

Design of Water Distribution System for Araromi Community, Ondo State Using EPANET

Abideen A. Shittu and James R. Adewumi

Abstract — It is crucial to supply an adequate and consistent amount of water through the planned network of pipes in order to satisfy the water needs of the constantly increasing population. This research covered the design process for the water supply system for Araromi in Ondo state, Nigeria. With the aid of the program EPANET, the area's water supply plan was simulated. Due to the unavailability of concise data about Araromi as at the time of this study, this research projected a population of 1400 persons, assumed a water demand of 300 liters/person/day, and supplied an overhead tank of 17,500liters with an 8-hour maximum supply. This study provides other researchers with a foundation to build future research in Araromi Ondo State, Nigeria.

Keywords — Design, Epanet, Network, Research.

I. INTRODUCTION

Water supply is the process of supplying an adequate and consistent amount of water through a planned network of pipes in order to meet the demands of a population that is always expanding [1]. A hydraulic system consisting of pipes, tanks, reservoirs, pumps, and valves, among other components, makes up a water distribution system. The provision of drinking or potable water to end users is essential; hence, the design of a new water distribution network or the expansion of an existing one must be given top priority to ensure an effective water supply [2].

The analysis and design of pipe networks can be a challenging task, especially when the network includes a variety of pipes, as it typically does in water distribution systems in major cities [3]. To calculate flows through a network of pipes, a variety of techniques have been employed in the past, including graphical methods, physical analogies, and mathematical models [3]. The computer program called EPANET simulates hydraulic and water quality behavior over a long time period in pressurized pipe networks. A network is made up of pipes, nodes (joints in the pipes), pumps, valves, and reservoirs or storage tanks [1].

This study examines the use of EPANET for the design and analysis of a water distribution system in Araromi, Ondo state Nigeria.

II. METHODOLOGY

A. Study Area

The water distribution system was designed for Araromi, which is situated in Akure, the state capital of Ondo Nigeria. Akure is located between the latitudes of 7°13'N and 7°17'N, and the longitudes of 5°07'E and 5°14'E [4].

The geographical location and elevation profile of Araromi were displayed using Google Earth Pro software as shown in Fig. 1. The geographical location obtained from the google earth software was then imported as the backdrop to the EPANET 2.0 interface and developed into the network as shown in Fig. 2 and Fig. 3.



Fig. 1. Location of Araromi Community on Google Earth.



Fig. 2. Water Distribution Network for Araromi Community on EPANET 2.0 with backdrop from Google Earth.

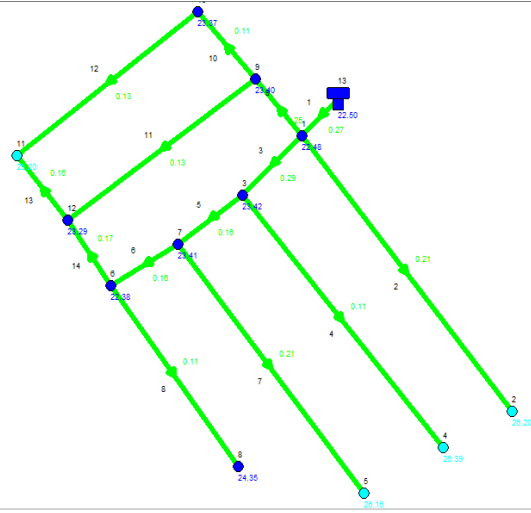


Fig. 3. Water Distribution Network for Araromi Community on EPANET 2.0.

B. Population Projection

The population was projected using Equation (1).

$$P_t = P_i (1 + r)^n \quad (1)$$

Where;

P_i is the initial population,

r is the annual growth rate,

n is the number of years,

P_t is the Projected population [5].

C. Water Distribution Design

There is no well-established water distribution design guideline or standard governing the study area. This research assumes water demand for Araromi to be at 300 liters/person/day. This is based on EPANET 2.0 design guide for hydraulic solver software used in the simulation [6]. Other assumptions made for this design were the number of houses = 200 and an average number of members per house = 7, which gave a total population of 1400. The required water demand in a particular junction was determined using Equation (2) put forward by [7].

$$D_t = D_p * P \text{ and } B_d = D/N_j \quad (2)$$

Where;

D_t is the Total demand in L/day,

D_p is Demand per person L/day,

P is Population,

B_d is Base Demand L/s,

N_j is the Number of Pipe Junctions

The peak flow for the design of the distribution system was gotten by multiplying the maximum hourly demand by a factor of 1.5.

The hydraulic theory of water distribution in pipes is the basis of the EPANET 2.0 software [8]. The mathematical model used in this design is Hazen-Williams' equation, with the coefficient of the roughness of pipe, C as 100.

D. Parameter Validation

The velocity parameter was validated using Equation (3).

$$4Q/(\pi D^2) \quad (3)$$

Where;

V is the velocity of flow across pipe length (m)

Q is the discharge or rate of flow through the pipe length (m³/s)

D is the diameter of the pipe length (m)

E. Design Standards

The design standards for EPANET 2.0 used for this design were provided by [9], as shown in Table I.

III. RESULTS AND DISCUSSION

The results of the junction simulation using EPANET 2.0 is shown in Table II.

The simulation's input is the demand as well as the elevation of the various junction. The simulation was used to create the network and pressure head.

The values for velocity, flow, and head-loss as generated from EPANET 2.0 were within the design guide range (Table III). For velocity, the results generated were within the range of 0.3 to 1.0 m/s. This is a tolerable range for pipe diameter of 100–300 mm (which describes the size of pipes used for this design).

TABLE I: DESIGN STANDARD FOR EPANET 2.0 SIMULATION [6]

S/No	Description	Standards
Demand		
1	Base demand/Average Daily Demand (ADD)	To be computed based on per capita of 300 liters per day for the total residential population
2	Maximum Daily Demand (MDD)	1.25 – 1.50
3	Peak Hour Demand (PHD)	1.50 – 3.00
Head Losses		
4	Head loss for pipe diameter of 100 – 300mm	1.0 – 3.0 m/km
5	Head loss for pipe diameter greater than 300mm	2.0 – 5.0 m/km
Velocities		
6	Velocity of flow for pipe diameter of 100 – 150 mm	0.3 – 1.0 m/s (optimum 0.4 m/s)
7	Velocity of flow for pipe diameter of 200 – 300 mm	0.4 – 1.5 m/s (optimum 0.5 m/s)
8	Velocity of flow for pipe diameter greater than 300mm	0.5 – 2.0 m/s (optimum 0.6 m/s)
Pressure		
9	Pressure downstream of district meter area	15 – 40 m (minimum 12.5 m)
10	Pressure downstream of district meter area and mains	25 – 60 m (minimum 12.5 m)
Pipe Material		
11	High Density Polyethylene (HDPE) pipes	100 – 600 mm
12	Ductile Iron	Greater than 600 mm
13	Domestic Connections (external diameter)	20, 25, 32, 40 and 50 mm

TABLE II: RESULTS FROM JUNCTION SIMULATION

Junction ID	Elevation (m)	Demand (LPS)	Head (m)	Pressure (m)
Junc 1	344	0.58	366.48	22.48
Junc 2	340	1.6	366.20	26.20
Junc 3	343	0.58	366.42	23.42
Junc 4	340	3.30	366.39	26.39
Junc 5	340	1.65	366.15	26.15
Junc 6	344	0.58	366.37	22.37
Junc 7	343	0.58	366.40	23.40
Junc 8	342	1.98	366.33	24.33
Junc 9	343	0.58	366.42	23.42
Junc10	343	0.58	366.35	23.35
Junc 11	341	0.58	366.21	25.21
Junc 12	343	0.58	366.31	23.31
Tank 13	344	-13.22	366.50	22.50

TABLE III: RESULTS FROM LINKS SIMULATION

Link ID	Length (m)	Diameter (mm)	Roughness	Flow (LPS)	Velocity (m/s)	Unit Head loss (m/km)	Friction Factor
Pipe 1	37.36	200	100	13.22	0.27	0.60	0.040
Pipe 2	250.11	75	100	1.65	0.21	1.10	0.049
Pipe 3	60.65	150	100	9.02	0.29	0.88	0.041
Pipe 4	232.67	100	100	3.30	0.11	0.14	0.048
Pipe 5	58.55	100	100	5.14	0.16	0.31	0.045
Pipe 6	56.92	75	100	2.91	0.16	0.44	0.047
Pipe 7	224.25	75	100	1.65	0.21	1.10	0.049
Pipe 8	159.68	75	100	1.98	0.11	0.21	0.050
Pipe 9	53.00	100	100	1.99	0.25	1.56	0.048
Pipe 10	63.91	50	100	-0.84	0.11	0.32	0.054
Pipe 11	169.55	75	100	0.57	0.13	0.62	0.055
Pipe 12	166.76	30	100	0.26	0.13	1.06	0.059
Pipe 13	59.31	30	100	-0.32	0.16	1.54	0.057
Pipe 14	56.54	50	100	-0.33	0.17	1.64	0.057

Also, the results generated for the head loss fell within the range of 0.1 to 3.0 m/km. This value falls within the tolerance range for pipe diameter of 100–300 mm (which describes the size of pipes used for this design).

The results obtained from the research are shown in Fig. 4–Fig. 6.

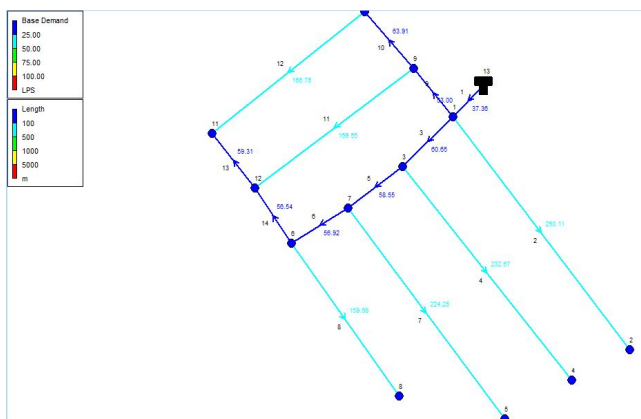


Fig. 4. Base demand vs Length.

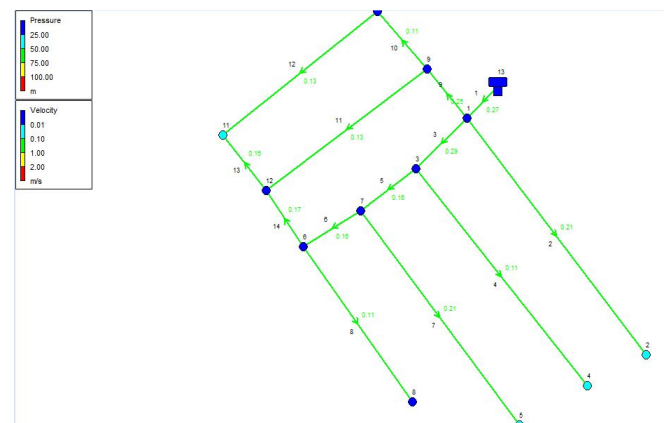


Fig. 5. Pressure vs Velocity.

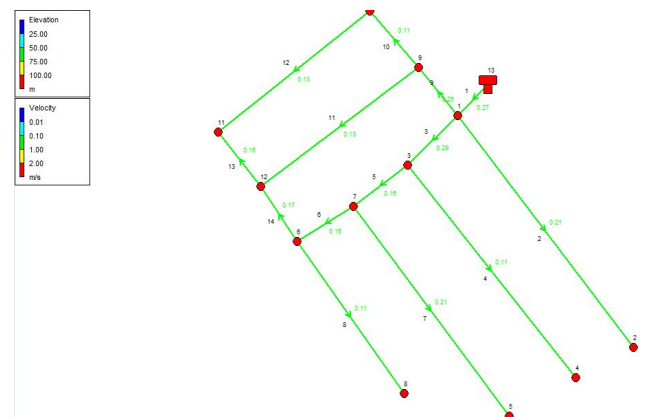


Fig. 6. Elevation vs Velocity.

IV. CONCLUSION

With the aid of EPANET, the water distribution system in this work was designed. The method of distribution used is a combined gravity and pumping system, in which the water is first pumped from an underground water source and then lifted up to the overhead water tanks, where it is then transferred to the main rising pipe by gravity and the loop system is the distribution system employed. The storage tank used in this study has a capacity of 17,500 liters. Since there is a higher demand for water during peak hours than at other times, the maximum supply is provided for 8 hours each day.

ACKNOWLEDGMENT

The authors wish to thank the Federal University of Technology, Akure for the privilege to carry out this study.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

REFERENCES

- [1] Kumar A, Kumar K, Bharanidharan B, Matial N, Eshita Dey, Mahan S *et al.* Design of water distribution system using EPANET. International. *Journal of Advanced Research*. 2015; 3(9), 789 – 812.
- [2] Alperovits E, Shamir U. Design of optimal water distribution systems. *Water Resources Research*. 1977; 13(6), 885 - 900.
- [3] Ramana GV, Sudheer SS, Rajasekhar B. Network analysis of water distribution system in rural areas using EPANET. *Procedia Engineering*. 2015; 119:496–505.
- [4] Adedipe OA., Mohammed M., Ayinuola TO, Okunade AA. Geoelectric Investigation of Araromi Area of Akure, Southwestern Nigeria. *Journal of Environment and Earth Science*, 2014; 4(21):170–181.
- [5] United Nations Educational, Scientific and Cultural Organization. UNESCO. *Water Supply and Sanitary Engineering. Version 1: Nigerian Technical Vocational Educational Revitalization Project-Phase II*. 2008.
- [6] Amgbara TO, Onungwe I, Uche CK, Uneke LA. Design and Simulation of Water Distribution Network Using Epanet 2.0 Hydraulic Solver Software for Okochiri Community, Okrika Local Government Area. *Journal of Advancement in Engineering and Technology*. 2020; 8(1).
- [7] Onungwe I, Rustum R. Design and Risk Management Analysis of Water Distribution Network (A Case Study of Borokiri Port Harcourt, Nigeria). Master's Degree Dissertation. School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University UK; 2017.
- [8] Rossman LA. EPANET 2.0 User's Manual, Water Supply and Water Resources Division National Risk Management Research Laboratory Cincinnati, OH 45268: United States of America Environmental Protection Agency; 2000.
- [9] Saleh M. Director-General of the Federal Electricity and Water Authority Dordrecht. [Imprint] Springer Netherlands; 2014.