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Study of Water Distribution Network Using EPANET modeling Approach

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***ABSTRACT**: The current study simulate the water distribution network of the semi-urban district Kalimoni, city of Juja, Kenya, based on February 2019 observation. The study area is served by RUJWASCO (RiuruJuja Water and Sewerage Company), which supplywater from Ndarugo river. The present study develop a model of the distribution system using EPANET software as a tool to assessthe hydraulic and water quality behaviour of the distribution network. The study used a trail-error method of the extimated demand to calibrate the model. The peak flow value was estimated to 100l/s. At that value the model was calibrated. The simulation of the network was carried out for 24 hour period supply corresponding to the actual supply. The study find that some nodes are facing very low pressure and the chlorine concentration generally in the network is above 0.8 mg/l which can be an issue in term of taste and odour to consummers.*

***KEYWORDS:** calibration, EPANET, Hydraulic, water quality, simulation, distribution system.*

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I. INTRODUCTION

Water is an essential commodity for life. Water availability in sufficient quantity and quality is the main goal of any water supply company. However a water distribution system is complex, understand it help to improve management and reduce loses.Over time the complexity of water distribution network was solved buy software based on mathematical algorithms. A series of models have been developed for analyzing a distribution network [1]. Among the varieties of software EPANET, developed by the United States Environmental Protection Agency's Water Supply and Water Resources Division is the commonly used models. The model presents the advantage to be free cost and open source. EPANET perform hydraulic and quality analysis over a single or extended-period simulation.[2]. The model can also allow extensions and be interfaced with GIS. One of the complete interfaces is calledGISpipe. EPANET was confirmed asa useful tool for measuring and controlling a water distribution system [3]. This study looked at how to analyze the hydraulic and water quality behavior of Kalimoni, a district of the Juja sub-urban town in Central Kenya using EPANET. The study is subdivided into two sections:

- Hydraulic analysis,
- Water quality analysis.

II. HYDRAULIC ANALYSIS

2.1 Methodology

The hydraulic model supporting this study is theKalimoni district main lines network developed in Gisand exported in EPANET 3.0 under GISpipe interface(figure 2.1). The consumption in Kalimoni is domestic.

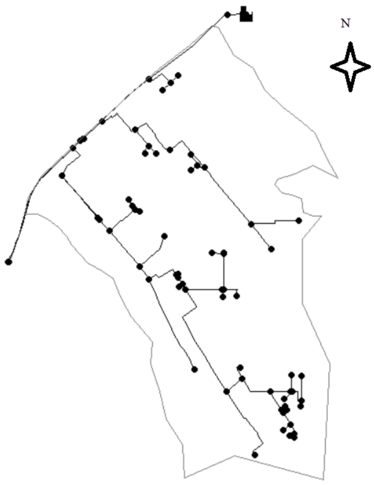

Figure: 2.1 Kalimoni district network

The model was calibrated using a trial and error method of the estimated peak demand. The peak demand is the average demand expressed in terms of daily and hourly peak factor.The demand pattern was introduced following the typical hourly demand variation graph [4].

The headloss equation was expressed with the Darcy-Weisbach head loss equation in the model.

2.2 Results and discussion

The peak flow or demand corresponding to the actual demand of the Kalimomi network after a series of a trial was found equal to 100l**/s.** At that value, the model was calibrated (table 2.1).The daily maximum water supply to the system (6000 m3/day) is way much less than the estimated demand (8640 m3/day).

Table 2.1 Calibration Statistics for Pressure

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
114	1	12.00	11.78	0.219	0.219
14	1	12.00	11.77	0.231	0.231
103	1	5.00	4.18	0.820	0.820
126	1	17.00	17.18	0.177	0.177
120	1	17.00	17.18	0.177	0.177
Network	5	12.60	12.42	0.325	0.409

Correlation Between Means: 1.000

The pattern chart is presented in figure 2.2.

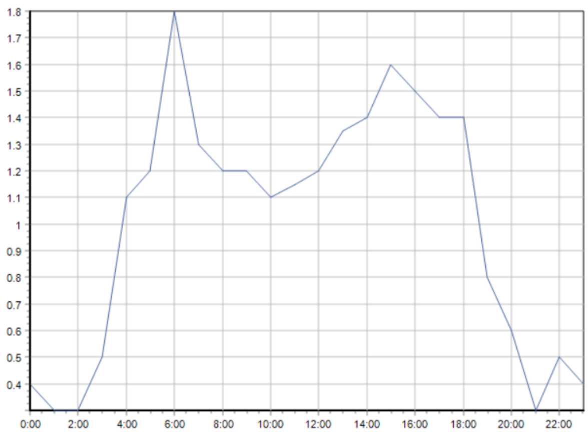

Figure: 2.2 Pattern chart from EPANET

The system flow balance chart is presented below (figure 2.3).

Figure: 2.3 System flow balance

Between 7 and 9 am we observe the first peak. At that time the consummation is far above the production.A second peak is observed also between 10 and 12 pm.

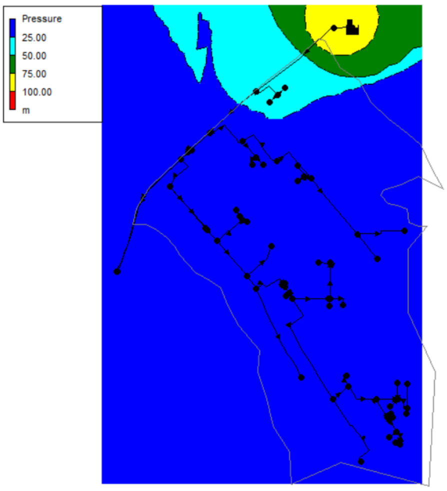

Figure: 2.4 Pressure contour

From figure 2.4 we observed that around 98% of the district area is under low pressure. The pressure range from 20.75 m to negative pressure(tableau 2.2).

Table 2.2 Junctions Pressure results

Junction ID	*Pressure*				
83	-2,344.57	27	-1,310.93	35	-2,345.46
101	-266.65	100	-1,760.42	63	-2,345.37
43	39.38	73	-1,748.96	109	-2,340.75
53	79.09	6	4.18	1	-2,341.75
46	-2,302.34	14	11.77	21	-2,339.65
13	-1,774.94	48	-1,766.03	2	-2,339.75
56	20.75	51	-2,354.97	78	-1,630.08
68	-1,546.31	126	17.18	40	-2,342.59
72	17.04	116	-1,622.22	86	36.36
38	-259.74	81	-2,344.75	7	-1,611.84
123	-2,336.94	39	-262.96	31	-266.36
47	-151.96	66	-246.59	118	-1,760.56
9	-1,309.17	62	-1,698.53	16	18.96
19	-2,343.96	5	-1,761.36	95	-2,339.76
110	17.18	58	37.36	23	-1,696.55
71	-1,762.17	4	-152.95	69	-1,777.14
61	-265.46	24	-2,273.26	55	41.02
34	-1,308.01	42	-154.81	57	-1,774.94
67	-2,353.53	120	17.18	17	-2,355.51

103	4.18	18	-262.59	10	-2,337.20
77	-1,306.95	32	-1,487.24	12	-2,301.86
89	-2,347.60	108	-3.6	82	-1,622.22
11	-2,340.57	96	-1,491.88	106	-148.82
30	-263.73	84	-2,263.86	114	11.78
124	-1,235.99	50	-1,307.92	94	15.1

The following table 2.3 shows that the headloss in the pipes ranges from1670.19m/km to 0. The speed in pipes areacceptable however thereare some extreme values.

Table 2.3 Pipes Flow/Velocity/headloss

Network Table - Links at 7:00 Hrs

	Flow	Velocity	Unit Headloss				
Link ID	LPS	m/s	m/km				
Pipe P312(3)	38.05	8.39	683.95	Pipe P302	1.82	0.93	19.26
Pipe P326	0.47	0.24	1.72	Pipe P324	0.39	0.2	1.29
Pipe P322	0.07	0.02	0.01	Pipe P308	0.11	0.02	0.02
Pipe P312(1)	37.56	8.28	667.26	Pipe P329	3.34	1.7	57.65
Pipe P299(2)	7.9	0.99	9.08	Pipe P311(3)	48.01	5.99	256.95
Pipe P312	25.66	5.66	323.78	Pipe P308(4)	0.89	0.2	0.72
Pipe P337	0.17	0.08	0.3	Pipe P308(3)	3.21	0.71	7.09
Pipe P319	0.3	0.15	0.81	Pipe P299	1.07	0.13	0.26
Pipe P328	1.32	0.67	10.85	Pipe P333	0.81	0.41	4.58
Pipe P304	60.62	13.36	1670.19	Pipe P331(2)	4.56	2.32	102.35
Pipe P308(2)	2.28	0.5	3.85	Pipe P310(1)	67.44	2.08	15.48
Pipe P303(1)	5.55	1.22	19.01	Pipe P125(2)	87.35	1.2	3.48
Pipe P334	0.18	0.09	0.32	Pipe P300	23.43	5.17	272.97
Pipe P308(1)	4.38	0.97	12.39	Pipe P320	0.56	0.28	2.36
Pipe P323	0.35	0.18	1.07	Pipe P307(1)	2.34	0.52	4.01
Pipe P321	0.14	0.07	0.2	Pipe P340	1.72	0.88	17.46
Pipe P327	0.34	0.17	1.01	Pipe P335	0.17	0.09	0.31
Pipe P299(1)	14	1.75	25.82	Pipe P125(1)	0	0	0
Pipe P17(1)	17.89	2.23	40.38	Pipe P338	0.35	0.18	1.05
Pipe P17	4.46	0.56	3.24	Pipe P311(1)	39.6	4.94	178.6
Pipe P307	0.65	0.14	0.42	Pipe 2	-113.71	3.51	40.97
Pipe P314	0.25	0.13	0.58	Pipe P331(1)	5.1	2.6	125.62
Pipe P303	15.41	3.4	124.39	Pipe 1	-118.78	3.67	44.46
Pipe P343	4.49	0.25	0.46	Pipe P311(4)	58.21	7.27	370.29
Pipe P332(1)	0.04	0.02	0.03	Pipe P339	0.24	0.12	0.54
Pipe P310	3.66	0.11	0.09	Pipe P340(1)	0.49	0.25	1.88
Pipe P325	0.25	0.13	0.59	Pipe P332	2.04	1.04	23.6
Pipe P336	0.16	0.08	0.28	Pipe P303(2)	12.47	2.75	83.93
Pipe 3	87.76	2.71	25.25	Pipe P22	86.91	2.69	24.8
Pipe P331	0.67	0.34	3.27	Pipe P330	6.34	1.4	24.2
Pipe P344	0.03	0	0	Pipe P303(3)	3.16	0.7	6.88
Pipe P312(2)	2.72	0.6	5.24	Pipe P303(4)	3.9	0.86	10.05
Pipe P300(1)	17.34	3.82	155.16	Pipe P333(1)	2.55	1.3	35.34
Pipe P309	1.67	0.21	0.57	Pipe P315	0.21	0.05	0.06
Pipe P311(2)	52.73	6.58	306.87	Pump 8	59.91	0	-85.09
Pipe P301	0.35	0.08	0.15	Pump 7	59.91	0	-85.09
Pipe P311	38.15	4.76	166.54				
Pipe P323(1)	2.11	1.08	25.17				
Pipe P341	0.35	0.08	0.15				
Pipe P301(1)	2.4	0.53	4.2				

III. WATER QUALITY ANALYSIS

3.1 Methodology

EPANETusekinetic order 1 to moderate reactions in the water mass.The *Kb* coefficient of order one reactions is assessed by sampling and analysis of water sample after a time of presence. The Kb coefficient can be evaluated using the expression:

$Ct = Coe^{-Kbt}$ (1)Which Kb is a coefficient of bulk flow, Ct the concentration at the time t and Co the initial concentration.[2]

Kw was determined following the procedure describedby[5]**.** The contribution of the wall was neglected in this study.

3.2 Results and discussion

Kbwasfound equal to -0.04hour^{-1} because of the reaction of decomposition.It was directly introduced to the software.

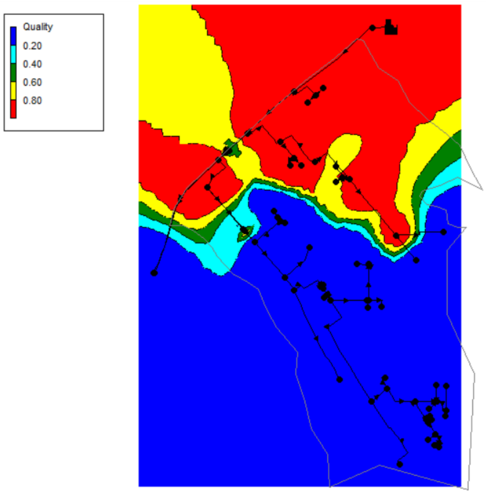

Figure: 3.1 Concentration tie-lines of chlorine throughout the system at 7 am

At seven we can observe from figure 3.1 that half of the area is below 0.20mg/l and the rest is above 0.60mg/l.

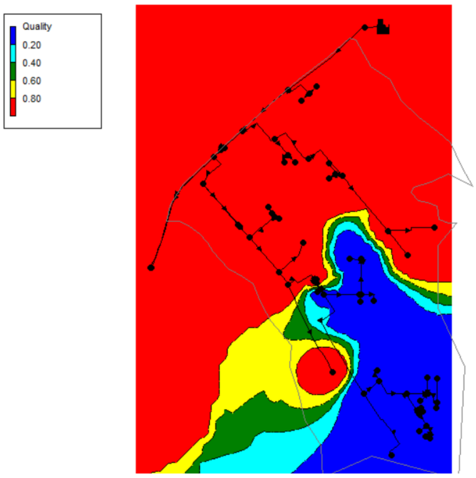

Figure: 3.2 Concentration tie-lines of chlorine throughout the system at 1 pm

At 1 pm 2/3 of the era is having the chlorine above 0.8 mg/l.

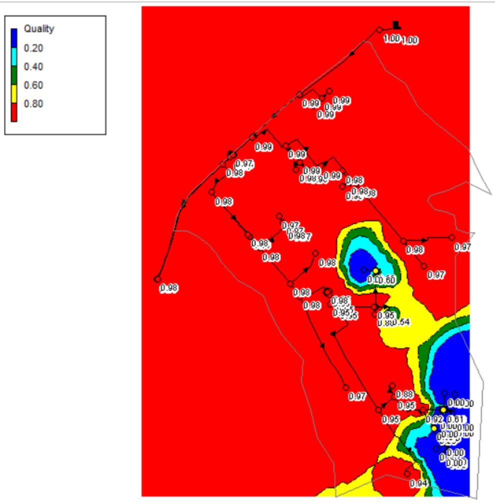

Figure: 3.3 Concentration tie-lines of chlorine throughout the system at 6 pm

At 6 pm the area is 98 % under chlorine above 0.8 mg/l.

IV. CONCLUSION AND RECOMMENDATIONS

From all the above, and Using EPANET hydraulic abilities, we discover that some area of the Kalimoni district face pressure and flow problems. During a daily supply, the network is not able to supply a sufficient quantity of water to all consumers and loses are high in the distribution system(The daily supply to the system (6000 m3/day) is less than the estimated demand (8640 m3/day)). Some pipes diameter are too small explaining also the presence of negative pressure. Residual chlorine is recommended to be maintained above 0.2 mg/l to avoid recontamination during the supply process. Using EPANET abilities to analyze water quality behavior, the current study has found out a high level of chlorine concentration in the distribution system all over the day.The chlorine is above 0.8 mg/l.However, it does not represent a direct danger for consumershealth, the taste and odor from a high concentration of chlorine in drinking water can be disturbing for consumers. Action should be taken tomaintain an adequate supply in terms of quantity and quality in the network.

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