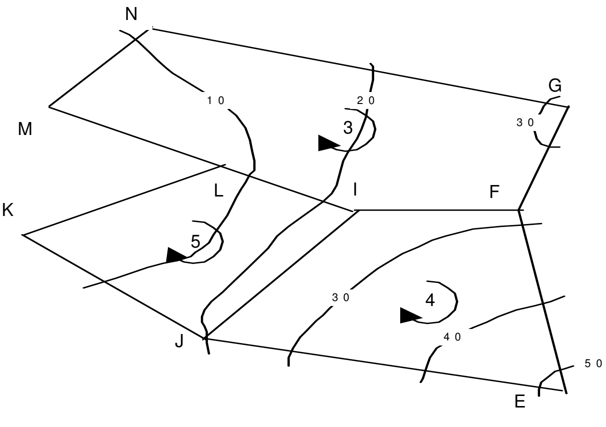


Nodal Pressure Distribution for Case VIII

Fig 5d Pressure contour maps for cases VII and VIII



Nodal Pressure Distribution for Case IX



Nodal Pressure Distribution for Case X

Fig 5e Pressure contour maps for cases IX and X

5. Conclusions

The demand for water is increasing at a faster rate in our society, hence the need to improve on the use of pipe distribution system to supply water to various consumers more effectively. It is this issue that the Kwara State Government wanted to address by introducing additional overhead steel reservoirs in different location within the metropolis. But the result obtained from this study shows clearly that the ultimate goal has not been achieved. To achieve a better result from such a project, the service reservoir should serve only the zones where the minimum residual pressure is satisfied. This is the only way consumers will enjoy and appreciate the efforts of the state government to improve water distribution in the city of Ilorin.

6. References

American Water Works Association (1956), Recommended Practice for Distribution System Records, C900, New York.

Ayanshola, A.M. (2002), Appraisal of Water Supply System in Ilorin Metropolis. A Seminar Paper, Civil Engineering Department, University of Ilorin, Ilorin, Nigeria.

Ayanshola, A.M. (2005), Pressure Distribution Analysis in Zonal Water Supply Pipe Network: A Case Study of Ilorin Metropolis, M.Eng. Project Report, Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.

Bhardwaj, V. (2001), Reservoirs, Towers, and Tanks: Drinking Water Storage Facilities, Tech Brief; National Drinking Water Clearinghouse, Tap Magazine. Web Site: www. ndwc. wvu. edu.

CIWAT Engineers, (2001), Customer Enumeration Final Report, National Water Rehabilitation Project, Kwara State Water Corporation, Ilorin, Nigeria.

Featherstone, E.R. (1983), Computational Methods in the Analysis and Design of Closed Conduit Hydraulic Systems, Development in Hydraulic Engineering I, Applied Science Publishers Ltd, New York, pp.111-150.

Jesperson, K. (2002), Water Systems Should Polish Security Plans; Tech Brief; National Drinking Water Clearinghouse, Tap Magazine. Web Site: www. ndwc. wvu. edu.

Haddadin, J.M. (2001), Water Scarcity Impacts and Potential Conflicts in the MENA Region. IWRA, Vol. 26, No.4, pp.460-470.

Kwara State Water Corporation (1973), Report of Tahal Consultants on Ilorin Water Supply Extension.

Okeola, O.G. (2000), Evaluation of the Effectiveness of Oyun Regional Water Supply Scheme, Kwara State, M.Eng. Project Report, Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.

Oyegun R.O. (1983), Water Resources in Kwara State, Nigeria, Matanmi and Sons Printing and Publishing Company Ltd, Ilorin, Nigeria.

Streeter, V.L. and Wylie, B.E. (1979) Fluid Mechanics, McGraw Hill Book Co. Ltd, Kogakusha, Japan.

Sule, B.F., Adeyemi, S.O., Agboola, S.D. and Katchy, C.C. (1999). Water Supply in Kwara State: Problems and Prospects. Proceedings of National Engineering Conference and Annual General Meeting of Nigerian Society Engineers, Ilorin, Nigeria, pp 258-268.

Sullivan C. (2001) The Potential for Calculating A Meaningful Water Poverty Index, Water International, Journal of the International Water Resources Association, Vol. 26, No. 4, pp. 471-480

Thermal Analysis Systems Company. (1999), Pipe Network (Hardy-Cross) Software, UK, Website http:/www.engineering-software. com/pr/sku27543 .htm

Washington State University Uniform Design Standards (1998), Water Distribution Systems, Part C, Section 02660-4.