SCENARIO-BASED SIMULATION OF EXISTING WATER DISTRIBUTION NETWORK FOR KUET CAMPUS IN BANGLADESH

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ABSTRACT

Water distribution network (WDN) that are vital in supplying communities with their water demand are designed to deliver water at adequate discharge and pressures according to demands and with specific acceptable quality. Since 2001, a water treatment plant (WTP) has been established at KUET campus with a view to supplying potable water to its residents through its distribution network. The main objectives of this study is to analyze and design the existing WDN for the future projected demand with Bentley WaterGEMS software as well as to execute scenario-based simulation of the WDN in terms of water flow, velocity, water pressure and head loss by ArcGIS. This study shows that the maximum flow of water was found to be above 5 L/s in the connection zone. The flow is then reduced up to 0-1 L/s at the consumption point. The maximum and minimum flow velocities of water were found to be around 1.10 m/s and 0-0.10 m/s, respectively. While, the standard value of flow velocity ranges 0.20m/s to 1.30m/s (BNBC, 2011). Also, the minimum and maximum head losses were around 0.00 m/m and 0.051 m/m, respectively while the maximum permissible head loss ranges 0.015 m/m-0.016 m/m (BNBC, 2011). Furthermore, the minimum water pressure were around 112 kPa that is less than the International Plumbing Code (IPC-2006) recommended value of 172.4 kPa. The ArcGIS scenarios shows that the designed water flows, velocities and water pressures in the teacher's residential area as well as the office building were found to be satisfactory. Whereas, that in the student residential halls were not up to the mark with the present sources, alignment and accessories of the distribution network.

Keywords:*ArcGIS,KUET campus, scenario-based simulation, water distribution network,WaterGEMS*

1. INTRODUCTION

Water is the major necessity of life, but unfortunately even today in the 21th century most of the people, especially belonging to the third world do not have potable water for their household usage. More than one thousand million people of the world do not have access to clean drinking water (Ibrahim, et al.; 2014). The majorities of the populations in developing countries are inadequately supplied with potable water and are thus bound to use water from sources that have high potential of contamination and provide the unsafe water for domestic and drinking purposes (WHO, 2011).In ensuring the supply of safe drinking water, the distribution system is as important as the water resources and treatment facilities. Water distribution systems include pipes, pumps, valves and reservoirs and are designed to deliver water at adequate discharge and pressures according to demands and with specific quality. Performance of a water distribution network can be defined as its ability to deliver a required quantity of water under sufficient pressure and an acceptable level of quality during different normal and abnormal operational situations.Modelling of existing and future water demand remains the most challenging task in water distribution system design. To facilitate the process somewhat, geographic information systems (GIS) are increasingly being co-opted to assign water demand to network nodes (Filion et al., 2007).

Over the last half-century, there has been an increasing trend of population settlement in developing countries like Bangladesh. For fulfilling the demand for higher education, the student seat facility is mounting every year in public universities of Bangladesh. Khulna University of Engineering & Technology (KUET) is one of the leading public universities in this country. At present, the residents of KUET campus are about 3400 and it is expected that this population will be twice within the next 35 years. This will certainly create severe problems due to rising water demands.KUETissituated at the southwest coastal belt of Bangladesh and consequently, salinity is the key water quality problems in this area (Hossain and Hassan, 2015). To eliminate the crisis of potable water, a water treatment plant (WTP) has been established at KUET campusin 2001 with a view to supplying potable water to its residents through its distribution network. The main goal of this paper is to study the hydraulic behavior of existing Water Distribution Network (WDN) as well as to analyze and design the WDN for the future projected demand with Bentley WaterGEMSsoftware.Also,thescenario-based simulation of the WDN is executed in terms of water flow, velocity, water pressure and head loss by ArcGIS.The plant was constructed to supplying potable water to the teacher's residential area and academic buildings.

2. METHODOLOGY

2.1 Study Area

Khulna University of Engineering & Technology (KUET), the present study area, is one of the leading public engineering universities in Bangladesh. It was founded in 1967 as Khulna Engineering College and converted to Bangladesh Institute of Technology (BIT), Khulna on 1986. Finally, this institute was upgraded as Khulna University of Engineering & Technology (KUET) in 2003. Presently, it comprises 14 Departments including major branches of Engineering and sciences offering both the undergraduate and postgraduate degrees, with 875 fresh UG and about 100 PG students in each year. It is situated at Fulbarigate covering a land area of 101 acres, about 13km north from Khulna City, a metropolitan City in Bangladesh. It is located at 22.8997°N and 89.5026°E on the bank of the Bhairab River with an annual average rainfall is 1809.4mm.

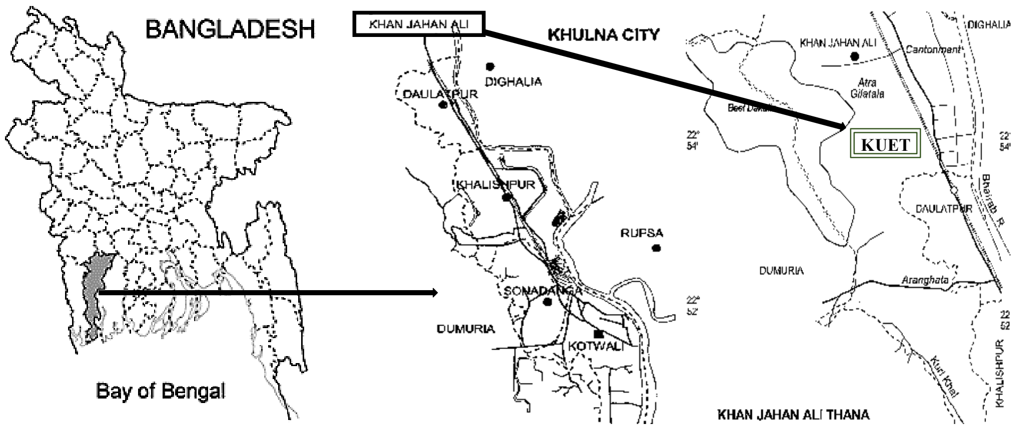

Figure 1: Study area boundary

2.2 KUET Water Distribution Network (WDN)

The KUET water distribution network was installed initially with the establishment of water treatment plant of KUET campus in 2001. The existing water distribution network is being used to supply potable watertreated by the existing water treatment plant to the teacher's residential area and academic buildings and since then it has been considered as the main source of water.

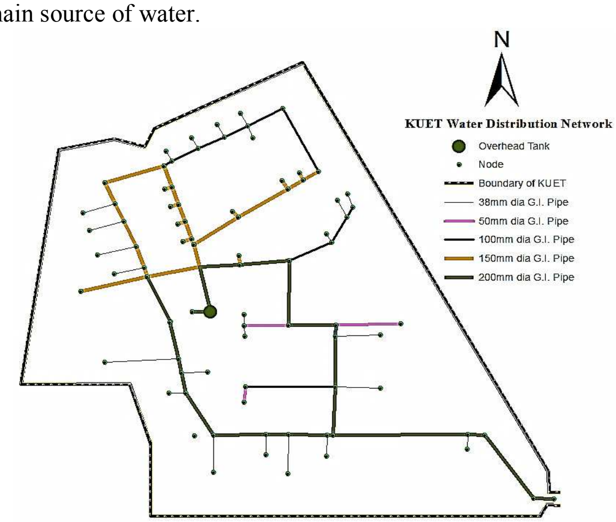

Figure 2:KUET Water distribution network

But the supplied water is not being used for drinking purpose rather than daily purposes due to high chloride and TDS content. Though the distribution network had been installed throughout the whole campus area, treated water is being supplied to teacher's and staff's residential areas and office buildings only, all the students residential hall of this campus contains their own on-site water supply system. The existing water distribution network is shown in figure 2.

2.3 Study Outline

This study has been designed withtwo major part i.e. data collection and software analysis. Data collection includes the collection of population data, future plan of respective authorities, collection of map and relevant information based on the existing network. Furthermore, software analysis includes model skeleton, defining various component as pump, reservoir, overhead tank, pressure reducing valve etc. Also, water demand, elevation of overhead tank, reservoir, and junction; pipe size and other relevant data were inputted and finally, the water flow, flow velocity, pressure and head loss has been computed in steady state analysis. The scenario-based simulation has been executed by ArcGIS in terms of water flow, flow velocity, pressure and head loss. The details framework for scenario-based simulation of distribution network is shown in figure below.

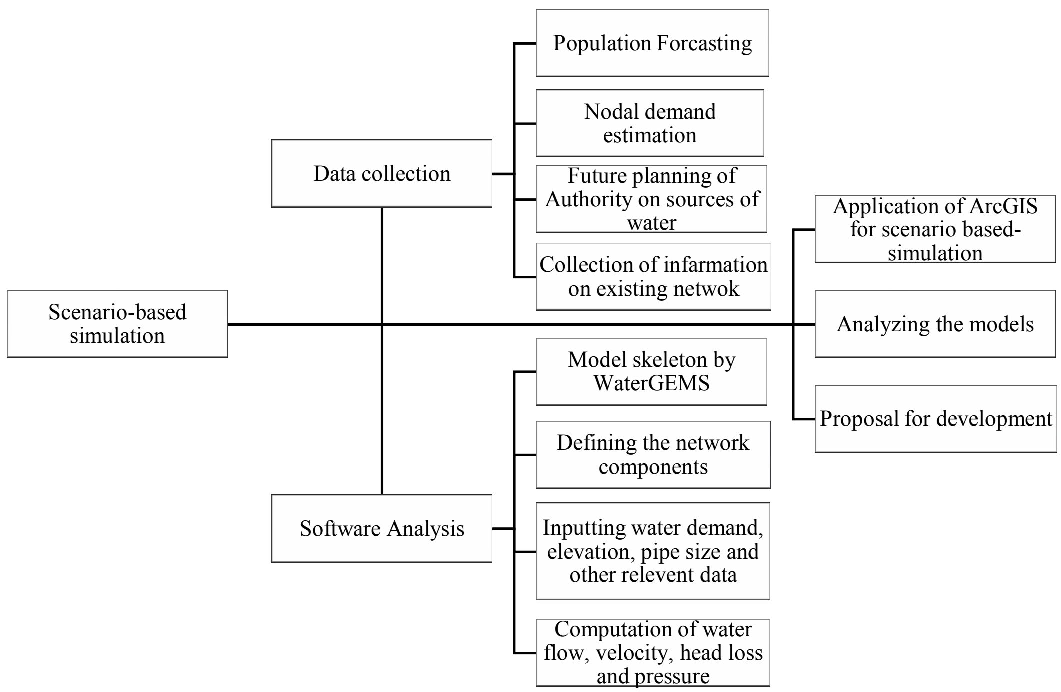

Figure3: Study framework on scenario-based simulation of WDN

3. RESULT AND DISCUSSION

3.1 Population projection and water demand estimation

3.1.1 Least Square method of enrolment projection

Least Square method of enrolment projection has been used for the projection of the residents of KUET campus. General form of equation for this method of projection is :(Mehta, 1994).

$Y = a+bX$ (1)

Where, ‘X’ is the Projected year and a, b are the slope of best fitting line

$\sum Y = n.a+b\sum X$ (2)

$\sum XY = a\sum X+b\sum X^2$ (3)

Where, n is the number of observations

Table 1: Population projection in least square method

Year	2000	2002	2004	2006	2008	2010	2012	2014	Total
Total(Y)	2079	2155	2307	2536	2688	2916	3296	3790	$\sum Y$=21767
X	1	2	3	4	5	6	7	8	$\sum X$=36
XY	2079	4310	6921	10144	13440	17496	23072	30320	$\sum XY$ =107782
X^2	1	4	9	16	25	36	49	64	$\sum X^2$ =204
After calculation, a = 1667.607 and b=234.0595									

For the year 2050 the value of X is 26 then Y is to be found around 7800. In our estimation, student growth rate was found to be around 5.69% per year.

3.1.2 Overall Demand estimation

The number of present population attached with KUET campus is approximately 4000 and the number of residents is about 3400 that is about 85% of total population. Again, according to our observation total population will be approximately 8000 in the year of 2050 and the number of resident will be expected to have about a number of 7800 for 85% resident coverage. The water demand is found by considering a consumption rate of 180 Litre/capita/day. Also 10% extra demand is considered for the office building. The details water demand estimation is shown in table 2.

Table 2: Water demand estimation

Type of Population	Number of Population	Consumption rate (Litre/capita/day)	Water Demand (Litre/day)	
			Net	With 10%
Present total resident	3400	180	6,12,000	6,73,200
Future Population (2050)	6800		12,24,000	13,46,400

3.1.3 Nodal Demand estimation

The nodal demand was calculated based on the demand of various buildings. For residential building the demand had been computed form the product if capacity of building and per capita water demand. For office building 10% demand of residential demand had been considered. Water demand in residential area is enlisted in table 3 below.

Table 3: Water demand in residential buildings

Sl. No	Name of Building	Capacity	Per capita demand	Demand (Liter/day)
1	Khan Jahan Ali Hall	250	180 Liter/day	45000
2	Dr. M. A. Rashid Hall	250		45000
3	BSMR Hall	650		108000
4	FazlulHaque Hall	250		45000
5	Amar Ekushy Hall	600		108000
6	Lalon Shah Hall	250		45000
7	Rokeya Hall	500		90000
8	Dormatory-1	100		18000
9	VC residence (Q-01)	10		1800
10	Q-02	30		5400
11	Q-03	30		5400
12	Q-04	30		5400
13	Q-05	30		5400
14	Q-06	30		5400
15	Q-07	30		5400
16	Q-08	30		5400
17	Q-09	30		5400
18	Q-10	35		6300
19	Q-11	35		6300
20	Q-12	35		6300
21	Q-13	35		6300
22	Q-14	35		6300
23	Q-15	35		6300
24	Q-16	35		6300
25	Q-17	35		6300
26	Q-18	35		6300
27	Q-19	35		6300
Total Residents		3400	Total Demand	6,12,000

3.2 Model Skeleton and Primary Model

3.2.1 Preliminary data for model skeleton

In this study Bentley WaterGEMS software has been used for model skeleton. The present master plan used by the KUET authority is used for alignment of existing pipeline. Also, all the accommodation and alignment are considered in model skeleton process. The used map or plan was fitted with a scaling of 1:500. An overhead tank has been considered having base, minimum, initial and maximum elevation of 25m, 28m, 30m, 35m, respectively. A total number of three Zoneswere considered in the entre design area and 'Connection Zone' was considered for reservoir only. A typical pump definition (standard 3 point type) was used in the analysis. The primary skeleton of model has been done in AutoCAD-13 and WaterGEMS environment. Then it was exported as EPANET file and the model was then analyzed basic WaterGEMS environment.

Table 4: Preliminary data for model skeleton

Element	Used value	Element	Used value
Design Software	Bentley WaterGEMS	Number of Overhead tank	1
Analysis Type	Steady State	Height of Overhead tank	30m
Friction Method	Hazen-Williams	Diameter of Overhead tank	6.10m
Friction Coefficient	150.0	Maximum elevation of tank	35m
Accuracy	0.001	Initial elevation of tank	30m
Pipe Materials	Galvanized iron	Minimum elevation of tank	28m
Pipe diameter	38mm, 50mm,100mm, 150mm, 200mm	Base elevation of tank	25m
Number of pipe	116	Used scaling	1cm=5m
Number of Junction	94	Number of Zone	3

3.2.2 Primary Model

The primary model developed in combined environment of AutoCAD-13 and WaterGEMSis shown in figure 4(a). For model skeleton a total number of 116 pipes and 94 junctions were used. Furthermore, five types of pipe diameter i.e. 38mm, 50mm, 100mm, 150mm and 200mm were used for the analysis. The used map or plan was fitted with a scaling of 1:500. The imputation of the scaling was performed as 1cm=5m as listed in table 4. The skeleton was performed in such a manner that existing model of pipeline network can be merged. Though, the water distribution network is not working presently in student residential hall, the design and analysis was performed for the entire area.

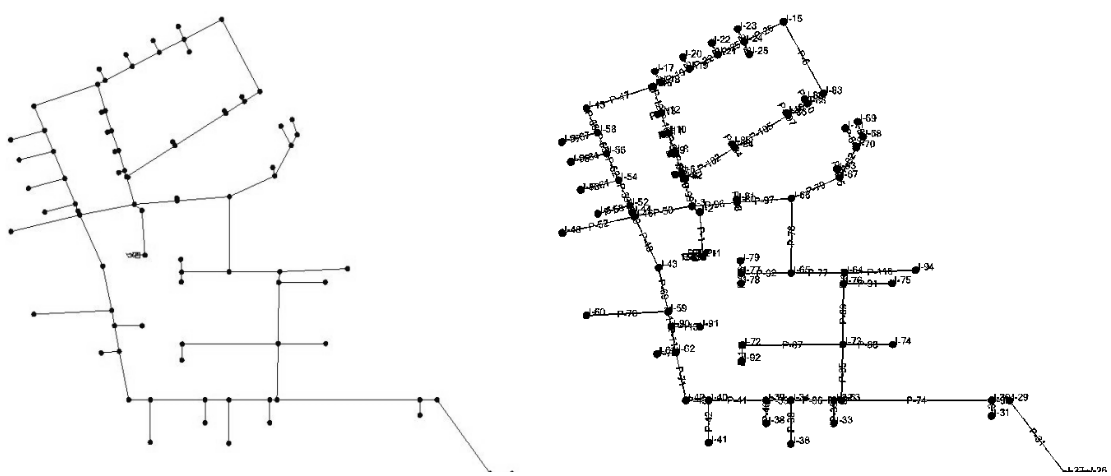

Figure 4: (a) Developed initial model by AutoCADandWaterGEMS (b) Analyzed Model in Basic WaterGEMS

The exported model as EPANET file that was analyzed in basicWaterGEMS environment is shown in figure 4(b). Here, the node, junction and pipe identification is labeled. The pipe materials used for the analysis are Galvanized iron and the accuracy of the analyzed value is configured with 0.001. A Steady State analysis was performed by considering Hazen-Williams friction coefficient as 150.Water distribution network model is assembled by applying two basic data entry procedures. At first, data is manually created by typing it into the model and then data has been transferred between various files by simply importing the data from one file to another, which also requires some additional manual editing techniques.

3.3 Water supply planning of KWASA

In Khulna region of Bangladesh, scarcity of drinking water is remarkable. To fulfill the crisis of potable water, Khulna Water Supply and Sewerage Authority (KWASA) is supplying water to the Khulna city dwellers through its distribution network from the groundwater source (GW) since March, 2008. Water supply by Khulna WASA comes from deep tubewells without water treatment through its limited distribution network system of

268 km length to the city dwellers and is able to meet 47.5% of the total demand for water of the city (Fahmida*et al*., 2013). A variety of physical, chemical and biological transformations can happen once the water travels through a distribution system. Recently a new pipeline of 150mm diameter has been connected to the existing network of KUET campus by a 100mm diameter pipeline as shown in figure-5 to fulfill the rising water demand in this campus area. However, the quality of supplied water is not satisfactory (Fahmida*et al*., 2013). Thus proper strategy should be taken for the treatment of supplied water by KWASA before its distribution to the residents.

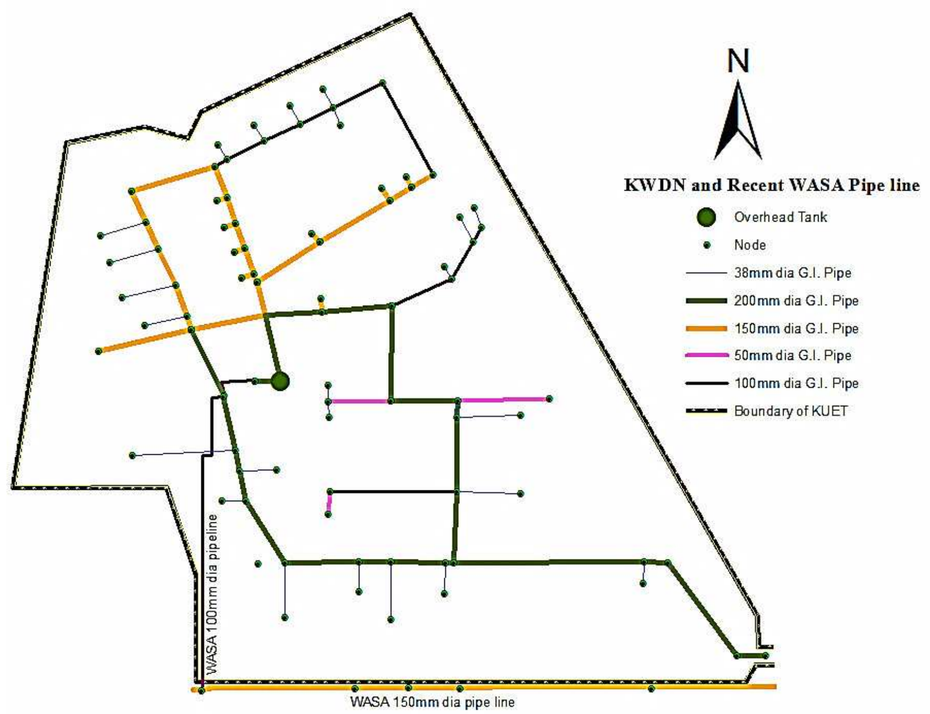

Figure 5: WASA pipeline alignment with existing WDN

3.4 Scenarios of KUET water distribution network

3.4.1 Simulated scenario based on Water flow

The simulated scenario of distribution network developed in ArcGIS in terms of flow of water is shown in figure 6(a). In performing validation, system demands, initial conditions and operational regimes need to be adjusted to match the conditions at the time the additional field data set was collected. The maximum flow of water was found to be above5 L/s in the connection zone. The flow is then reduced up to 0-1 L/s at the consumption point. The designed flows found in the teacher's residential area and the office buildings are satisfactory. While, the flows in student residential areaswere not found to be satisfactory with the present alignment of the distribution network. The scenario shows that the water flow in main line of the teacher residential area ranges 3-5 L/s. Also, the water flows at main line in staff quarter and office or academic building were found to be 2-3 L/s and 1-3L/s, respectively. Furthermore, the flow in the student residential area was found to be only 1-2L/s. Therefore, an alternative source of water as KWASA may be considered as a solution of this problem.

3.4.2 Simulated scenario based on flow velocity

The simulated scenario of distribution network developed in ArcGIS in terms of flow velocity is shown in figure 6(b). The maximum and minimum flow velocities of water were found to be around 1.10 m/s and 0-0.10 m/s, respectively. While, the standard value of flow velocity ranges 0.20m/s to 1.30m/s (BNBC, 2011). The velocity of flow in main line of the teacher residential area ranges 0.10-0.20 m/s. Also, the water flow at main line in staff quarter and office or academic building were found to be 0.10-0.40 m/s and 0.10-0.30 m/s, respectively. Therefore, the flow velocities found in the teacher's residential area and the office building are satisfactory. Whereas, the flow in student residential hall having high water demand was not found to be satisfactory with the present alignment of the distribution network. The flow in this area was found to be only 0-0.2 m/s.

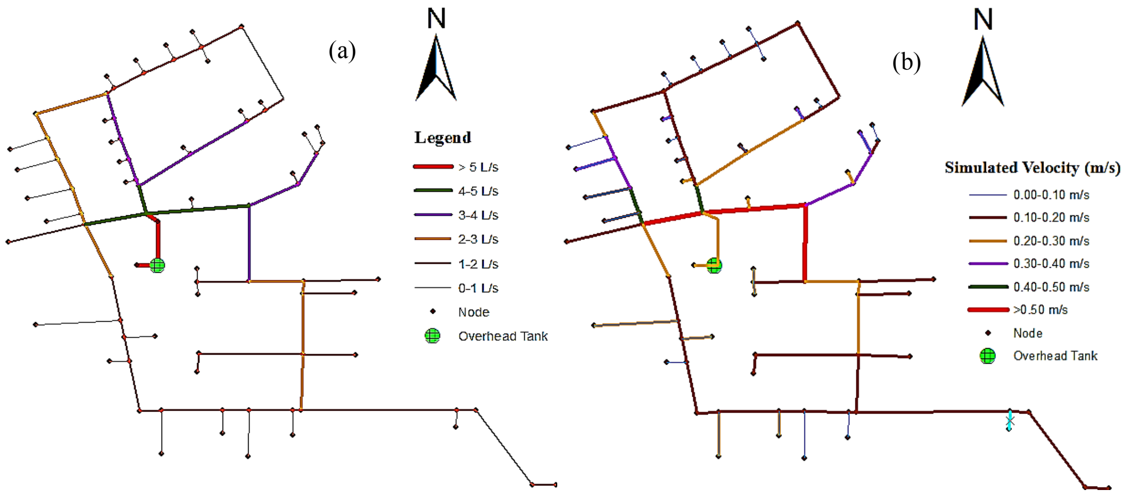

Figure 6: Scenario based on (a) Water flow, (b) Flow velocity

3.5 Simulated scenario based on head loss

The simulated scenario of distribution network developed in ArcGIS in terms of head loss is shown in figure 7(a). The minimum and maximum head losses were found to be around 0.00 m/m and 0.051 m/m, respectively. In most of the pipeline the head loss were found to be zero. The scenario shows that the head loss in main line of the teacher residential area ranges 0.00-0.020 m/m. Also, the head losses at main line in staff quarter and office or academic building were found to be 0.00-0.030 m/m. Furthermore, the head loss in the student residential area was found to be only 0.00-0.051 m/m while the maximum permissible head loss ranges 0.015 m/m-0.016 m/m (BNBC, 2011). Therefore, the head loss in the most of the consumption point in student residential area were not up to the mark.

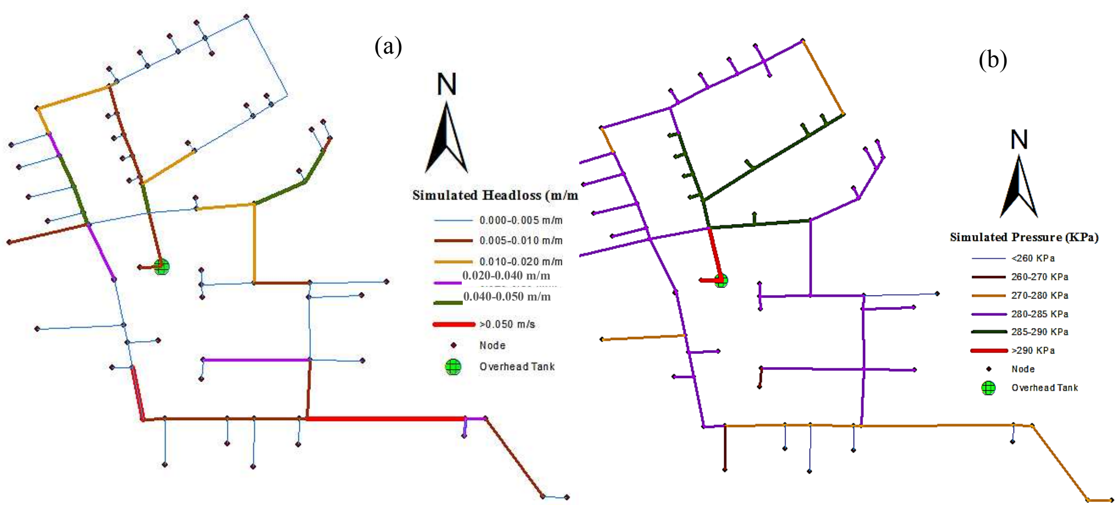

Figure 7: Scenario based on (a) Head Loss, (b) water pressure

3.6 Simulated scenario based on Water Pressure

The simulated scenario of distribution network developed in ArcGIS in terms of water pressure is shown in figure 7(b). The maximum and minimum water pressures were found to be around 293 kPA and 112 kPa, respectively. The designed water pressure found in the teacher's residential area and the office building are satisfactory. Whereas, the water pressure in student residential hall having high water demand was not found to be satisfactory with the present alignment of the distribution network. The scenario shows that the water pressure in main line of the teacher residential area ranges 270-290 kPa. Also, the water pressure at main line in staff quarter and office or academic building were found to be 270-285 kPa and 260-285 kPA, respectively. Furthermore, the water pressure in the student residential area was found to be only 112-280 kPa. The minimum water pressure were around 112 kPa that is less than the International Plumbing Code (IPC-2006) recommended value of 172.4 kPa

4. CONCLUSIONS

The study was addressed by analyzing and designing the water distribution network for the future projected demand with Bentley WaterGEMS software. The maximum flow of water was found to be above5 L/s in the connection zone. The flow is then reduced up to 0-1 L/s at the consumption point. The maximum and minimum flow velocities of water were found to be around 1.10 m/s and 0-0.10 m/s, respectively. While, the standard value of flow velocity ranges 0.20m/s to 1.30m/s (BNBC, 2011). Also, the minimum and maximum head losses were around 0.00 m/m and 0.051 m/m, respectively while the maximum permissible head loss ranges 0.015 m/m-0.016 m/m (BNBC, 2011). Furthermore, the minimum water pressure were around 112 kPa that is less than the International Plumbing Code (IPC-2006) recommended value of 172.4 kPa. The ArcGIS scenarios shows that the designed water flows, velocities and water pressures in the teacher's residential area as well as the office building were found to be satisfactory. Whereas, water flows, velocities and water pressures in the student residential halls were not up to the mark with the present sources, alignment and accessories of the distribution network. The flow, velocity and pressure in the student residential area as displayed in the simulated scenarios were found to be only 1-2L/s, 0-0.2 m/s and 112-280 kPa, respectively. Based on the study, following recommendations have been drawn:

a) An alternative source of water supply in addition to the existing system should be considered for fulfilling the rising water demand.
b) Supplied water by KWASA can be considered as an initial solution of this problem but the microbial treatment of supplied water is prerequisite for the provision of safe water supply.
c) The Bhairob River can be considered as an alternate raw water source but more reliable further studied is desirable earlier the final choice of river water as raw water source in case of the water supply system of KUET campus.

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