EFFECTIVE WATER DISTRIBUTION NETWORK FOR CUET CAMPUS

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ABSTRACT
Chittagong University of Engineering and Technology campus is fully dependent on ground water. The existing water distribution network is unable to fulfil the increasing water demand as per VISION-2020, adding new stuffs, students, teachers, departments, halls, buildings etc. This study aimed at determining future water demand and providing a new effective water distribution system. The present (2016) water demand is 395480 gpd, whereas water demand of CUET campus after 2020 will be 583700 gpd.

Keywords: Ground water; vision 2020; future demand; effective water distribution system

INTRODUCTION
Water is not only the essential element for existence of life but also the symbol of advanced civilization whereas all old civilizations were founded centring water source. But with the increasing of world population useable water demand for life also increasing wherein useable water sources are limited. So now, only any well planned and designed water distribution system can meet the current and future demand with our limited water resources. CUET is a small area with a population of more than 4000. In near future it would be increased to several times and then to meet the water demand with limited resources will be the challenge for civil engineers. Here we proposed a modified water distribution network for future CUET campus of year 2020.

METHODOLOGY
1. Design flow calculation by $Q = \dfrac{fqPf}{1-0.01w}$ formula.
2. Diameter adjustment by Hazen-Williams formula and other minor losses.
3. Flow adjustment by Hardy Cross method**.**

Table 1: Consumption of water

Nature of consumption	Quantity (gpcd)	Nature of consumption	Quantity (gpcd)
Office building	10-15	Single family houses	35-50
Educational institutions	10-25	Multifamily houses	50-9
Hostels and halls of residence	30-40	Restaurants	0.5-5
Hospitals	130-350	(per person per meal)	
Factories	10-20	Laundries	3-6
		Domestic animals	3-15

(M.A. Aziz, 1975)

Besides, peak factors of water consumption for rural areas, upazilla town, and district headquarter and city corporations are 3,2,2,1.5 respectively.

Zone Wise Water Distribution Network
We divided CUET campus into 12 zones. Each zone consists of a certain number of populations that's why a main outlet required for each zone. To meet every zonal demand we covered all zones under a loop distribution system which contains 15 different loops

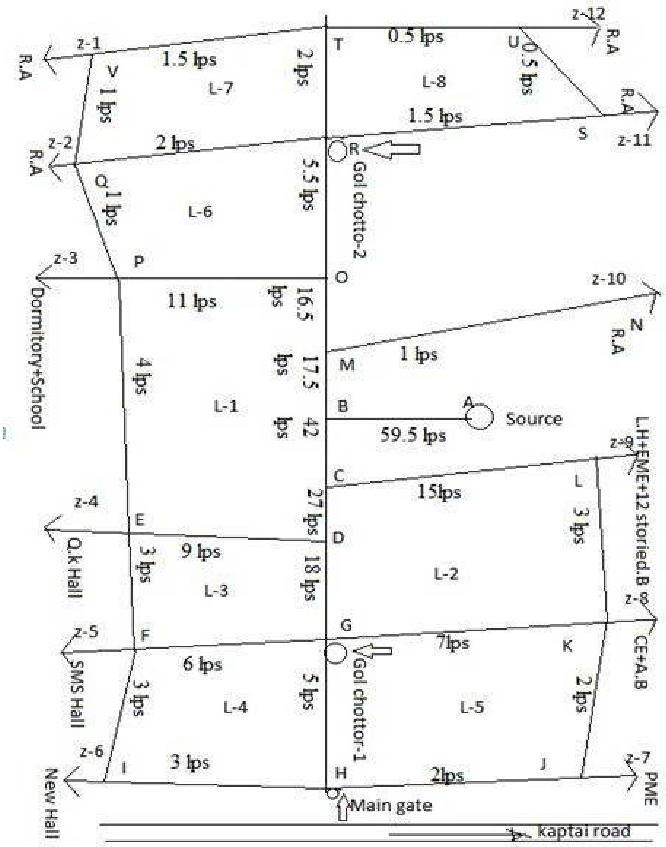

Fig 1: Proposed pipe network of CUET campus (with assumed flow)

Design Flow

$$Q=\frac{fqPf}{1-0.01w} \qquad \text{(Feroze, 2000)}$$

Q=peak design flow the water supply distribution system is designed for peak water demand of future population. The Design flow can be computed by using the equation per day,
f=peak factor, q=average water consumption, Pf=design population, w= loss and wastage.
Now this equation can be simplified to calculate design flow in lps (litter per second) from gpd (gallon per day).

$$Q = \frac{2\times A\times 3.785}{(1-0.01\times 10)\times 24\times 3600} \text{, A=q Pf}$$

$$= 9.735\times 10^{-5}\times A$$

1 gallon= 3.785 litre, W=Loss=10%, f = 2

Table 2: Sample of design flow calculation for zone-1

Zone	Building	Population	Water requirement	Total demand (gpd)	Design flow (lps)	Design flow(round figure)
Z-1	8 different buildings	450	450×50	22500	2.2	2.5

Similarly; zone-2, zone-3, zone-4, zone-5, zone-6, zone-7, zone-8, zone-9, zone-10, zone-11, zone-12 require the design flow of 2,6,10,6,6,4,8,12,1,1,1 lps respectively.

Adjustment of Diameter by Calculation of Head Loss

Available pressure head at source= 35m.
Allowable head loss in any root=17 m.
Available pressure head at end (for three storied building) =14 m (S.K. Garg)
Available pressure head at end (for five storied building) =20 m (S.K. Garg)

The process of adjustment of diameter is done by method of trial and error. Hazen-William has given a solution of calculating head loss per unit length of pipe. The Hazen-Williams equation can be written as-

$Q=3.7\times10^{-6}C\ D^{2.63}\ (H/L)^{0.54}$

Q=peak flow, D=diameter (mm), H=head loss (m),

L=length of pipe (m), C=roughness co-efficient, H/L= slope= S.

For definite value of C=120 the equation becomes-

$H_f/L=1.59\times10^{6}(Q^{1.85}/D^{4.87})$ (Feroze, 2000)

Major Head loss occur due to friction and can be calculated from this equation as-

$H_f=(H/L)\times L$

The process involved in the design is to make a pipe layout, assume the pipe size and then work out the terminal pressure head which could be made available at the end of each pipe section when discharging peak flow. The available pressure heads are checked to see whether they correspond to permissible residual pressure head, if not the pipe size is changed and then the system is reinvestigated until satisfactory condition are obtained.

There are several minor losses are to be taken into account such as-

Loss at entrance- $h_{en}=\dfrac{0.5v^2}{2g}=0.025v^2=0.041\dfrac{Q^2}{D^4}$, (Khurmi, 2003)

Here, v,g,Q,D are the velocity at entrance point, gravitational acceleration, discharge and Pipe diameter respectively.

Loss at exit- $h_{ex}=\dfrac{v^2}{2g}=0.051\ v^2=0.0823\dfrac{Q^2}{D^4}$, (Khurmi, 2003)

Here, v,g,Q,D are the velocity at exit point, gravitational acceleration, discharge and Pipe diameter respectively.

Loss for contraction- $h_c=k_L\dfrac{v^2}{2g}=0.051\ k_L\dfrac{Q^2}{D^4}$, k_L= 0.1-0.45, (khurmi, 2003)

Fig: pipe suddenly contracted

Consider a liquid flowing in a pipe having a sudden contraction in 2-2

Let, D1= diameter of section 1-1

D2= diameter at section 2-2

Losses of head due to sudden contraction, $h_c=k_L\dfrac{v^2}{2g}$

The constant K_L depends upon the ratio D1/D2.

D1/D2	1	1.1	1.25	1.5	2	2.5	3	3.5	4
kL	0	0.1	0.19	0.28	0.375	0.4	0.42	0.43	0.45

Loss due to sudden enlargement- (Borda-Carnot equation)

$h_{el}=\dfrac{(v_1-v_2)^2}{2g}=0.051\,(v_1-v_2)^2=0.082\,(\dfrac{Q_1}{Q_1^2}-\dfrac{Q_2}{Q_2^2})^2$, (Khurmi, 2003)

Where v_1, v_2 are the velocities and Q_1, Q_2 are the discharges on the two sides of the section in where sudden enlargement occurs.

Loss due to bending (only for T-junction)

$h_b = 0.2\ \dfrac{v^2}{2g} = 0.016\ \dfrac{Q^2}{D^4}$, (Munson, Young, SI version)

Table 3: Sample of Trial for Loop-1(BCDEPOMB) to Adjust Pipe Diameter

Loop	Pipe	Q	D	L	H_f/L	H_f	h_{en}	h_{ex}	h_c	h_{el}	h_b	H_t	Δ
	BC(+)	42	160	128	0.029	3.78	0.11	0.22	0	0	0.04	4.15	0.13
	CD(+)	27	160	134	0.013	1.75	0.046	0.09	0	0	0	1.88	
L-1	DE(+)	9	110	110	0.0106	1.17	0.023	0.05	0.013	0	0.009	1.25	
	BM(-)	17.5	160	76	0.0058	0.44	0.019	0.04		0	0.007	0.51	
	MO(-)	16.5	160	30	0.0052	0.16	0.017	0.03		0	0	0.21	
	OP(-)	11	110	140	0.0154	2.15	0.034	0.07	0.019		0.013	2.29	
	PE(-)	4	80	368	0.0111	4.1	0.016	0.03	0.009	0.001	0.006	4.17	

Terminal Pressure at Various Points

At point A, assumed pressure where the source located is 35 m. Same as pressure at other points from B to I we can get by deducting head loss from pressure available at previous point. For an example at point A, the available pressure is 35 m and when water travel through AB path then it get total head loss 4.97.So the available pressure at point B is 35-4.97=30.03. Same as R=29.31-1.55=27.76, S=27.76-0.549=27.21,C=30.03-4.155=25.87, D=25.87-1.88=23.9, T=27.76-0.601=27.16, U=27.16-0.264=26.9, E=23.9-1.25=22.75, F=22.75-0.698=22.05, Q=27.03-0.518=26.5, V=26.5-0.77=25.74, G=23.9-0.45=23.45, H=23.45-2.043=21.40, O=29.52-0.209=29.31, P=29.31-2.28=27.03, I=21.40-0.825=20.5, J=21.4-1.66=19.74, K=23.45-3.807=19.643, L=25.87-4.346=21.52, M=30.03-0.509=29.52, N=29.52-1.213=28.3 m.

- All terminal residual pressures are between the limit of available pressure>18m. (S.K. Garg)

Flow Adjustment

The determination of probable flow in each pipe in a pipe network requires complicated and tedious trial and error solutions. In any looped pipe network two conditions must be satisfied.

- ❖ The flow entering a junction must equal the flow leaving it.
- ❖ The algebraic sum of the pressure drop (head loss) around any closed loop must be zero.

Hardy- Cross developed a method of successive approximation in which the circuits are balanced, distribution of flow is determined and the above two conditions of flow are satisfied.

According to Hardy-Cross-

$$\Delta_c = \frac{\sum H}{x \times \sum \frac{H}{Q}}$$ here, $\sum H$=sum of head loss and x=1.85

Sample of Trial for Adjustment of Flow

Table 4: LOOP-1(BCDEPOMB)

Loop	pipe	Q_1	D	L	H_f/L	H_f	h_{en}	h_{ex}	h_c	h_{el}	h_b	H_t	H_t/Q	Δc	Q_2
	BC(+)	41.96	160	128	0.0295	3.77	0.11	0.22	0	0	0.043	4.148	0.099	0	41.96
	CD(+)	27.03	160	134	0.0131	1.75	0.046	0.09	0	0	0	1.889	0.07	0	27.03
	DE(+)	8.95	110	110	0.0105	1.15	0.022	0.05	0.013	0	0.009	1.242	0.139	0	8.95
L-1														0	
	BM(-)	17.54	160	76	0.0059	0.45	0.019	0.04		0	0.008	0.512	0.029	0	-17.54
	MO(-)	16.54	160	30	0.0053	0.16	0.017	0.03		0	0	0.21	0.013	0	-16.54
	OP(-)	11.15	110	140	0.0157	2.2	0.035	0.07	0.02		0.014	2.343	0.21	0	-11.15
	PE(-)	4.04	80	368	0.0114	4.18	0.016	0.03	0.009	0.001	0.006	4.244	1.05	0	-4.04
Δ c= 0.0096(negligible)											∑	-0.03	1.61		

RESULT AND DISCUSSION

As per our calculation shown as sample templates in previous discussion, we got our required flows as well as adjusted diameters of pipes presented in the table below for different zones.

Pipe	Length (m)	Adjusted diameter (mm)	Adjusted flow (lps)	Pipe	Length (m)	Adjusted diameter (mm)	Adjusted flow (lps)
AB	75	160	59.5	HI	121	80	2.95
BC	128	160	41.96	FI	190	80	3.05
CD	134	160	27.03	KJ	198	90	1.88
DE	110	110	8.95	HJ	210	70	2.12
BM	76	160	17.54	PQ	145	60	1.11
MO	30	160	16.54	OR	222	100	5.39
OP	140	110	11.15	RQ	266	70	1.93
PE	368	80	4.04	QV	220	60	1.04
CL	349	130	14.88	RT	190	80	1.99
LK	302	80	2.88	TV	220	60	1.46
DG	64	160	18.08	RS	298	80	1.47
GK	352	100	7	SU	185	50	0.47
EF	100	100	3.02	TU	110	50	0.53
FG	105	90	6.04	MN	345	60	1
GH	210	90	5.07				

Here we like to mention that we tried to present a sample of outline for simple water distribution network in where water transmission depends on gravity flow only and whole territory is almost flat. But our CUET campus is not totally flat through its whole territory so pumping system might have been adopted in some outlet points located too high than our assumed elevation.

CONCLUSIONS

CUET is located at Raojan thana under Chittagong district which is about 25km away from city corporation area. Its water supply system is totally relied on ground water. In this campus, present water demand (2016) is 395480 gpd and as per vision 2020 future demand is 583700 gpd. Due to different losses present distribution system can't provide water in each point with required pressure and amount as well as future demand cannot be satisfied for improper pipe dimension. Only a new proper designed water distribution system oriented by all necessary data and measurement can fulfil the water demand aroused for vision 2020 project. In this circumstance our proposal of effective water distribution system if adopted with real features and required measures then it can solve all future problems engaged with water distribution system.

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BIBLIOGRAPHY

S. Khurmi, edition: 2003, A Text Book of Hydraulics, Fluid Mechanics and Hudraulic Machinesr, S. Chand & Company Ltd.

M.A. Aziz, copyright 1975, A Textbook of Water Supply Engineering, Hafiz Book Centre Dacca.

M. Feroze Ahmed, Md. Mujibur Rahman, First Edition: June, 2000, Water Supply & Sanitation, ITN-Bangladesh

Bruce R. Munson,Donald F. Young, Theodore H Okiishi, Wade W. Huebsch, Sixth Edition, Fundamentals Of Fluid Mechanics- Copyright @2010 By John Wiley & Sons, Inc, U.K

S. K. Garg. 3rd edition (1984), Water Supply Engineering- Khanna Publishers.