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Analysis and Design of Water Distribution Network Using EPANET: A Case Study of HSTU Campus of Dinajpur, Bangladesh

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Abstract: This paper represents the analysis and design of the Water Distribution Network (WDN) system using EPANET for Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. Supply of water is essentially required for academic, administrative, student hostel and residential buildings according to their occupancies. Water supply system with sufficient pressure head and technical sustainability is nowadays a challenging task for the researcher, respected authority and government tackling the crisis in provided safe water due to the rapid increase in population. EPANET is a public domain software developed by the US Environmental Protection Agency (EPA) which is used widely to design and analysis of water supply network system with reference to technical sustainability. HSTU is a renowned public university located at northern part of Bangladesh having 89 acres campus area and population around Ten Thousand (2020) including teachers, students and staffs. Present Water Distribution System in HSTU campus has been found inadequate to cover the total campus and most the building has individual suction pump. In recent future such types of water distribution network system in HSTU may or may not be suitable. Hence, this study is all about the analysis and design of a new water distribution network and provide conclusion about the suitability of the network for recent future. Various public demands, quantities of inflows and out flows of the over-head reservoir are taken into consideration during the analysis. Study materials are to be used for this study include HSTU campus plan, network parameters such as block wise population, and water demand, elevations, pipe length and EPANET software. An extended period simulation of water distribution network system is carried out during the analysis using EPANET. This study is carried to provide the knowledge about various demands, pressure head, pipe flow and diameter, head losses and a new network of supply will make aware of the new demands. Water distribution network system design using EPANET will provide an overall improvement over the existing network and evaluate the supply network for future.

Keywords: EPANET, Water Distribution Network, Population, Water Demand, Hydraulic Simulation

1. Introduction

Water is an inorganic and transparent chemical substance that is nearly tasteless, colorless and odorless. It is the main component of the of the hydrosphere strata of the earth and compulsory for all living organisms. Providing adequate amount of clean water is utmost necessary and has been considered as one of the most important task in human history. Greater portion of primitive civilizations rise near water sources. Around 3500 years ago human began transporting water through pipes [1]. It is therefore expected that early civilizations arisen around river valleys such as those of the Nile in Egypt, Indus in India, Hwangho in China and Euphrates and Tigris in ancient Mesopotamia [2]. Primitive people used to deliver water over long distance using channel for daily use. Safety, reliability, affordability, and accessibility of fresh water is prime requirements for good health. Water is a critical resource that supports human life and culture, ecological functions and economic activities. With progressive population growth the needs, the incremental water supply demand substantially increased day by day. This is leading to a crisis of water management in many locations which is acknowledged in various international declaration [3].

Water covers 71% of the total area of Earth's surface, most of them are present in seas and oceans. Little portion of water can be found as groundwater (1.7%), another 1.7% is presents in the form of glaciers and ice caps of North and South pole, and percentage of water presents in air vapor and clouds and precipitation is (0.001%) [4]. It has been estimated that a minimum of 7.5 litres of water per person per day is required in the home for drinking, preparing food, and personal hygiene, the most basic requirements for water; at least 50 litres per person per day is needed to ensure all personal hygiene, food hygiene, domestic cleaning, and laundry needs [5]. In 2010, about 85% of the global population (6.74 billion people) had access to piped water supply through house connections [6, 7].

The aim of this study is to analysis and design of a water distribution network system using EPANET for HSTU campus in Dinajpur, Bangladesh. A water distribution system is a hydraulic infrastructure which consists of pipes, tanks, reservoirs, pumps, and valves that convey water to the consumers from source or a centralized treatment plant or wells in order to satisfy residential, commercial, industrial and firefighting requirements [8, 9]. World Health Organization (WHO) defines the water distribution system as a tree-like structure consists of pipes and nodes that carry water from sources to the consumers [10]. The most important concern in designing a water distribution system is to gratify consumers demand during the entire lifetime for the desired demand conditions under the limit of quantity and quality concern. Hence, it is necessary to plan and construct a suitable water distribution network system for continuously growing populations of HSTU in order to provide sufficient and uniform quantity of water through the designed network of pipes. Water distribution network is one of the main components of water supply system that needs to design and handle carefully because of cost involved and its purpose. Construction cost of a large water distribution network is higher although in the long run it saves a lot of money and life, but at primary stage a large investment is to be required. Nearly 80% to 85% of the total cost of whole water supply system expended into the water transmission and the water distribution network [11, 12]. Despite this, the function of these supply systems often goes unobserved until there is a major breakage or operational failure. As failure events are likely unavoidable and often dramatic and costly, so a proper water distribution system is required to avoid such unexpected hazards. WDN system also entails great social, economic, and environmental burdens. The most common challenges in WDN include water quality degradation, capacity shortages, infrastructure aging and deterioration, demand increases, and their ever-increasing energy consumption coupled to the global energy crisis. In water utility systems, a great amount of water is loss as leakage while in transport from source up to consumers. Water loss represents inadequacy in water delivery and measurement operations in distribution networks. By acquiring a continuous water supply, cities in the developing world must ensure that their water systems become more efficient and effective by reducing water losses, gradually increasing tax of water, enhancing staff productivity, increasing revenue Collection, and ensuring safe and reliable water supplies. When the productivity will increase, then investments in new infrastructure will lead to more feasible and workable water services [13].

In this particular study analysis and hydraulic simulation of distribution network system is done by the EPANET 2.0 software. The analysis of pipe networks has long been one of the most computationally complex problems which hydraulic engineers have to contend with [14]. EPANET is a software application used throughout the world that performs extended period simulation of hydraulic and water quality behavior within pressurized water supply pipe networks. It has the capabilities to analyzed unlimited number of pipes and User Manuals for better understanding the software can also be downloaded free [15]. EPANET has the capability of tracking the pressure and demand in each nodes, flow, velocities and head losses in each pipes, height of water in each tank and concentration of chlorine species throughout the network during the extended period simulation. It also traces the water age and source in addition to chemical species [16]. EPANET is specially designed as a simulation tool for better realization of the movement and fate of drinking water components within distribution systems. It can be applied in several ways such as in distribution systems analysis. Sampling programs design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment [16, 17].

Objectives of the study:

To analyze and design a WDN for HSTU campus and assess the present water demand and predict the future demand.

To determine all the hydraulic parameters of distribution system.

To provide equitable and constant water supply.

2. Study Area

This particular study was conducted in Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. HSTU is a government- financed renowned public Science and Technology University at Dinajpur Sadar upazila in Rangpur Division, Bangladesh. The HSTU campus is located at 9 km from Dinajpur city on Dinajpur-Rangpur highway (NH 5), and around 10 km from Dinajpur railway station. The university is geographically situated at latitudes of 25.6987° North and longitudes of 88.6562° East. This university campus spread over an area of 89 acres of land with ample greenery and having populations around Ten Thousand including students, teachers and other academic or administrative staffs. Due to the rapid increase in population in the last few years, the current water supply system is failing to meet the water needs of the consumers. So the purpose of this study is to design a sustainable water supply system for HSTU campus. Total campus is divided into two zones having two separate distribution networks with individual elevated storage tank and pumping system. Campus profile of HSTU are given in "*Table 1*".

Table 1. *Campus Profile.*

Types of Building	No. of Building
Academic Building	9
Hostel Building	11
Quarter Building	23
TSC	1
Auditorium	2
Firm	2
Medical Center	1
Guest House	2
Employe Club	1
VC Banglow	1
Gymnasium	1
Office Building	3
Mosque	2
Vaterinary Clinic	1
Fire Hydrants	6
Storage Tank	2

Satellite view of HSTU campus as shown in "*Figure 1*".

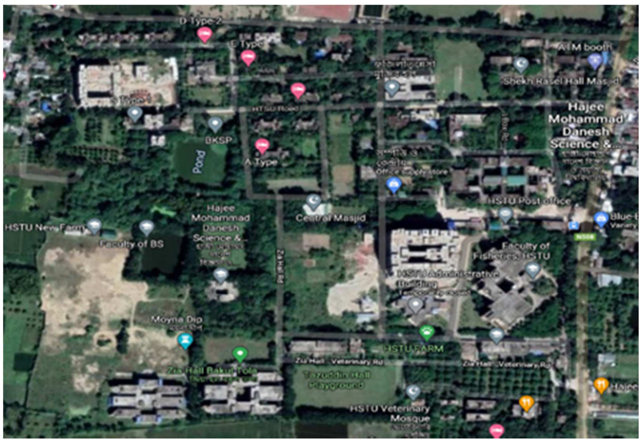

Figure 1. *Study Area.*

3. Methodology

3.1. Materials

The materials used in this study consists of HSTU campus plan, water distribution parameters such as population and water demand etc. Distribution network parameters like nodal elevation, demand and pipe length, diameter etc. and EPANET software.

3.2. Layout of Distribution Network

Landscape of HSTU campus was firstly collected from Engineering Section of HSTU. After conducting several surveys on HSTU campus the Landscape of HSTU was upgraded using AutoCAD version 17. Landscape displays the layout of all the road and the permanent features. The distribution network was drawn up after completion of the preparation of landscape of HSTU. This university campus has the irregular pattern of roads and other permanent features that's why the dead end system was selected. Intermittent supply system was considered for HSTU campus to bring economy in the design of the distribution system. Water should be supplied twice a day for 3 hours, once at night and once a day. Pumping and storage supply system is best suited for this purpose. Total campus area was divided into two zones having two individual supply network under an elevated storage tank for each network. Tank 1 serves zone 1 called Old Agricultural college campus situated into northern portion of the campus. Zone 2 including the southern old Veterinary College Campus and central portion of the campus is being served by Tank 2.

3.3. Leveling Work

Leveling was done to determine elevation of the campus at selected point which is subjected to the elements of the water distribution network. Points were selected according to the layout of the distribution network and the elevation was recorded by using Google Earth with respect to a selected point called datum. Depth of water table was selected as datum and elevation of all the points were measured with respect to datum in meter. Depth of node or supply pipe line was considered 2 meter below the ground surface.

3.4. Population and Demand Calculation

Population of campus was calculated from the number of buildings and their occupancies. Future population was calculated in terms of academic, student hostel, residential and other types of building and their capacity that could be constructed in the near future. After calculating population of the campus quantity of water required to supply can be calculated from the provision stated in Bangladesh National Building Code (BNBC). BNBC code provide minimum standards for the design, installation and maintenance of water supply and distribution system within a building and its premises. It also provides the demand of different types of the building according to their occupancies. Liter per Capita per Day (LPCD) demand as per BNBC code shown in "*Table 2*".

Table 2. *Per Capita Demand* [18].

Types of Consumption	Demand in LPCD
Single Family	135
Single Family (full facilities)	400
Mess, Hostels,	70
Educational Facilities	45
Normal Medical Facilities	225
Offices (full facilities)	45
Offices	30
Low Fire Risk Storage	6
Private Garage	5
Small assembly	5
lodge or hotel	135
Sport facilities	5

3.5. EPANET Input

Elevation of the node were provided into EPANET as calculated before in step 3.3. Selected Water supply system for HSTU campus is intermittent type and water has to be supplied twice a day for 3 hours at once. Litter per Second (LPS) was selected as flow units for EPANET. So the demand has to be calculated in LPS for 3hour×2= 6hour supply. At first stage it has been supplied from 12 AM to 3 AM and in the second stage from 12 PM to 3 PM. Pipes or links were drawn in the EPANET software by connecting two nodes. Landscape of HSTU (.wmf) file was used as a backdrop map. Co-ordinates of the backdrop map were provided in such a way that the actual length of pipe can be obtain from the EPANET software while drawing pipe or link using auto-length. Diameter of the pipes were provided in millimeter. Correction of the diameter might be required and correction was provided in trial and error method. In this particular study Hazen-williams equation was used as head loss formula. So the pipes roughness co-efficient was used 140 [19]. Elevated storage reservoirs were provided with sufficient capacity to serve the water requirements throughout the day. Pump data was provided as pump curve which express the capacity of the pump in terms of discharge and total head. Here total head represents the summation of static, velocity and frictional head loss. Surface water source like river of large lake are not presently available so underground water has to be used as a source of water. In our study depth of submersible pump 300ft was considered as datum so the head of both reservoirs are considered as zero.

3.6. Hydraulic Simulation

After a water distribution network has been described suitably, it's hydraulic and water quality behavior were analyzed. The hydraulic simulation was done for a period of 24 hours and report time starts from 12 AM. During the simulation period the pressure, demand of each node and flow, velocity of each pipe were noticed [16, 20].

4. Results and Discussions

EPANET results were obtained after completing successful simulation. Water distribution network system in HSTU campus consists of 112 nodes or junctions, 112 cast iron links or pipes of varying diameter, 2 pumps, 2 elevated storage tanks and underground water as source reservoirs. An extended period simulation of WDN system using EPANET was conducted and changes in the hydraulic parameter like nodal demand, pressure and pipe flow, velocity, head loss were observed at each hydraulic time steps. 24 hours simulation period was selected within which water was supplied twice from 12 AM to 3 AM and 12PM to 3 PM. Total water demand per day for zone 1 and zone 2 were 435.24 and 633.55 cubic meter respectively. Total quantity of water to be supplied into the networks were 1068.79 cubic meter per day. Reporting start time of hydraulic simulation was set as 13:00 hour or 1 PM because demand of water was highest then.

4.1. Nodes Result

Water Distribution Network of HSTU campus has 112 nodes. The elementary input data for nodes are elevation, base demand and demand pattern. Hydraulic head and pressure are the output results computed from EPANET at 13 hours are shown in "*Table 3*".

Table 3. *Nodes Result.*

Node ID	Elevation m	Demand LPS	Head m	Pressure m
Junc 1	87.002	0	108.62	21.61
Junc 2	87.306	0	108.38	21.07
Junc 3	87.306	0	108.27	20.96
Junc 4	87.306	0.685	108.23	20.92
Junc 5	87.306	0	107.90	20.60
Junc 6	87.306	0.261	107.48	20.18
Junc 7	87.002	0.359	107.66	20.66
Junc 8	87.002	0	108.11	21.11
Junc 9	87.002	0.08	107.97	20.97
Junc 10	86.697	0	108.01	21.32
Junc 11	86.697	0.016	108.00	21.30
Junc 12	86.697	0.359	107.40	20.70
Junc 13	86.087	0.216	105.18	19.09
Junc 14	87.002	0.014	108.05	21.05
Junc 15	87.002	0	107.77	20.76
Junc 16	86.697	0	106.01	19.32
Junc 17	86.697	0.626	105.91	19.21
Junc 18	86.697	0.604	105.94	19.24
Junc 19	86.697	0	105.70	19.00
Junc 20	86.697	0.615	105.63	18.94
Junc 21	86.697	0.144	105.28	18.58
Junc 22	87.002	0.767	107.64	20.64
Junc 23	87.306	0	107.50	20.20
Junc 24	87.611	2.396	106.85	19.23
Junc 25	87.306	0	107.45	20.14
Junc 26	87.306	0.067	107.43	20.12
Junc 27	87.002	0	106.35	19.35

Node ID	**Elevation m**	**Demand LPS**	**Head m**	**Pressure m**
Junc 28	87.002	0.013	106.35	19.34
Junc 29	87.002	0.048	105.68	18.68
Junc 30	87.002	0.447	108.22	21.22
Junc 31	87.002	0	108.34	21.34
Junc 32	87.002	1.863	107.99	20.99
Junc 33	87.002	0	107.61	20.60
Junc 34	87.002	0.745	107.50	20.50
Junc 35	87.002	0.186	107.09	20.09
Junc 36	86.392	0	107.81	21.42
Junc 37	86.697	0	106.85	20.15
Junc 38	86.697	0.345	106.30	19.60
Junc 39	86.697	0	106.85	20.15
Junc 40	86.697	0.374	106.58	19.89
Junc 41	87.002	0.359	105.46	18.46
Junc 42	86.392	0.411	107.52	21.12
Junc 43	87.002	0	107.51	20.51
Junc 44	87.002	0	107.38	20.38
Junc 45	87.002	0	107.06	20.05
Junc 46	87.306	0.288	106.26	18.96
Junc 47	87.002	0.072	106.88	19.88
Junc 48	86.392	0	107.12	20.73
Junc 49	86.392	0.288	106.66	20.27
Junc 50	87.002	0.403	106.14	19.13
Junc 51	87.002	0	105.15	18.15
Junc 52	87.002	0	103.14	16.13
Junc 53	87.002	0.381	102.77	15.77
Junc 54	86.087	0.034	103.08	16.99
Junc 55	85.782	0.319	106.78	21.00
Junc 56	86.697	0	103.87	17.17
Junc 57	86.697	0	103.78	17.08
Junc 58	86.697	0.359	103.55	16.85
Junc 59	86.697	0.374	103.52	16.82
Junc 60	86.697	0	101.79	15.09
Junc 61	86.697	0	101.56	14.86
Junc 62	86.697	0.388	101.35	14.65
Junc 63	86.697	0.41	101.33	14.63
Junc 64	87.306	0.273	98.74	11.44
Junc 65	87.002	0	106.61	19.61
Junc 66	87.002	0	106.13	19.13
Junc 67	86.697	0.431	105.52	18.83
Junc 68	87.002	0.359	105.86	18.85
Junc 69	87.002	0.417	105.08	18.07
Junc 70	87.002	0	106.36	19.36
Junc 71	87.002	0.374	105.60	18.6
Junc 72	85.782	2.981	106.26	20.48
Junc 73	86.392	0	108.00	21.61
Junc 74	87.306	0	107.62	20.31
Junc 75	87.306	0	107.55	20.24
Junc 76	86.392	0.479	105.82	19.43
Junc 77	87.306	4.792	107.36	20.06
Junc 78	87.306	2.023	107.43	20.12
Junc 79	87.002	9.583	107.11	20.1
Junc 80	86.392	0	107.02	20.63
Junc 81	86.392	0	106.71	20.32
Junc 82	87.002	0	105.46	18.46
Junc 83	87.002	0	105.32	18.32
Junc 84	87.002	0.359	104.67	17.67
Junc 85	87.002	0.338	105.01	18.01
Junc 86	87.002	0	104.44	17.44
Junc 87	87.002	1.118	104.17	17.16
Junc 88	86.087	0.108	103.71	17.62
Junc 89	86.392	0	104.59	18.19
Junc 90	86.392	1.162	104.07	17.68
Junc 91	86.392	0.072	104.43	18.04
Junc 92	86.392	0.072	104.30	17.91
Junc 93	86.392	0.404	106.82	20.42
Junc 94	86.392	0	106.15	19.76

Node ID	Elevation m	Demand LPS	Head m	Pressure m
Junc 95	86.392	0	106.07	19.68
Junc 96	86.087	0.008	106.07	19.98
Junc 97	86.392	0.04	105.99	19.6
Junc 98	86.697	0	103.55	16.85
Junc 99	86.087	0.064	103.21	17.12
Junc 100	87.002	0.108	103.20	16.19
Junc 101	86.697	0.101	103.06	16.37
Junc 102	86.697	0	107.63	20.93
Junc 103	86.697	0	107.52	20.82
Junc 104	86.697	0.072	107.39	20.69
Junc 105	86.697	0.969	107.39	20.69
Junc 106	85.782	0	107.35	21.57
Junc 107	85.782	0.853	107.19	21.41
Junc 108	86.087	3.466	107.08	20.99
Junc 109	85.782	1.677	104.70	18.92
Junc 110	86.087	0	106.08	19.99
Junc 111	86.087	1.198	105.09	19.00
Junc 112	85.782	0.266	99.47	13.69
Resvr R1	0	-31.281	0	0
Resvr R2	0	-45.778	0	0
Tank T1	107.289	11.13	108.65	1.36
Tank T2	106.375	16.446	108.06	1.69

The above “Table 3” shows during simulation at 13.00 hours the highest pressure generated at junction 1 and 73 is 21.61m and lowest pressure generated at junction 64 is 11.44m.

4.2. Links Result

This supply network has 112 links and the Direction of flow depends upon the hydraulic head and considered that pipe allows full flow at all the time. The elementary input data for pipes are diameter, length and roughness co-efficient. Flow rates, velocity and head loss are the output results obtained from EPANET at 13 hours are shown in “Table 4”.

Table 4. *Links Result.*

Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Head-loss m/km
Pipe 1	9.32	175	20.151	0.838	3.98
Pipe 2	76.81	125	7.270	0.592	3.10
Pipe 3	44.94	80	1.990	0.396	2.48
Pipe 4	3.89	40	0.685	0.545	10.06
Pipe 5	43.58	40	0.620	0.493	8.36
Pipe 6	8.48	20	0.261	0.831	49.28
Pipe 7	7.88	25	0.359	0.731	30.00
Pipe 8	44.52	50	0.685	0.349	3.39
Pipe 9	6.39	15	0.080	0.453	22.40
Pipe 10	13.11	40	0.591	0.47	7.65
Pipe 11	10.88	15	0.016	0.091	1.14
Pipe 12	20.51	25	0.359	0.731	30.00
Pipe 13	81.65	20	0.216	0.688	34.71
Pipe 14	70.93	15	0.014	0.079	0.89
Pipe 15	119.9	100	5.280	0.672	5.09
Pipe 16	71.78	50	1.989	1.013	24.42
Pipe 17	12.64	40	0.626	0.498	8.51
Pipe 18	9.05	40	0.604	0.481	7.97
Pipe 19	25.71	40	0.759	0.604	12.16
Pipe 20	8.02	40	0.615	0.489	8.24
Pipe 21	25.97	20	0.144	0.458	16.38
Pipe 22	10.04	40	0.767	0.61	12.40
Pipe 23	68.42	80	2.524	0.502	3.85
Pipe 24	19.09	50	2.396	1.22	34.48
Pipe 25	12.74	25	0.128	0.261	4.44
Pipe 26	5.15	20	0.067	0.213	3.97
Pipe 27	80.64	15	0.061	0.345	13.55
Pipe 28	10.34	15	0.013	0.074	0.77
Pipe 29	77.5	15	0.048	0.272	8.70
Pipe 30	8.79	25	0.447	0.911	45.02
Pipe 31	59.17	80	2.794	0.556	4.64
Pipe 32	16.06	50	1.863	0.949	21.63
Pipe 33	41.43	40	0.931	0.741	17.75

Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Head-loss m/km
Pipe 34	8.78	40	0.745	0.593	11.75
Pipe 35	19.58	20	0.186	0.592	26.32
Pipe 36	154.4	125	9.640	0.786	5.23
Pipe 37	41.03	40	1.078	0.858	23.29
Pipe 38	19.89	25	0.345	0.703	27.87
Pipe 39	15.34	100	0.733	0.093	0.13
Pipe 40	8.23	25	0.374	0.762	32.36
Pipe 41	46.25	25	0.359	0.731	30.00
Pipe 42	7.56	25	0.411	0.837	38.54
Pipe 43	39.65	80	3.589	0.714	7.38
Pipe 44	17.53	50	1.051	0.535	7.49
Pipe 45	10.85	25	0.360	0.733	30.15
Pipe 46	13.43	20	0.288	0.917	59.14
Pipe 47	9.56	15	0.072	0.407	18.43
Pipe 48	25.84	40	0.691	0.55	10.22
Pipe 49	7.75	20	0.288	0.917	59.14
Pipe 50	26.43	25	0.403	0.821	37.16
Pipe 51	78.98	50	2.219	1.13	29.91
Pipe 52	51.37	25	0.415	0.845	39.23
Pipe 53	10.85	25	0.381	0.776	33.49
Pipe 54	12.4	15	0.034	0.192	4.59
Pipe 55	30.48	25	0.319	0.65	24.10
Pipe 56	62.81	50	1.804	0.919	20.38
Pipe 57	8.26	40	0.733	0.583	11.40
Pipe 58	7.61	25	0.359	0.731	30.00
Pipe 59	8.09	25	0.374	0.762	32.36
Pipe 60	90.49	40	1.071	0.852	23.01
Pipe 61	17.45	40	0.798	0.635	13.34
Pipe 62	6.03	25	0.388	0.79	34.64
Pipe 63	6.03	25	0.410	0.835	38.36
Pipe 64	56.88	20	0.273	0.869	53.56
Pipe 65	104	80	4.562	0.908	11.51
Pipe 66	16.65	40	1.207	0.96	28.71
Pipe 67	14.47	25	0.431	0.878	42.08
Pipe 68	9.14	25	0.359	0.731	30.00
Pipe 69	26.65	25	0.417	0.85	39.58
Pipe 70	38.69	80	3.355	0.667	6.52
Pipe 71	23.35	25	0.374	0.762	32.36
Pipe 72	18.78	80	2.981	0.593	5.24
Pipe 73	15.55	200	29.332	0.934	4.17
Pipe 74	90.24	175	20.831	0.866	4.23
Pipe 75	14.19	150	14.854	0.841	4.80
Pipe 76	33.78	25	0.479	0.976	51.17
Pipe 77	14.44	80	4.792	0.953	12.61
Pipe 78	7.51	50	2.023	1.03	25.20
Pipe 79	85.24	125	9.583	0.781	5.18
Pipe 80	67.61	80	3.954	0.787	8.83
Pipe 81	50.64	80	3.229	0.642	6.07
Pipe 82	54.43	50	1.923	0.979	22.94
Pipe 83	13.81	40	0.697	0.555	10.39
Pipe 84	21.65	25	0.359	0.731	30.00
Pipe 85	11.6	25	0.338	0.689	26.83
Pipe 86	34.52	40	1.226	0.976	29.56
Pipe 87	11.04	40	1.118	0.89	24.92
Pipe 88	18.79	15	0.108	0.611	39.04
Pipe 89	63.93	40	1.306	1.039	33.23
Pipe 90	19.27	40	1.162	0.925	26.76
Pipe 91	8.48	15	0.072	0.407	18.43
Pipe 92	15.42	15	0.072	0.407	18.43
Pipe 93	5.4	25	0.404	0.823	37.33
Pipe 94	35.47	25	0.321	0.654	24.38
Pipe 95	38.21	20	0.048	0.153	2.14
Pipe 96	14.1	15	0.008	0.045	0.31
Pipe 97	12.67	15	0.040	0.226	6.20
Pipe 98	48.64	20	0.273	0.869	53.56
Pipe 99	22.89	15	0.064	0.362	14.82
Pipe 100	8.99	15	0.108	0.611	39.04

Link ID	Length m	Diameter mm	Flow LPS	Velocity m/s	Unit Head-loss m/km
Pipe 101	14.05	15	0.101	0.572	34.49
Pipe 102	89.06	125	8.501	0.693	4.15
Pipe 103	5.07	40	1.041	0.828	21.83
Pipe 104	7.1	15	0.072	0.407	18.43
Pipe 105	6.59	40	0.969	0.771	19.12
Pipe 106	84.93	125	7.460	0.608	3.26
Pipe 107	10.5	40	0.853	0.679	15.10
Pipe 108	39.38	80	3.466	0.69	6.92
Pipe 109	149	50	1.677	0.854	17.81
Pipe 110	91.8	50	1.464	0.746	13.85
Pipe 111	35.15	40	1.198	0.953	28.32
Pipe 112	129.4	20	0.266	0.847	51.05
Pump Pu1	#N/A	#N/A	31.281	0	-108.65
Pump Pu2	#N/A	#N/A	45.778	0	-108.06

The above "Table 4" shows during simulation at 13.00 hours the highest flow or discharge generated through the pipe 73 is 29.332 LPS and lowest flow generated through the pipe 28 is 0.013 LPS.

4.3. Results in Color-coded Map

"*Figure 2"* illustrate the color-coded map for node demand and link flow of water distribution network at 13 hours.

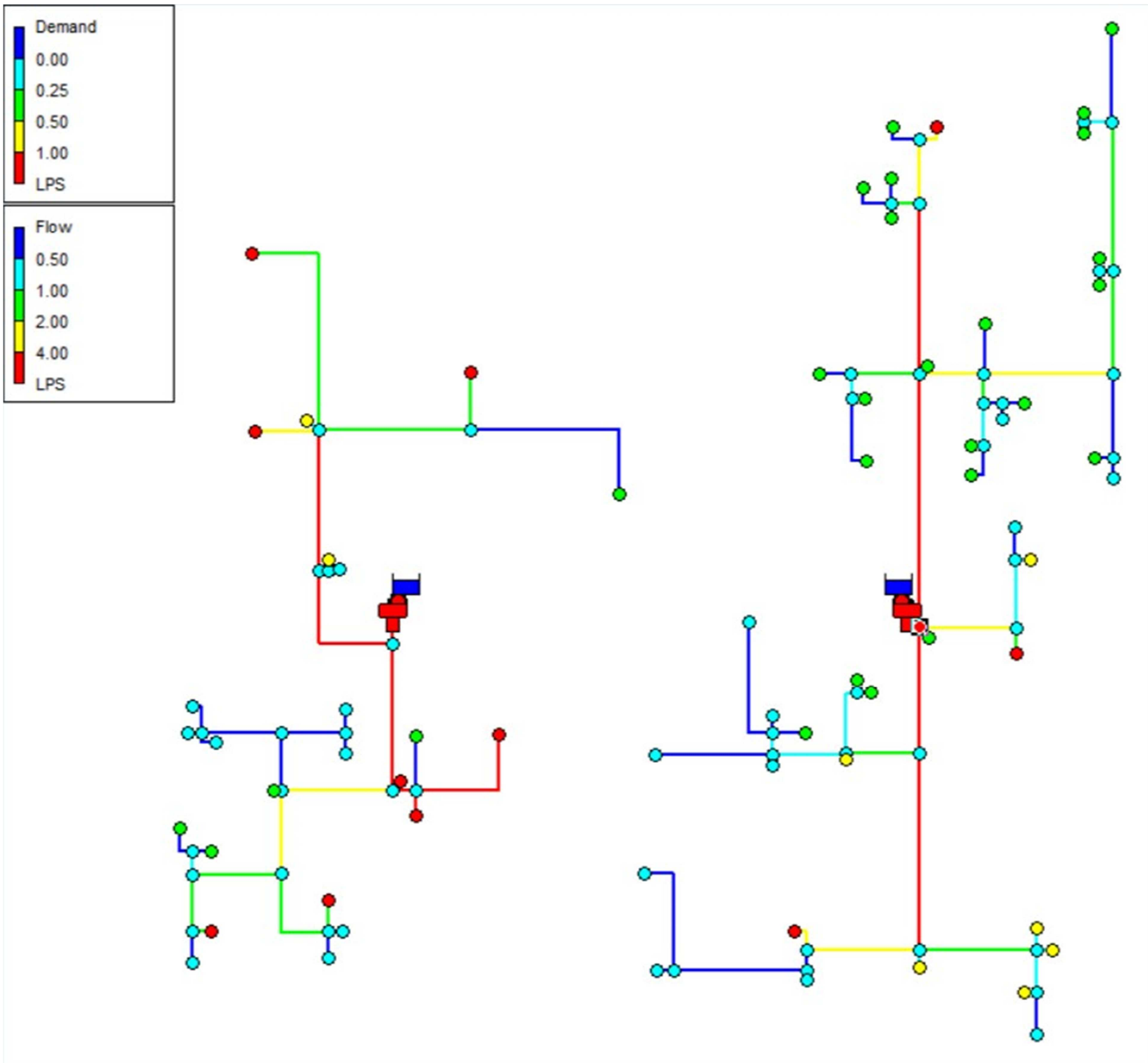

Figure 2. *Color-coded map for node demand and link flow.*

In the color coded map, the node having demand less than 0 LPS is in blue color, node having demand within the range of 0 to 0.25 LPS is in mint green color, node having demand within the range of 0.25 to 0.5 LPS is in green color, node having demand within the range of 0.5 to 1 LPS is in yellow color and finally node having demand more than 1 LPS is in red color. The link having flow less than 0.5 LPS is in blue color, link having flow within the range of 0.5 to 1 LPS is in mint green color, link having flow within the range of 1 to 2 LPS is in green color, link having flow within the range of 2 to 4 LPS is in yellow color and finally link having flow more than 4 LPS is in red color.

"*Figure 3"* illustrate the color-coded map for node pressure and link velocity of water distribution network at 13 hours.

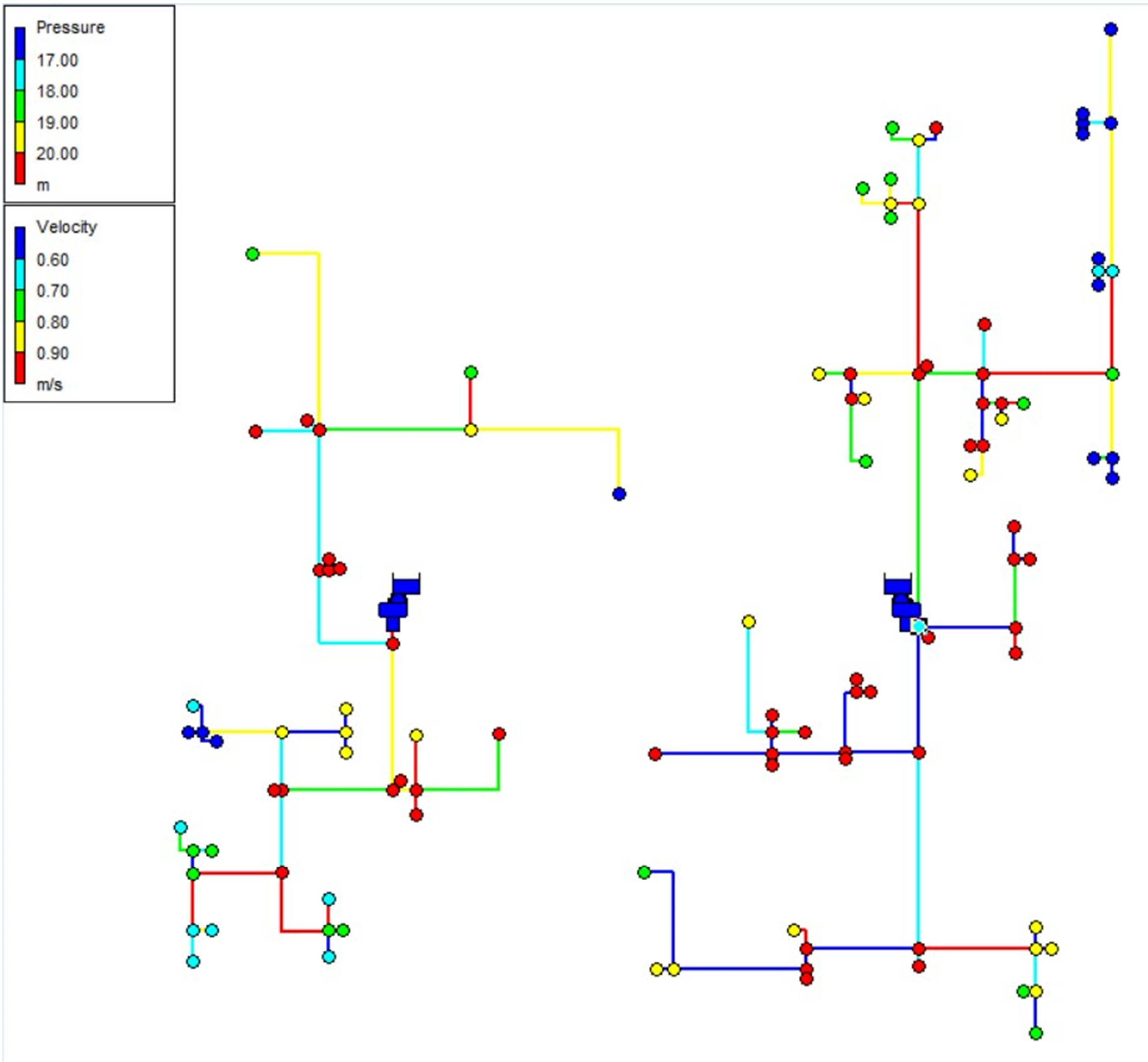

Figure 3. *Color-coded map for node pressure and link velocity.*

In the color coded map, the node having pressure less than 17 m is in blue color, node having pressure within the range of 17 to 18 m is in mint green color, node having pressure within the range of 18 to 19 m is in green color, node having pressure within the range of 19 to 20 m is in yellow color and finally node having pressure more than 20 m is in red color. The link having velocity less than 0.60 m/s is in blue color, link having velocity within the range of 0.60 to 0.70 m/s is in mint green color, link having velocity within the range of 0.70 to 0.80 m/s is in green color, link having flow within the range of 0.80 to 0.90 m/s is in yellow color and finally link having velocity more than 0.90 m/s is in red color.

4.4. Results in Graph

"*Figure 4"* illustrate the graphical representation of node pressure distribution at 13 hours.

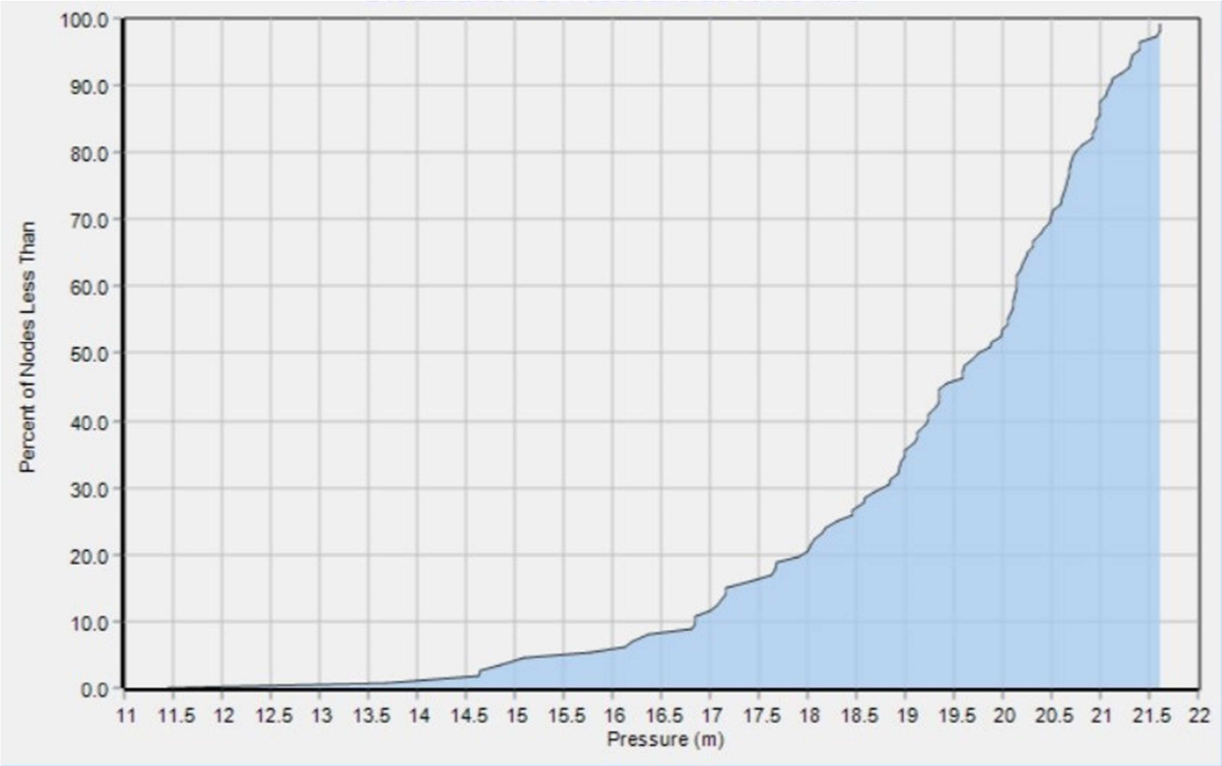

Figure 4. *Distribution of node pressure.*

In the above "Figure 4" X axis represents the nodal pressure or water head in meter and Y axis represents the total percentage of nodes having pressure less than that particular water pressure. This graph demonstrates that maximum number of nodes having pressure within the range of 17 to 21.5 m.

"*Figure 5"* illustrate the graphical representation of link flow distribution at 13 hours.

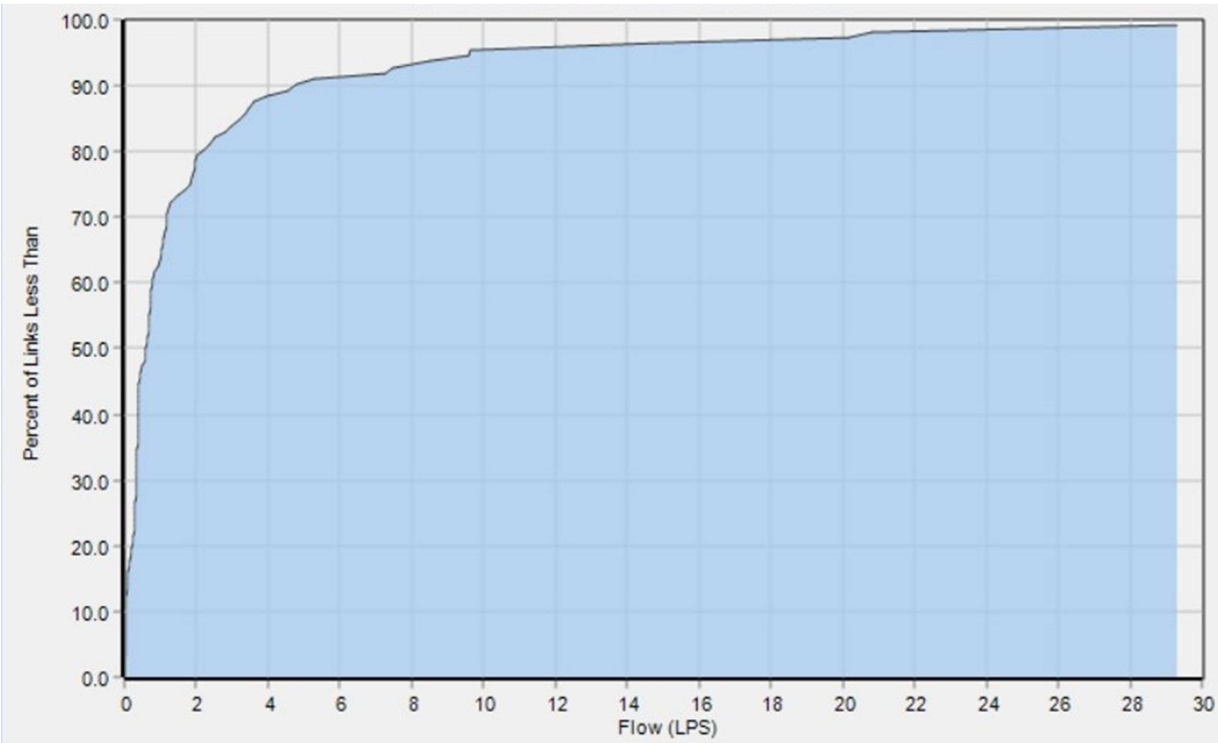

Figure 5. *Distribution of link flow.*

In the above "Figure 5" X axis represents the link or pipe flow in LPS and Y axis represents the total percentage of links having flow less than that particular flow. This graph demonstrates that maximum number of link having flow within the range of 0 to 3 LPS.

"*Figure 6"* illustrate the graphical representation of link velocity distribution at 13 hours.

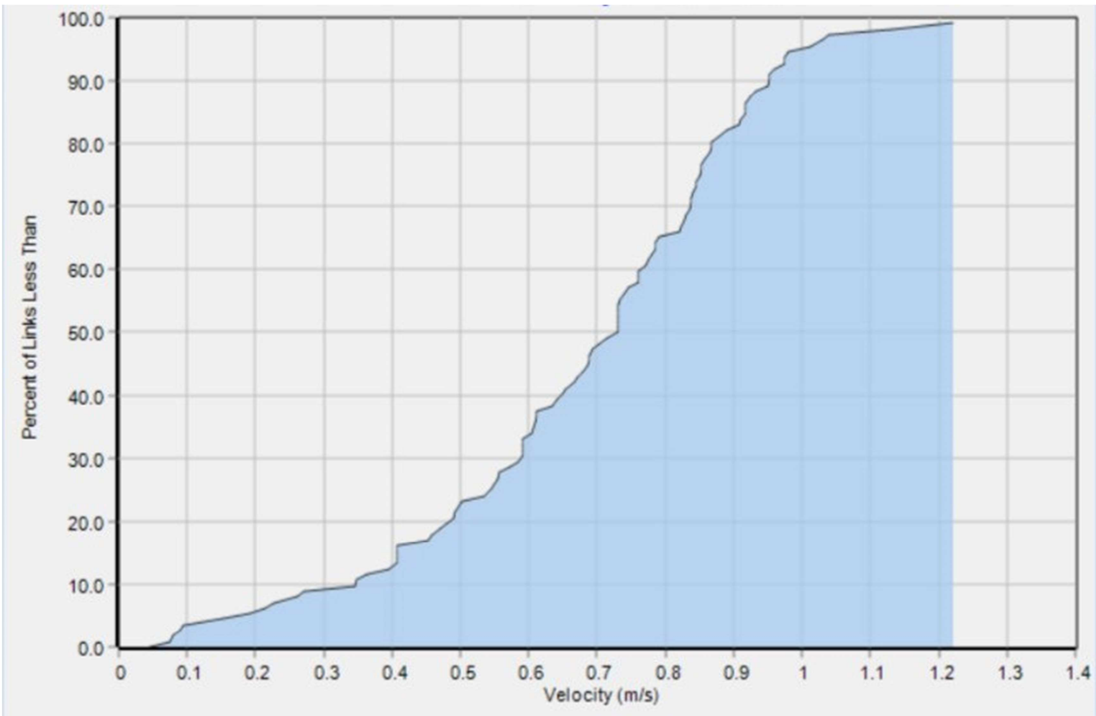

Figure 6. *Distribution of link velocity.*

In the above "Figure 6" X axis represents the link or pipe velocity in m/s and Y axis represents the total percentage of links having velocity less than that particular velocity. This graph demonstrates that maximum number of link having velocity within the range of 0.5 to 1 m/s.

5. Conclusion

The prime consideration of this study was to analyze and design of a water distribution network for HSTU campus. Total number of 112 nodes, 112 links, 2 elevated storage tanks and 2 pumps are provided in distribution network to meet the water requirement. The evaluation tools have been explored throughout the case study to identify the poor performance, network expansion points, nodes demand requirement [21]. Highest and lowest pressure for node is generated within the range from 11.44 m to 21.61 m which is much higher than the 10 m or 1 bar required to maintain service standard of water supply. About 45.5% nodes having pressure above 20 m, percentage of node having pressure within 15 m to 20 m is 50% and 4.5% nodes having pressure below 15 m. Flow through the pipes ranges from 0.013 LPS to 29.332 LPS. Percentage of the number of pipes having velocity above 1 m/s is 4.5%, 71.5% pipes having velocity within the range between 0.5 m/s to 1 meter per second and rest of the 24% pipes having velocity below 0.5 m/s. For this particular study velocity through the pipe in the design network is much lower than the scouring limit 3 m/s. Largest and smallest diameter are provided 200 mm and 15 mm respectively. Simulation was carried out during the peak hour, pressure of water presents in the network is adequate enough to meet the water requirement by storing water into the individual underground storage tank of each building and there is no negative pressure in any node. Velocity of water through the pipes of this particular water distribution networks remained much lower than the scouring limit and the networks will be reliable in near future to meet the additional demand of water.

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