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ESTABLISHING PLANNED WATER SUPPLY NETWORK IN AN URBAN AREA OF BANGLADESH: A CASE STUDY

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ABSTRACT

This paper presents a state-of-the-art methodology for designing and establishing planned water supply networks in Muksudpur Paurashava under Gopalganj district in Bangladesh, which have no existing water supply system. The main objective of this study is to simulate three different arrangements of pipe networks (option-1: surface water source with treatment plant, option-2: groundwater source without treatment plant, option-3: groundwater source with treatment plant) for selecting the best one. Network simulation is carried out in the framework of ArcGIS using its analytical capability. The simulation indicates that for first and third option, a high lift pump (abstracting water from clear water reservoir) having capacity of 187.17 m^3hr^{-1} with a delivery head of 10 m is enough to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to selected design year 2040. However, only two production wells having 150 mm diameter, which considers a safe yield of 102 m^3hr^{-1}, are required in case of option-2 to satisfy daily water requirement of 4,492 m^3d^{-1}. The analysis in case of option-3 suggests that production wells should be located evenly within Paurashava area as well as closer to proposed treatment plant and minimum distance should be maintained between them. Since different simulations are performed for alternative combinations of surface water and groundwater sources with and without considering water treatment plant, the study emphasizes that special attention should be given for selecting suitable water source based on socio-economic aspects of locality, water quality, system cost-effectiveness and other environmental issues.

Keywords: ArcGIS, Muksudpur Paurashava, Water supply network, Water treatment plant

INTRODUCTION

Globally a large amount of budget is invested for providing and/or upgrading the piped water supply facilities. Even then, a vast population of the world remain without safe piped water facilities. Around 80 to 85 percent cost of a water supply project have been used in the distribution system (Swamee and Sharma, 2008). Therefore, design of water supply system has attracted many researchers because of its involvement with high cost. The main objective of designing a water distribution system is to size and configure it properly so that it can meet existing and future demands while providing pressures at desired level. In order to facilitate the process somewhat, geographic information systems (GIS) are increasingly being co-opted to assign water demand to network nodes based on user classifications such as residential, commercial, industrial, institutional, etc (Filion et al., 2007). In Bangladesh, urban

population is increasing rapidly as a result of natural urban growth and migration from rural areas. The current urban population is about 38 million and will be reached to about 74 million by 2035 (BBS, 2005). Such growth of population in urban area will certainly impose huge burden on urban water supply facilities, which may cause a large number of people to be lived without access to safe water supply. The declining trend of available water supplies is one of the most important environmental concerns faced by the country at present. Department of Public Health Engineering (DPHE) in cooperation with City Corporation or Paurashava has installed distribution networks for water supply necessary to deliver water to the urban dwellers in major cities of Bangladesh (Karim and Mohsin, 2009). Therefore, the objective of the present study is to establish a planned water supply network in Muksudpur Paurashava of Muksudpur upazilla under Gopalganj district in Bangladesh (Figure 1) based on available demand and supply scenarios, which has no piped water supply system at present.
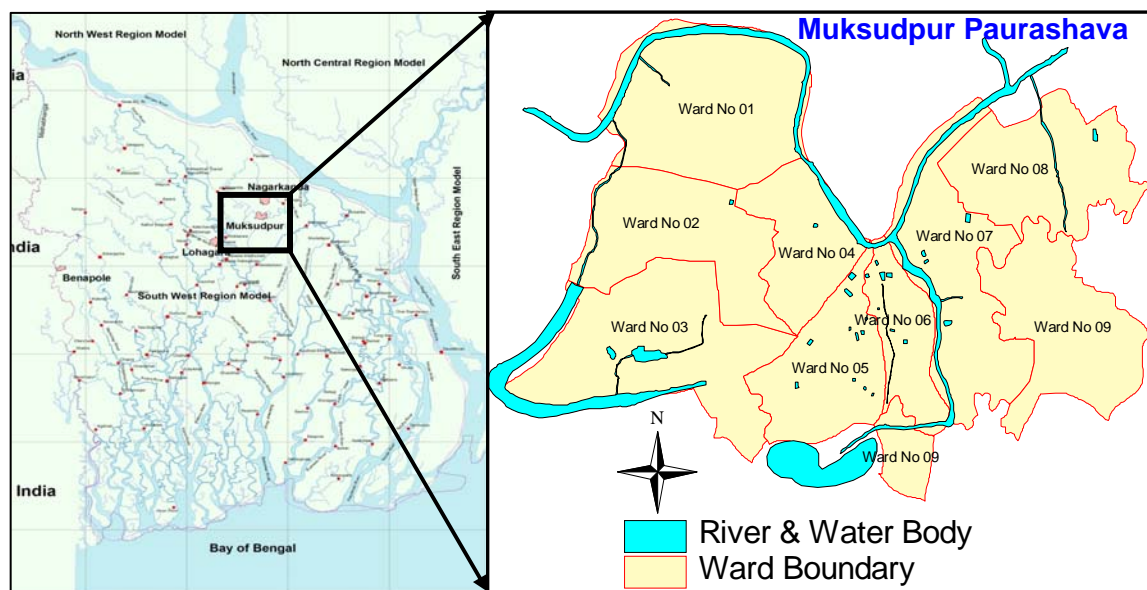

Figure 1: Location of Muksudpur Paurashava (study area) in Bangladesh

METHODOLOGY

Simulation of water distribution network requires input data from many sources. The necessary data and information includes population projection, land use plan, available water sources, and topographic information etc. Extensive surveys are carried out to collect these data from the field However, some data such as present water consumption and population cannot be measured directly and it is rarely known precisely. In that case, several well-recognized techniques are employed for estimating and quantifying the data and information. For example, geometric progression method is used to forecast the projected population based on available census data. Accurate assessment of domestic water consumption is not possible, where there is no piped water supply because the consumers meet their daily water requirement from both groundwater and surface water sources even sometimes from rainwater source. It is one of the most difficult parameters to determine while modeling the drinking water distribution networks (Alcocer-Yamanaka et al., 2012). Therefore, domestic water consumption has been proposed on the basis of the published literatures of previous projects or studies on water supply and water consumption analysis. However, different design criteria have been assumed on the basis of the adopted design criteria of previous DPHE projects, field surveys, and available literatures on water supply system. Water demand up to the end of design period (2040) has been estimated considering intended population coverage by piped water supply system, consumers per connection for different types of service connections, population served through each type of service connection, non-domestic demand including fire demand, water loss and backwash water (in case of water treatment plant). The step-by-step methodology followed to carry out this study is presented in Figure 2.
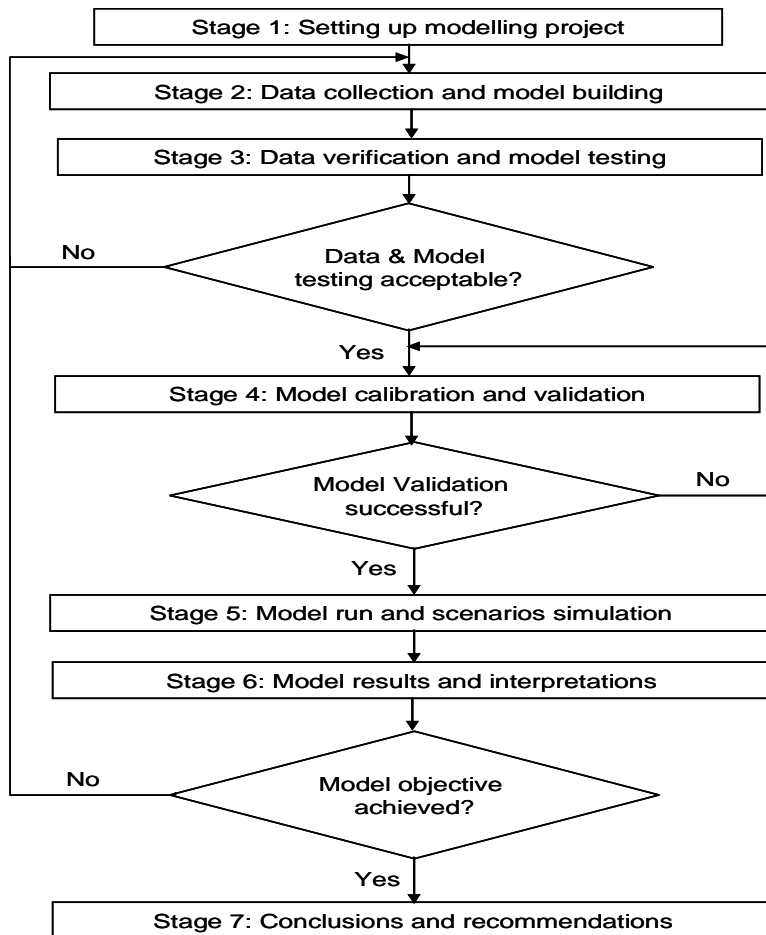
Figure 2: Methodological framework used for pipe network simulation
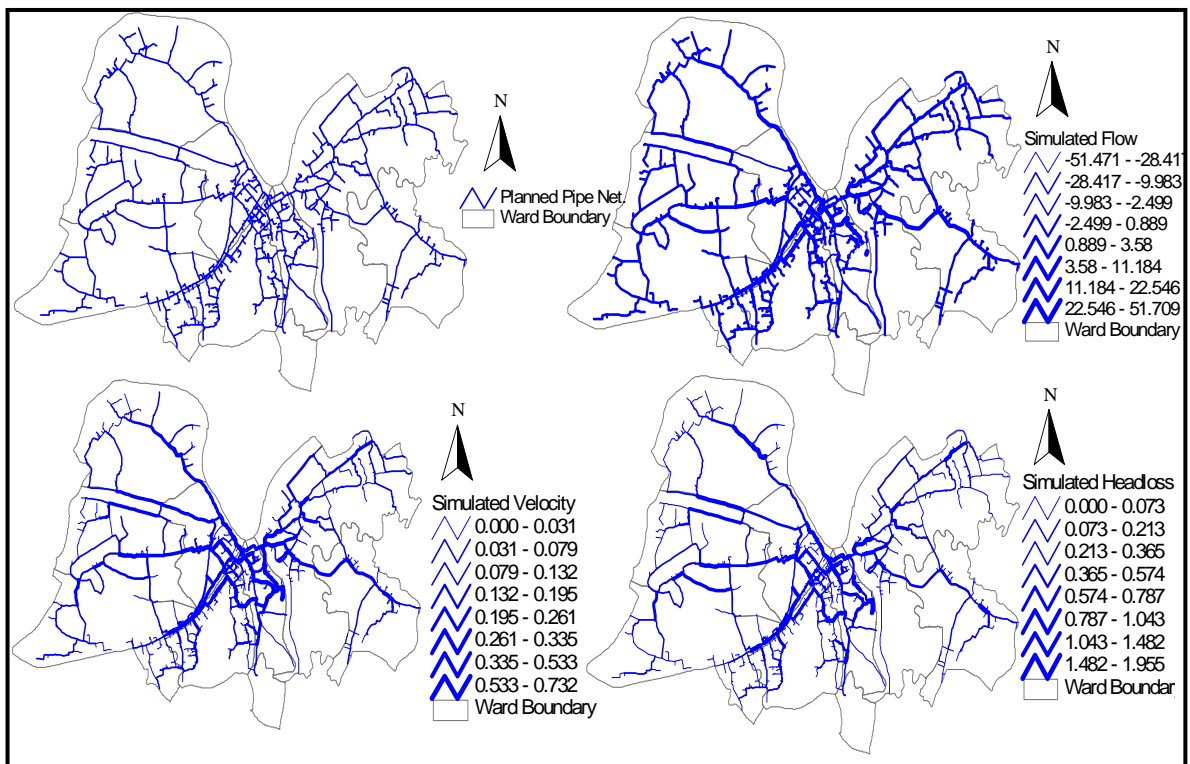

Figure 3: Simulated hydraulic parameters for proposed distribution network of Muksudpur Paurashava

For nodal demand assessment, the area under each node, population density, assessment of service connections of each type and flow through each type of connection is needed. Digitizing and linking of all these spatial and non-spatial data has been done by using the analytical ability of ArcGIS toolkit. Nodal demand calculation has been performed by a customized program developed in MS Excel spreadsheet. Three types of data such as pipe network, water demand, and operational data are necessary for assembling a water distribution model. The 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. The model is then calibrated and calibration process involves adjustments of different parameters such as roughness coefficient of pipe, spatial distribution of nodal demand, altering pump operating characteristics, pipe diameter and some other model attributes until the model results reasonably satisfies the study objectives. After that, the model is validated using extra sets of additional data under different operational conditions. 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 different hydraulic properties of simulated networks for planned water supply scheme are presented in Figure 3.

RESULTS AND DISCUSSIONS

Scenario-based Arrangement of Network Model

Kumar River and Kamlapur Khal are flowing through Muksudpur Paurashava and the water is suitable as surface water (SW) source for drinking water supply to the Paurashava. The test results indicate that groundwater (GW) is also feasible for the Paurashava. As both surface and groundwater sources are available, three alternative models of water distribution pipe network for Muksudpur Paurashava have been built.

- Option-1: model is built for SW source with water treatment plant,
- Option-2: model is developed for GW source without water treatment plant and
- Option-3: model is constructed by considering GW source with water treatment plant.

For both SW and GW source with water treatment plant (WTP), one high lift pump (abstracting water from clear water reservoir) of capacity 187.17 m^3hr^{-1} at one bar (10 m) delivery head is enough to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to design year 2040. For GW source, the pipe network models have been built on the basis of the secondary data and the past experience in the field. Safe yield from one 150 mm diameter production well is 102 m^3hr^{-1} has been assumed, and the location of these well are evenly distributed within the Muksudpur Paurashava area. On the basis of the above assumption, total two production wells are required to meet the daily water demand of 4,492 m^3d^{-1} at the end of design period 2040. Based on the simulation, it is also estimated that a pump of 102 m^3hr^{-1} at one bar (10 m) delivery head, is sufficient to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to the design year of 2040.

Scenario-1: Surface Water Supply Model

In case of SW source for water supply, treatment of raw water is a must. Pipe network model for SW source starts from the clear water storage reservoir located on the ground of the SW treatment plant. High lift pumping station will be required to add required quantity of treated water with certain discharge head to achieve the targeted minimum residual pressure (5 m water column) at any point of the distribution pipe network. Output of the model is presented in the form of junction data, pipe data and high lift pump data. High lift pump situated on the ground surface just after the clear water storage tank of the WTP abstracting required quantity of treated water from the clear water storage tank will add into the distribution system with certain discharge head to maintain the minimum residual head (5 m water column) at any point of the pipe network. Then, the pipe network model is simulated and

after each run of the pipe network model, the network is calibrated with pump discharge head and suitable pipe diameters to satisfy the design criteria. The proposed pipe length for water supply in Muksudpur Paurashava is presented in Table 1.

Table 1: Ward-wise proposed pipe length for SW supply model (scenario-1)

Ward No.	Pipe Length (km)					Grand Total (km)
	100 mm Dia	150 mm Dia	200 mm Dia	250 mm Dia	300 mm Dia	
Ward No: 01	6.83	0.51	0.00	0.00	0.00	7.34
Ward No: 02	8.05	0.68	0.00	0.00	0.00	8.73
Ward No: 03	13.27	0.31	0.00	0.00	0.00	13.59
Ward No: 04	4.62	3.72	0.08	0.00	0.00	8.42
Ward No: 05	8.94	1.71	0.21	0.00	0.00	10.87
Ward No: 06	3.78	1.35	0.78	0.95	0.50	7.36
Ward No: 07	6.78	2.13	0.37	0.28	0.00	9.56
Ward No: 08	9.75	0.00	0.00	0.00	0.00	9.75
Ward No: 09	4.98	1.39	0.00	0.00	0.00	6.37
Total (km)	67.01	11.80	1.44	1.23	0.50	81.99

Scenario-2: Ground Water Supply Model without WTP

A GW model generally consists of reservoirs, pumps, junctions and pipe network. In absence of GW source assessment result, model has been simulated by reservoirs only instead of pumps and reservoir combination as source. Like the SW supply model, similar representation approach has been followed in output for junction data and pipe data. Reservoir data is an additional output for GW supply model. Considering these points, the pipe network model is run and after the run, the network is calibrated with pump discharge head and suitable pipe diameters to satisfy the design criteria. The proposed pipe length with their dimensions is presented in Table 2.

Table 2: Ward wise Proposed Pipe Length for GW Supply Model (scenario-2)

Ward No.	Pipe Length (km)				Grand Total (km)
	100 mm Dia	150 mm Dia	200 mm Dia	250 mm Dia	
Ward No: 01	6.83	0.51	0.00	0.00	7.34
Ward No: 02	7.61	0.40	0.56	0.17	8.73
Ward No: 03	10.00	1.53	1.80	0.30	13.64
Ward No: 04	6.73	1.69	0.00	0.00	8.42
Ward No: 05	10.63	0.24	0.00	0.00	10.87
Ward No: 06	6.65	0.68	0.00	0.00	7.32
Ward No: 07	7.28	0.94	1.20	0.22	9.64
Ward No: 08	9.66	0.09	0.00	0.00	9.75
Ward No: 09	4.98	1.39	0.00	0.00	6.37
Total (km)	70.37	7.46	3.56	0.70	82.08

Scenario- 3: Ground Water Supply Model with WTP

In case of GW source, if the GW quality is not suitable for direct supply to the consumers, WTP is required to bring the water quality according to the WHO/Bangladesh water quality standard. As the source selection was not finalized during the model built up, another model has been simulated for GW source with WTP. Pipe network model for GW source with treatment, starts from the clear water storage reservoir located on the ground of the GW treatment plant. In that case, high lift pumping station is necessary to inject required quantity of treated water with certain discharge head to achieve the targeted minimum residual pressure (5 m water column) at any point of the distribution pipe network. The pipe network model is simulation by pipe network modeller and output of the model is presented in the form of junction data, pipe data and high lift pump data. However, the location of the WTP for this case has been selected as same as that of SW model (scenario-1). This is why all model output remains the same (Table 1) for surface water model as described in scenario-1.

CONCLUSIONS AND RECOMMENDATIONS

In this study, three alternative models of water supply distribution networks have been simulated for water supply purposes in Muksudpur Paurashava of Gopalganj district in Bangladesh based on the collected data and information. The study deals with three alternative scenarios, among which the first scenario refers to the combination of SW source with WTP, second option is relevant to GW source without WTP, and third model is built by using GW source with WTP. The result obtained in first option concludes that one high lift pump having capacity of 335.54 m^3hr^{-1} having a delivery head of 10m is sufficient to maintain minimum residual pressure of 5 m water column at any point of the distribution network up to the end of design period at 2040. According to second scenario, the study concludes that the daily water demand of 8,053 m^3d^{-1} at the end of design period can be met by only three production wells, which consider a safe yield of 102 m^3hr^{-1} from each 150 mm diameter production well. However, water supply network is designed and proposed based on simulation results in all scenarios in the Paurashava area. Since the pipe network is simulated for different combinations of SW and GW sources with or without WTP, the study suggests that proper attention should be paid in selecting appropriate water sources based on the socio-economic aspects of the locality, environmental issues, taste of the consumers and cost effectiveness of the system. The study also concludes based on third option that production wells should be located closer enough to the WTP as well as minimum distance should be maintained among the production wells to reduce the cost of water withdrawal and/or water production. The study concludes that minimum water pressure at the consumers end should ensured not less than 5 m water column based on design criteria. This indicates that the owner of the multi-storied buildings requires underground water reservoir, but it is not necessary for a single storey building. Finally, the study emphasizes that the water supply network is totally dependent on projected population. However, if the projected population gets changed in future by any means, the designed diameter of the pipe networks will be changed. In addition, if the safe abstract rate of GW changes accordingly, number of production wells will be changed. Accordingly, the study recommends that the whole distribution network should be redesigned in those changing conditions.

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