Journal of Engineering and Applied Sciences 14 (Special Issue 7): 10180-10185, 2019
ISSN: 1816-949X

Developed a Hydraulic Model as a Useful Tool in the Improvement of the Water Pipe Network in Al-Hilla City

Alaa Hussein Al-Fatlawi and Teeba Salih Merjan
College of Engineering, University of Babylon, Hillah, Iraq

Abstract: The main objective of this study is designing of Water Distribution Network (WDN) based on loops hydraulically. The existing water distribution network could not able to service the total area after the subsequent years due to population inflation and the increasing of water demand. Thus, new design of water distribution network suggested to insurance the population consumption and water demand of the present area after 25 years from base year of 2018. The data for the water pipe network such as the maps, diameters, material, utilities, land ordinates and the area supply method were obtained from Babylon Water Directorate.

Key words: Babylon, maps, population, hydraulically, utilities, ordinates

INTRODUCTION

The design of municipal Water supply and Distribution Systems (WDSs) is still practiced in professional studies using gross simplifying assumptions and a rigid-static analysis. As a result, the system is not tested under various conditions which can be encountered during its operational life and under different water demand scenarios. This may create frequent failures in meeting the actual demand or pressure requirements during the operation of the system operation in real life conditions. In the opposite direction the system is often over-designed and very costly. During the recent years the scientific community has produced a large number of innovative methods which can offer significant improvements in the design of WDSs. Apart from the improvements of well-known solvers for the analysis of WDSs (Jeppson, 1976; Larock *et al*., 2000; Tsakiris and Spiliotis, 2014), more realistic description of the conditions of nodal demands, roughness of pipes and their variability can also offer significantly in the accuracy of the results derived (Xu and Goulter, 1996; Spiliotis and Tsakiris, 2012 a). It is expected that even with the most conventional tools currently used in practice, some guidance for the assumptions and the range of values of some important parameters related to the materials used is still needed. In this context an attempt was recently made to produce and propose some practical guidelines for the analysis of WDSs, mainly targeted towards professional engineers (Tsakiris and Spiliotis, 2014). In short the five-generation classes and their basic characteristics are concisely presented in Table 1. The recent developments for the analysis of WDSs (generation classes 3 and 4) incorporate (Tsakiris, 2014):

- The dependence of nodal outflow on the pressure at the node
- The uncertainty analysis of nodal outflow and pipe roughness

Major assumptions: In the professional practice the conventional design of an urban water supply and distribution system is based on a number of simplifying assumptions, the most critical of which are:

- The design discharge is based on the expected average demand of the estimated future population
- Empirical multipliers are used for estimating the maximum water demand
- The system is solved for steady state operation with the expected maximum demand
- The type of materials to be used is decided prior to the analysis of the system
- Pipe roughness and local energy losses are estimated using bibliographic data
- The internal diameters of the pipes are predetermined irrespective of the type of coating (e.g., internal coating in steel pipes has different depth if it is of epoxy resin or cement)
- Energy losses are calculated with the expected maximum water demands concentrated at the nodes, uniformly and simultaneously distributed

The major problem in this type of design is that all of the parameters involved are considered constant and

Corresponding Author: Alaa Hussein Al-Fatlawi, College of Engineering, University of Babylon, Hillah, Iraq

Table 1: The five-generation classes methods for the analysis of WDSs Tsakiris (2014)

Generation class	Basic characteristics	Representative references
1	Sequential solution of Q-equation or H-equations	Cross (1936)
2	A linear system is solved in any iteration for determining the ΔQ and Δh	
	Linear	Wood and Charles (1972)
	Newton-Raphson	Shamir and Howard (1968)
3	Pipe equations are solved for Q and h	
	Simultaneously (e.g., Gradient method/EPANET)	Todini and Pilati (1988)
4	Analysis based on pressure dependent outflow (head driven simulation)	
	h-N-R Hazen-Williams	Tabesh *et al*. (2002)
	Linear flow along branches	Giustolisi and Todini (2009)
	EPANET	Siew and Tanyimboh (2012)
	h-N-R Darcy-Weisbach	Tsakiris and Spiliotis (2014)
5	Taylor series expansion around the mean (for	
	Q or h)	Xu and Goulter (1996)
	Fuzzy sets Q	Gupta and Bhare
	Fuzzy sets h	Spiliotis and Tsakiris (2012)

reliable throughout the life cycle of the system. It is of outmost importance that at least few additional tests and procedures could be implemented for narrowing the range of systematic errors in the operation of these systems. These can be:

- The analysis of the entire system, water cycle analysis from the source to the end user
- The “dynamic” simulation of the system during a 24 h expected operation
- The testing of the system for scenarios representing demand concentration at certain parts of the system (e.g. where concentration of population is expected to increase or extension of the system seems likely to occur in the future)
- The description of the demand at the nodes and the pipe roughness by their range instead of constant values

Design criteria: Conventionally during the design of a WDS, the principal criterion is the fulfilment of flow and head requirements in all parts of the urban area. In most of the cases the water distribution system is isolated and analysed separately from the water supply network (from the source to the service reservoir).

However, even if the system incorporates the water supply and the distribution systems together, the criterion which is used is to find the solutions which lead to the minimum total construction costs. Based on this single criterion the source of water, the location of the service reservoirs and the dimensions of the mains are selected. Today in the new complicated world, obviously, this single criterion seems very weak if our objective is to rationally design the system for most reliable and effective operation during its whole life.

MATERIALS AND METHODS

Description of area: The area for which we are designing the water distribution system is Al-Hilla city. The population of the area is 692055 (Babylon census directorate, 2018). The distribution system designed, here is loop system. Water is supplied to the whole districts of Al-Soub Al-Kabeer via. a five separated pumping stations as shown in Fig. 1.

Estimation the population consumption: The data for the water-pipe network such as the maps, diameters, material, utilities, land ordinates and the area supply method were obtained from Babylon Water Directorate. Some suggestion were carried out in the design. Also, fire flow rate state in the design criteria shall be 0.95 m^3/min (1368 m^3/day) for each fire hydrant were calculated in Table 1 where the percentage of the total consumption of water Al-Hilla city was 450 L per capita per day. Table 2 show pump stations and the districts served and its demand.

EPANET2 program: EPANET2 is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks.

A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET2 tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition, to chemical species, water age and source tracing can also be simulated. EPANET2 is

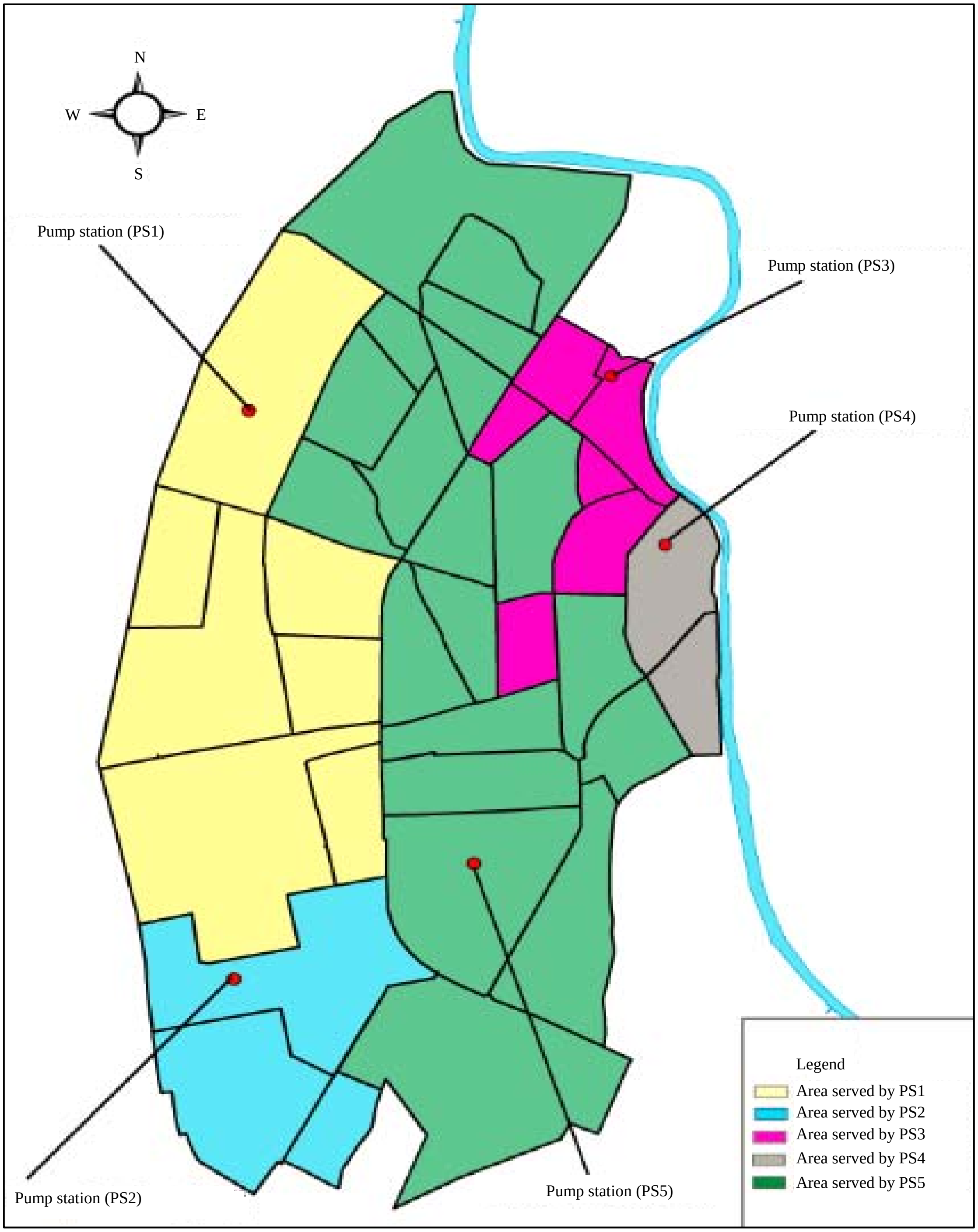

Fig. 1: Location of the pump stations and the area surved

designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. EPANET2 can help assess alternative management strategies for improving water quality throughout a system. These can include (Table 3):

- Altering source utilization within multiple source systems
- Altering pumping and tank filling/emptying schedules
- Use of satellite treatment such as re-chlorination at storage tanks
- Targeted pipe cleaning and replacement

Table 2: Pump stations and the districts served and its demand

Pump station	Capacity m^3/h	Districts	Expected pop., 2043	Domestic demand m^3/h	Fire demand m^3/h	Total m^3/h
Muhazim PS1	2400	Muhazim	4907	92	57	149
		17 Nisan	31601	592	57	649
		Almealimin	19483	365	57	422
		Almuhandisn	19356	362	57	419
		Alaskari	22435	420	114	534
		Aleamarat Alsekeniah	6365	119	57	176
Al-Tuhmazia PS2	2400	Al- Tuhmazia, Alakrmyn	70888	1329		
				51+1278		
				(PS1+PS2)	114	1443
		HamzaAldally	10745	201	57	258
		Alsinaei	20644	387	57	444
		Naseege	9156	171	57	228
Altiyaruh PS3	1200	Altiyaruh	10292	192		
				78+114		
				(PS2+PS3)	57	249
		Alsaha	6278	117	57	174
		Altadamun	7758	145	57	202
		Albustan	1192	22	57	79
		Alkhadih	12940	242	57	299
		Aljameih	6937	130	57	187
Aljabal PS4	1200	Alakrad, Almahdia	33585	629		
				88+541		
				(PS3+PS4)	57	686
Suggested water		Aljamiein, Aljumhuri	21996	412	57	469
treatment plant PS5	8000	Mustafa ragib, Alibrahimia	18733			
				351		
				133+218		
				(PS4+PS5)	114	465
		Alshawi	28311	530	114	644
		Alaskan	20461	383	57	440
		Nadir 3	16869	316	57	373
		Nadir 1and Nadir 2, Alzahraa	36622	686	57	743
		Almurtada	11238	210	57	267
		Almukhabrat, Alsundubad	11597	217	114	331
		Alhussain	11603	217	57	274
		Faza'a and Manie	34866	653	114	767
		Alasatdhih	19313	362	57	419
		Alkaramih	33440	627	114	741
		Albuhtri	5513	103	57	160
		Alemam	10483	196	57	253
		Aldubat	7636	143	57	200
		Alshuhadaa	14464	271	57	328
		Almuharibin	23800	446	57	503
		Alsadr, Alaintifaduh	52037	975	171	1146
		Total	692055	12613	2565	15178

Table 3: Summary analysis of Al-Hilla city water network

Districts	Elevation (m)	Demand (m^3/h)	Pipe type	Roughness	Diameter (mm)	Length (m)	Valves	
Muhazim	27.30 -28.62	0.19	DI	120	200	38646	Gate valve	6
			PVC	150	160	1228	Air release valve	3
					100	38646	Wash valve	4
17 Nisan	27.11-27.70	0.84	DI	120	200	27640	Gate valve	6
			PVC	150	200	1242	Air release valve	4
					100	2981	Wash valve	3
Albuhtri	27.11 -27.70	0.84	DI	120	200	3008	Gate valve	6
			PVC	150	160	1096	Air release valve	3
					100	25978	Wash valve	3
Aleamarat Alsekeniah	26 -26.81	1.89	DI	120	200	2898	Gate valve	6
			PVC	150	160	1078	Air release valve	3
					100	27842	Wash valve	3
Altuhmazia Alakrmyn	26.02 -27.56	1.09	DI	120	200	3278	Gate valve	6
			PVC	150	160	2780	Air release valve	5

Table 3: Continue

Districts	Elevation (m)	Demand (m^3/h)	Pipe type	Roughness	Diameter (mm)	Length (m)	Valves	
				100		91743	Wash valve	4
Alaskan	27.01- 27.99	0.64	DI	120	200	1897	Gate valve	4
			PVC	150	160	765	Air release valve	3
				100		27842	Wash valve	3
Alshawi	27.01- 27.67	1.03	DI	120	200	2898	Gate valve	6
			PVC	150	160	1101	Air release valve	3
				100		43009	Wash valve	4
Almurtada	27-27.82	0.31	DI	120	200	2432	Gate valve	5
			PVC	150	160	972	Air release valve	3
				100		63250	Wash valve	3
Aljameih	27-27.92	0.15	DI	120	200	4008	Gate valve	5
			PVC	150	160	1885	Air release valve	3
				100		29321	Wash valve	5
Almealimin	26.10-26.76	0.45	DI	120	200	2378	Gate valve	4
			PVC	150	160	1006	Air release valve	4
				100		9549	Wash valve	3
Alasatdhih	26.09-26.99	1.12	DI	120	200	2778	Gate valve	4
			PVC	150	160	1028	Air release valve	3
				100		54776	Wash valve	3
Hamza	27-27.88	0.77	DI	120	200	3006	Gate valve	5
Aldally			PVC	150	160	1897	Air release valve	3
				100		6890	Wash valve	3
Almuhandisn	26.01-26.83	0.97	DI	120	200	31452	Gate valve	4
			PVC	150	160	1087	Air release valve	4
				100		31452	Wash valve	3
Alaskari	27.07-27.95	0.34	DI	120	200	3094	Gate valve	6
			PVC	150	160	1888	Air release valve	4
				100		30892	Wash valve	4
Faza'a and	27.17-27.85	0.45	DI	120	200	1569	Gate valve	5
Manie			PVC	150	160	799	Air release valve	3
				100		19876	Wash valve	3
Nadir 3	27.09 - 27.82	0.69	DI	120	200	2844	Gate valve	4
			PVC	150	160	1033	Air release valve	3
				100		29041	Wash valve	3
Nadir1, Nadir	27.04-27.89	1.35	DI	120	200	1476	Gate valve	6
2, Alzahraa			PVC	150	160	543	Air release valve	3
				100		22342	Wash valve	3
Alsinaei	27.14-27.69	0.64	DI	120	200	1432	Gate valve	4
			PVC	150	160	508	Air release valve	2
					100	13862	Wash valve	2
Naseege	26.01-26.99	0.15	DI	120	200	6789	Gate valve	9
			PVC	150	160	2701	Air release valve	3
					100	49780	Wash valve	5
Alsundubad	27.13-27.70	0.19	DI	120	200	1084	Gate valve	7
Almukhabrat			PVC	150	160	2351	Air release valve	3
					100	33908	Wash valve	4
Alkadhia	26.54-27.60	0.05	DI	120	200	2908	Gate valve	6
			PVC	150	160	1089	Air release valve	3
					100	68984	Wash valve	3
Altiyaruh	27.28-27.99	0.11	DI	120	200	3412	Gate valve	6
			PVC	150	160	2365	Air release valve	3
					100	26800	Wash valve	3
Alsaha	27.10-27.44	0.21	DI	120	200	3003	Gate valve	4
			PVC	150	160	1144	Air release valve	3
					100	6947	Wash valve	3
Alsadr	27.3-28							
Alaintifaduh		0.47	DI	120	200	6090	Gate valve	12
			PVC	150	160	3365	Air release valve	6
					100	79826	Wash valve	7
Alemam	27-27.77	0.18	DI	120	200	2765	Gate valve	6
			PVC	150	160	1055	Air release valve	4
					100	29992	Wash valve	5
Aldubat	27.12-27.66	0.50	DI	120	200	2654	Gate valve	5
			PVC	150	160	985	Air release valve	4
					100	23091	Wash valve	3
Alshuhada	27-27.94	0.34	DI	120	200	2654	Gate valve	6
			PVC	150	160	985	Air release valve	5
					100	32091	Wash valve	5

Table 3: Continue

Districts	Elevation (m)	Demand (m^3/h)	Pipe type	Roughness	Diameter (mm)	Length (m)	Valves	
Almuharibin	26-27.16	0.53	DI	120	200	3008	Gate valve	7
			PVC	150	160	1096	Air release valve	6
					100	28978	Wash valve	5
Alakrad	27-27.87	1.15	DI	120	200	2801	Gate valve	5
Almahdia			PVC	150	160	987	Air release valve	4
					100	29242	Wash valve	3
Aljamiein	26-26.98	1.95	DI	120	200	2908	Gate valve	4
Aljumhuriu			PVC	150	160	1090	Air release valve	3
					100	27880	Wash valve	3
Mustafa ragib	26.10-26.97	1.19	DI	120	200	3610	Gate valve	4
Alibrahimia			PVC	150	160	2205	Air release valve	3
					100	36128	Wash valve	3
Alhussain	27-27.99	0.25	DI	120	200	2955	Gate valve	6
			PVC	150	160	1160	Air release valve	3
					100	29077	Wash valve	3
Alkaramih	26.10-26.92	0.97	DI	120	200	1657	Gate valve	7
			PVC	150	160	890	Air release valve	4
					100	45204	Wash valve	5
Albusatan	27-27.82	0.04	DI	120	200	1011	Gate valve	4
			PVC	150	160	3821	Air release valve	3
					100	36036	Wash valve	2
Altadamun	27-27.91	0.15	DI	120	200	2801	Gate valve	4
			PVC	150	160	1050	Air release valve	3
					100	26687	Wash valve	3

RESULTS AND DISCUSSION

Before building a model, it is necessary to gather information describing the network. Introduces and discusses sources of data used in constructing the models, also presented the simulation of the EPAENT2 Model for the case study area. Table 3 shows summary analysis of area under study water network.

CONCLUSION

In this research, the water distribution system has been design with the help of EPANET2 in which we use number of nodes, number of pipe, elevation, demands, diameter and length of Al-Hilla city. Once successful run is done using EPANET2 tool after simulation. Design of the water supply scheme for proper supply of water is efficient to meet the daily requirement of water. The selected pipe sizes for suggested water distribution network is adequate and will meet avarage water demands and fire protection while maintaining adequate or prescribed pressure in the system.

REFERENCES

Cross, H., 1936. Analysis of Flow in Networks of Conduits or Conductors. University of Illinois at Urbana-Champaign, Illinois,.

Giustolisi, O. and E. Todini, 2009. Pipe hydraulic resistance correction in WDN analysis. Urban Water J., 6: 39-52.

Jeppson, R.W., 1976. Analysis of Flow in Pipe Networks. Ann Arbor Science Publishers, Inc., Collingwood.

Larock, B., R. Jeppson and G. Watters, 2000. Hydraulics of Pipeline Systems. CRS Press, Boca Raton, Florida, USA.,.

Shamir, U. and C.D. Howard, 1968. Water distribution system analysis. J. Hydraul. Eng., 94: 219-234.

Siew, C. and T.T. Tanyimboh, 2012. Pressure-dependent EPANET extension. Water Resour. Manage., 26: 1477-1498.

Spiliotis, M. and G. Tsakiris, 2012. Water distribution network analysis under fuzzy demands. Civil Eng. Environ. Syst., 29: 107-122.

Tabesh, M., T.T. Tanyimboh and R. Burrows, 2002. Head-driven simulation of water supply networks. Intl. J. Eng. Trans. A. Basics, 15: 11-22.

Todini, E. and S. Pilati, 1988. A Gradient Algorithm for the Analysis of Pipe Networks. In: Computer Applications in Water Supply, Coulbeck, B. and O. Chun-Hou (Eds.). Wiley, Hoboken, New Jersey, USA., pp: 1-20.

Tsakiris, G. and M. Spiliotis, 2014. A newton-raphson analysis of urban water systems based on nodal head-driven outflow. Eur. J. Environ. Civil Eng., 18: 882-896.

Tsakiris, G., 2014. Rational design of urban water supply and distribution systems. Water Util. J., 8: 5-16

Wood, D.J. and C.O. Charles, 1972. Hydraulic network analysis using linear theory. J. Hydraul. Eng., 98: 1157-1170.

Xu, C. and I.C. Goulter, 1996. Uncertainty Analysis of Water Distribution Networks. In: Stochastic Hydraulics 96, Tickle, K.S., I.C. Goulter, C. Xu, S.A. Wasimi and F. Bouchart (Eds.). August Aime Balkema, Amsterdam, South Africa, ISBN:9789054108177, pp: 609-616.