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Design and Simulation of Water Distribution Network Using Epanet 2.0 Hydraulic Solver Software for Okochiri Community, Okrika Local Government Area

Amgbara, Tamunokuro O [1], Onungwe, Ishmael[1], Uche, Chikadibia K.A.[2] , Uneke, Louis A [1]
[1] Department of Civil Engineering Technology, Kenule Beeson Saro – Wiwa Polytechnic, Bori, Nigeria.
[2] Department of Civil Engineering, Kampala International University, Ishaka, Uganda
*Corresponding author: Uche, Chikadibia K.A., E-mail: chikadibia.uche@gmail.com
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ABSTRACT
Safe drinking water, sanitation and good hygiene are fundamental to human health, survival, growth and development. The task of making potable water available is distant from actualization especially in Nigeria. The objective of this study is to design and simulate a water distribution network for Okochiri community in Okrika L.G.A. EPANET 2.0 hydraulic solver computer software, was used in the design and simulation of the water distribution network. EPANET 2.0 hydraulic solver software is based on the theory of Hazen – Williams equation and produces results that are in conformity with the simulation guidelines. The input parameters were: area of the distribution network, elevation of the distribution nodes, projected population and standard base water demand. The network simulation which captured nodal and linkage parameters generated results as follows: pressure head (64m), average velocity of flow (0.4m/s), PVC pipe diameter (400mm) roughness coefficient (130) and average head loss (0.05 m/km). The study recommends the execution of this design model for affordable, potable and available water supply for the inhabitants of the study area.

Keywords: *Water, distribution, EPANET 2.0, Okochiri community*

INTRODUCTION
Water is said to be the main source of life; animals, plants, living and non- living things need water to exist [1]. Safe drinking water, sanitation and good hygiene are fundamental to human health, survival, growth and development. Potable water supply and sanitation is attached to development of any given community or locality. According to the World Health Organization (WHO), waterborne diseases account for 1.5 million human deaths per annum and an estimated 3.6 percent of the total Disability Adjusted Life Year (DALY) global burden. In its estimates it was recorded that 58 percent of that burden or 842,000 deaths per year are attributable to a lack of safe drinking water supply, sanitation and hygiene [2].The provision of potable and accessible water involves identifying sufficient quantity of water, ensuring the quality of water and provision of a robust water transmission and distribution system to satisfy the current demand and accommodate population expansion. Governments all over the world including that of Nigeria have prioritized the provision of potable and accessible water for its citizens. To this effect the United Nation Conference at Mardel Plata in 1977, directed member countries to ensure that "All people, whatever their stage of development and socio – economic condition have the right to accessible drinking water in quantities and of quality sufficient for their basic needs". Water quality aspects are of great importance as confirmed in UN water conference in 2002. It is not just enough for water to be available and accessible, the quality of water does however have a great influence on public health because poor quality of water is likely to lead to outbreak of infectious water – related diseases which might lead to epidemic [3];[4]. Thus, for water to be satisfactory for human consumption it must meet standards such as prescribed by [5]; [6]; [7]; [8]; and [9].
The task of making potable water available is distant from actualization [10]. This is evident as UNICEF reported that access to safe water remains a big challenge for majority of Nigerians in the Multiple Indicator Cluster Survey (MICS) conducted by the National Bureau of Statistics [11]**.** The Nigerian government as part of its Millennium Development Goal, Goal 7, Target 10; has aimed to reduce by 50%, the proportion of people without sustainable access to safe drinking water by the year 2015 [12].

2.0 MATERIALS AND METHODS

2.1 Description of Location
Google earth application was used to display the specific location of Okochiri; indicating the study area. Elevation finder was used to ascertain the spot height of each of the node points covering the study area,

2.2 Population
The geometric mean method for population forecast is one of the practical methods for which population projection can be carried out over a specific period of time [3]. A population of 50000 persons was allotted to Okochiri for the purpose of this study which was projected to 30 years for the water distribution network project design. The formula for the geometric mean method is given as follows:

$$P_n = P\,(1 + IG/100)^n \quad (1)$$

Where;
n is the number of years,
P is the current population,
IG is the percentage geometric mean – taken as 2.53% [13].

2.3 Standard Base Water Demand
There is no well-established water distribution design guideline or standard governing the study area. The research adopts water demand for the local community of Okochiri to be at 305 liters per person per day. This is based on EPANET 2.0 design guide for hydraulic solver software used in the simulation. On this basis, the required water demand in a particular junction is determined using the formula put forward by [14].

$$D_T = Dp * P \quad (2)$$

$$B_d = \frac{D}{Nj} \quad (3)$$

Where;

D_T: Total Demand in L/day,

Dp: Demand per Person L/day,

P: Population,

Bd: Base Demand L/s,

Nj: Number of Pipe Junctions.

The base demand is then multiplied by the peak hourly demand (a factor of 2.5 as adopted from the design standards). This maximum water demand will be the standard base demand for the water distribution design.

2.4 Design Theory

The EPANET 2.0 software is based on the hydraulic theory of water distribution in pipes [15]. The mathematical model to be used in this design is:

Hazen – Williams equation

$$S_f = \frac{10.7}{D^{4.87}}\left({}^{Q}/_{C}\right)^{1.852} \quad (4)$$

Where

S_f is friction slope head-loss along the length of pipe

Q is the discharge or rate of flow through the pipe length (m^3/s)

D is the diameter of the pipe length (m)

C is Hazen – Williams Roughness Constant

2.5 Validation

The results obtained from the simulation using the hydraulic solver will be validated to be certain that the calibration done at the conception of the simulation is in line with the hydraulic principles adopted as used in real life situation.

The pressure parameter is validated using the following equations:

$$P = H - E \quad (5)$$

Where

H is Pressure Head,

E is Nodal Elevation.

$$H = Rh - S_f \quad (6)$$

Where

Rh is Reservoir Head

S_f is head loss.

The velocity parameter is validated using the following equation

$$V = \frac{4Q}{\pi D^2} \quad (7)$$

Where

V is velocity of flow across pipe length (m)

Q is the discharge or rate of flow through the pipe length (m^3/s)

D is the diameter of the pipe length (m)

2.6 Design Standards

Design Standards for EPANET 2.0 were provided by [16]. Table 1 shows the design standards for EPANET 2.0 simulation. These standards were used in validation of the results of the simulation.

Table 1: Design Standards for EPANET 2.0 Simulation

S/No	**Description**	**Standards**
Demand		
1	Base demand/Average Daily Demand (ADD)	To be computed based on per capita of 350 liters per day for the total residential population
3	Maximum Daily Demand (MDD)	1.25 – 1.50
4	Peak Hour Demand (PHD)	1.50 – 3.00
5	Unaccounted for water	10% of average demand
Head Losses		
6	Head loss for pipe diameter of 100 – 300mm	1.0 – 3.0 m/km
7	Head loss for pipe diameter greater than 300mm	2.0 – 5.0 m/km
Velocities		
8	Velocity of flow for pipe diameter of 100 -150 mm	0.3 – 1.0 m/s (optimum 0.4 m/s)
9	Velocity of flow for pipe diameter of 200 -300 mm	0.4 – 1.5 m/s (optimum 0.5 m/s)
10	Velocity of flow for pipe diameter greater than 300 mm	0.5 – 2.0 m/s (optimum 0.6 m/s)
Pressure		

11	Pressure downstream of district meter area	15 – 40 m (minimum 12.5m)
12	Pressure downstream of district meter area and mains	25 – 60 m (minimum 12.5m)
Pipe Material		
13	High Density Polyethylene (HDPE) pipes	100 – 600 mm
14	Ductile iron	Greater than 600 mm
15	Domestic Connections (external diameter)	20, 25, 32, 40 and 50 mm

3.0 RESULTS AND DISCUSSION

3.1 Location Specifications

Area of study location: Google Earth application as used in this study enhanced the extraction of the area of study location from the spatial cloud before it was traced in EPANET 2.0 interface and later developed into the network for which the analysis was carried out. Figure 1 shows the specific location of Okochiri indicating the study area.

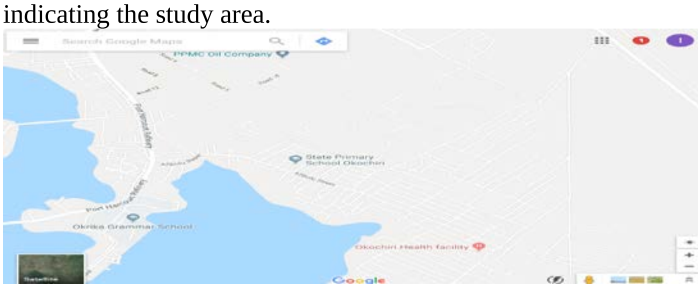

Figure 1: Specific location of Okochiri indicating the network of the study area.

Elevation of node points: Elevation finder allowed for the imputation of the various nodal heights to enhance the positioning of each junction with respect to the required head needed for smooth flow of water through the links. Figure 2 shows the spot heights of some selected points of the study area in the elevation finder interface.

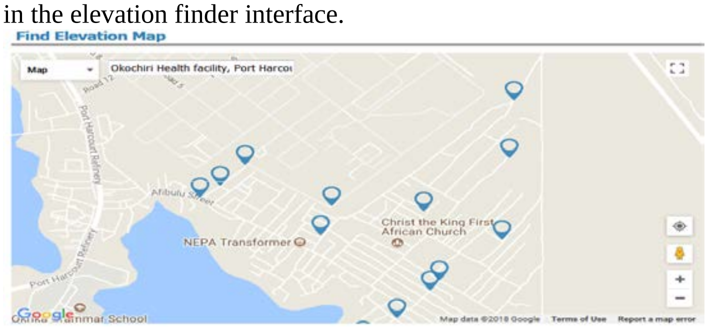

Figure 2: The spot heights of some selected points of the study area in the elevation finder interface.

3.2 Projected Population

The population of Okochiri Community was determined for a projection of 30 years. Table 2 shows the projected year – on – year population figures for Okochiri Community for 30 years.

Table 2: Projected year – on – year population figures for Okochiri Community for 30 years.

Projected Year	Population	Growth Rate	Growth Factor
0	50000	0.0253	1265
1	51265	0.0253	1297.0045
2	52562.0045	0.0253	1329.818714
3	53891.82321	0.0253	1363.463127
4	55255.28634	0.0253	1397.958744
5	56653.24509	0.0253	1433.327101
6	58086.57219	0.0253	1469.590276
7	59556.16246	0.0253	1506.77091
8	61062.93337	0.0253	1544.892214
9	62607.82559	0.0253	1583.977987
10	64191.80357	0.0253	1624.05263

11	65815.8562	0.0253	1665.141162
12	67480.99737	0.0253	1707.269233
13	69188.2666	0.0253	1750.463145
14	70938.72975	0.0253	1794.749863
15	72733.47961	0.0253	1840.157034
16	74573.63664	0.0253	1886.713007
17	76460.34965	0.0253	1934.446846
18	78394.7965	0.0253	1983.388351
19	80378.18485	0.0253	2033.568077
20	82411.75292	0.0253	2085.017349
30	105803.2	0.0253	2676.82

3.3 Standard Base Water Demand

With careful evaluation of (2) and (3) considering the factor of peak hourly demand, the Standard Base Water demand was determined as 5.7 liters/seconds, for the maximum projected population. This is the maximum water demand at any junction of the distribution nodes.

3.4 Simulation of the distribution network

Simulation of the distribution network using EPANET 2.0 with input of the earlier determined parameters was successful.

Figure 3 shows the water distribution network for Okochiri community

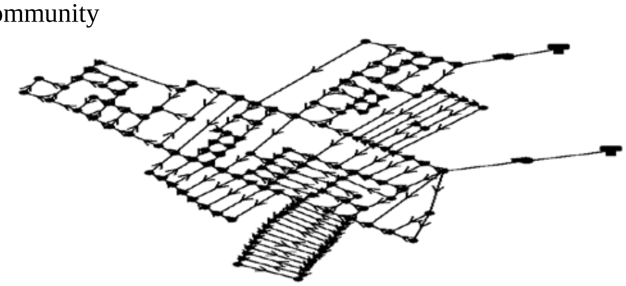

Figure 3: Water distribution network for Okochiri Community

Figure 4 shows pump curve for the network

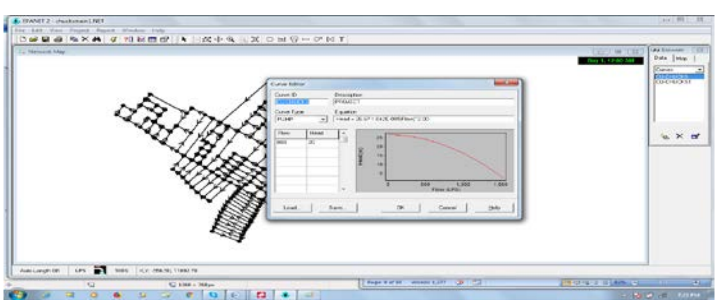

Figure 4: Pump curve for the network

Figure 5 shows demand pattern for the network

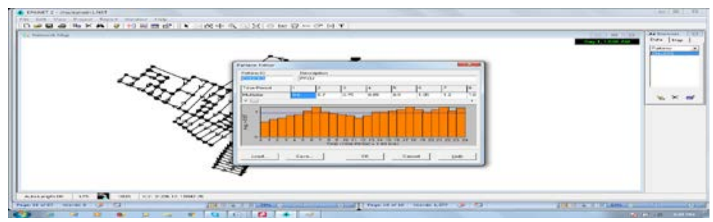

Figure 5: Demand pattern for the network

Figure 6 shows simulation duration setting

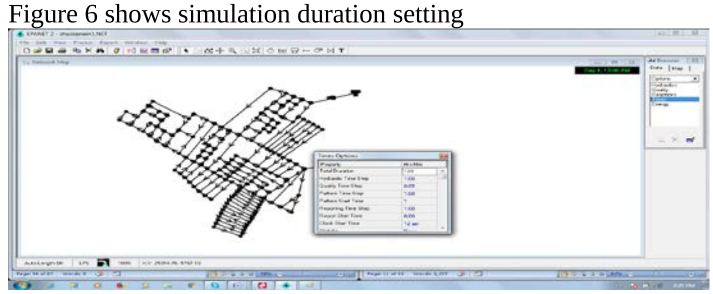

Figure 6: Simulation duration setting

Figure 7 shows successful simulation of the distribution network

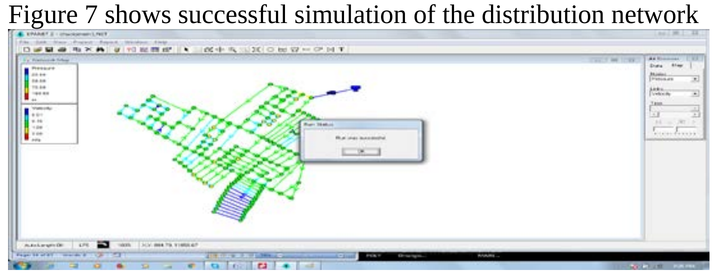

Figure 7: Successful simulation of the distribution network

3.5 Node points/Junction Simulation

The results of node points/junction simulation using EPANET 2.0 is shown in Table 3. The standard base demand and the elevation of the different nodal points constitute the input for the simulation. The network and pressure head were generated from the simulation.

Table 3: Results from Node points/Junction Simulation

Node ID	Elevation (m)	Standard Base Demand (L/s)	Head (m)	Pressure (m of water)
Junc 2	17.4	5.7	82.77	65.37
Junc 3	13	5.7	82.53	69.53
Junc 4	16.4	5.7	82.68	66.28
Junc 8	16.9	5.7	82.63	65.73
Junc 9	17.8	5.7	82.69	64.89
Junc 10	17.9	5.7	82.53	64.63
Junc 11	15	5.7	82.53	67.53
Junc 12	14.7	5.7	82.53	67.83
Junc 13	13.5	5.7	82.53	69.03
Junc 14	13.6	5.7	82.54	68.94
Junc 15	14.9	5.7	82.54	67.64
Junc 16	14.3	5.7	82.57	68.27
Junc 19	14.4	5.7	82.66	68.26
Junc 20	15.1	5.7	82.59	67.49
Junc 22	17.3	5.7	82.84	65.54
Junc 23	17.2	5.7	82.81	65.61
Junc 24	0	5.7	82.8	67.44
Junc 25	16	5.7	82.8	66.8
Junc 26	16	5.7	82.77	66.77
Junc 27	15.8	5.7	82.53	66.73
Junc 29	16.1	5.7	82.53	66.43
Junc 30	16.3	5.7	82.54	66.24
Junc 31	15.8	5.7	82.53	66.73
Junc 32	15	5.7	82.53	67.53
Junc 33	14	5.7	82.55	68.55
Junc 34	16.2	5.7	82.57	66.37
Junc 35	14.7	5.7	82.59	67.89
Junc 36	15.3	5.7	82.55	67.25

Junc 37	17	5.7	82.54	65.54
Junc 39	16.7	5.7	82.62	65.92
Junc 40	15	5.7	82.62	67.62

The pressure head values generated from EPANET 2.0 simulation was within the design guide range for pressure downstream of district meter area and mains. Majority of the values thus generated are within the range 64m to 68m. It is interesting to point out that the values as generated from the simulation is slightly higher than 25m – 60m (minimum 12.5m) range. This is considered to be within a tolerable range.

3.6 Links/Pipe Simulation

The results of links/pipe simulation using EPANET 2.0 is shown in Table 4. The standard base demand and the elevation of the different nodal points constitute the input for the simulation. The pipe length, diameter, roughness, velocity and head-loss were generated from the simulation.

Table 4: Results from Links/Pipe Simulation

Link ID	Length (m)	Diameter (mm)	Roughness	Flow (L/s)	Velocity of flow (m/s)	Unit Head-loss m/Km	Friction Factor
Pipe 5	200	400	130	-40.87	0.33	0.3	0.022
Pipe 8	100	400	130	-1.43	0.01	0	0.034
Pipe 9	100	400	130	-7.13	0.06	0.01	0.029
Pipe 10	100	400	130	5.71	0.05	0.01	0.03
Pipe 13	100	400	130	4.27	0.03	0	0.031
Pipe 14	100	400	130	-18.54	0.15	0.07	0.025
Pipe 15	100	400	130	-6.93	0.06	0.01	0.029
Pipe 17	100	400	130	7.69	0.06	0.01	0.029
Pipe 20	100	400	130	3.15	0.03	0	0.034
Pipe 21	50	400	130	-6.81	0.05	0.01	0.029
Pipe 22	100	400	130	4.26	0.03	0	0.031
Pipe 23	50	400	130	-1.16	0.01	0	0.034
Pipe 25	100	400	130	-3.16	0.03	0	0.032
Pipe 26	100	400	130	-3.7	0.03	0	0.032

Pipe 27	50	400	130	-9.4	0.07	0.02	0.028
Pipe 28	100	400	130	-17.31	0.14	0.06	0.025
Pipe 30	100	400	130	12.63	0.1	0.03	0.027
Pipe 31	100	400	130	8.35	0.07	0.02	0.028
Pipe 32	100	400	130	-32.77	0.26	0.2	0.023
Pipe 33	100	400	130	-31.36	0.25	0.18	0.023
Pipe 34	100	400	130	1.05	0.01	0	0.032
Pipe 35	100	400	130	-38.11	0.3	0.27	0.023

The values for pipe length, diameter, roughness, velocity of flow and head-loss as generated from EPANAET 2.0 were within the design guide range. For velocity of flow, the results generated are within the range of 0.01 to 0.33 m/s. This is a tolerable range for pipe diameter greater than 300mm (which describes the size of pipes used). This range of values are below the optimum velocity which keeps the pipe safe from the effect of water hammer since the tendency of pipe burst is high in situation where such flowing fluid has no solid [16] and [17].

Likewise, for the head-loss, the results generated are within the range of 0 to 0.3 m/km. This value falls within the tolerance range for pipe diameter greater than 300mm (which describes the size of pipes used).

3.7 Validation of Simulation results

The values for pressure, head loss and velocity of flow generated by the EPANET 2.0 simulation were validated. The need to validate or check the results obtained from the hydraulic solver as presented in table 3 and 4 is very important to ascertain that the calibration done at the conception of the simulation is in line with the hydraulic principles adopted as used in real life situation.

The values for pressure head were validated with careful evaluation of (5) and the result was in line with the result generated by EPANET 2.0 for junction 2 as shown in table 3

Hazen Williams head loss (4) was evaluated to validate the head-loss. The result corresponds with the results obtained from EPANET 2.0 simulation for pipe 5 as shown in table 4.

The values for velocity of flow were validated with careful evaluation of (7). The result shows similarity with result generated by EPANET 2.0 simulation for pipe 5 as shown in table 4.

4.0 CONCLUSION AND RECOMMENDATIONS

Design and simulation of water distribution network for Okochiri community, Okrika Local Government Area was successfully done. The parameters considered in this design and simulation includes: area of the distribution network, elevation of the distribution nodes, projected population and standard base water demand. The design was based on hydraulic principles of water distribution in pipes using Hazen – Williams equation. EPANET 2.0 hydraulic solver software was used to carry out a simulation for the water distribution network. The junction simulation produced a pressure head range of 64 to 68m. Pipe simulation produced generated pipe lengths of 50 to 200m, pipe diameter of 400mm, pipe roughness coefficient of 130, velocity of flow in the range of 0.01 to 0.3 m/s and head – loss of 0 to 0.3 m/km. These values were within the tolerance range of the EPANET 2.0 design standards. The results of the simulation were validated to ascertain that the calibration done at the conception of the simulation is in line with the hydraulic principles adopted as used in real life situation.

This study should be adopted by the local authority and a standard water design guideline be developed by the nation, region and states. The government should partner with relevant institutions to improve the availability and accessibility of statistical data to enhance engineering development and research. EPANET 2.0 software as used in this research work should be considered as one of the CAD application to be taught in the institutions of higher learning.

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