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# ANALYSIS AND PLANNING OF WATER SUPPLY NETWORK SYSTEM OF GOPALGONJ POURASHAVA USING DIFFERENT GIS TECHNIQUES

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**Abstract**: GIS is a very strong tool for urban planners in decision making. The technology is new to Bangladesh and becoming popular in the field of infrastructure planning and management. This study is a very preliminary endeavor in automated planning initiatives of this country. The aim of the study is to show the capabilities and potentiality of Geographic Information System (GIS) to automate and analyze the water supply system in a district headquarter, which needs information based planning for future expansion of water related services. The study analyzes the efficiency of existing water supply network system using NETWORK *allocation* function. The study shows that 61% of distribution path are close to the existing coverage through water pipe line. It also delineates suitable sites for setting up new overhead tanks considering the existing water supply coverage, water demands in different landuses and their relative weighted valuation using Model Builder tool of ARC View. It has been identified that 1028132 $m^2$ (13% of the Pourashava area) in different locations is suitable for constructing new tanks. The study will assist to adopt the appropriate policy measures in order to safeguard the interest of people for drinking water supply.

**Key words**: Geographic Information System, network allocation, served and deprived zone, site selection, water supply and weighted overlay

## Introduction

Bangladesh is one of the most densely populated countries in the world facing massive urban problems. Here all the urban centers are not well served by planned community facilities like water supply, sanitation, electricity, education etc. The paradox of community water supply in developing countries is that everyone should have, as the rules say, access to water supply, but in fact, many people are far away from its service. They may have access to water but only at a long walking distance or in too little volume or of poor quality. Over 62% of people in developing countries or about 1100 million are deprived of adequate water supply [Cairncrross *et al.* (1983)]. The World Health Organization's data for 1980 show that among the urban population of developing countries, only about 55% had house connections and an additional 20% had access to public taps; about half of these supplies are intermittent [Ahmed and Rahman (2000)]. In our country, this coverage hardly exceeds 5% in *Pourashavas** and *Upazilas*† [GoB (1999)]. In practice, the situation is even more critical because the water supply systems do not necessarily provide good services in terms of quality, quantity and availability of water.

Gopalgonj District‡ Headquarters *(Pourashava)* is an area facing typical urban problems particularly the crisis of portable water. Approximately 30% of the population in this area is

* An elected body of the local government under a district.
† Second tier of local administrative unit under a district.
‡ Administrative unit of the government under the charge of a Deputy Commissioner comprising a number of *upazilas*.

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covered under piped water supply services while in major cities of Bangladesh; it ranges from 50% to 65% [DPHE (1999)]. According to the Population Census of 1991, the population density of the study area is 2900 persons per sq. km with an average growth rate of 3.5 percent [BBS (1991), DPHE (1999)]. But its basic urban facility like piped water supply system cannot keep pace with the growth of population. The present water demand is 3487 $m^3day^{-1}$ for the population of 40,000 [GoB (1999), DPHE (1999)]. However, the supply to the citizens takes place only once in a day through the fully loaded overhead tank contributing a little more than 675 cum/day [DPHE (1999)]. Besides, lack of proper technology, planning and maintenance, the distribution network is getting damaged within a very short period of time. Inappropriate demand estimation, manual data recording or storing systems and myopic planning stand as constraints against the future expansion of the existing system, which results in wastage of resource and money.

To ensure a sound water supply network system, an automated management facility i.e., GIS based planning is capable of providing better result [Aronoff (1993)]. In our country, traditional mapping system is used to record the information on service networks [Karim (1998)]. Generally, it takes long time to identify any problem in the distribution system as well as to accomplish any repairing task. GIS has made it possible to link geographical record associated with the water sources, distribution network, pump and overhead tank's location, which is capable enough to integrate and analyze their whole operations more efficiently. In this research, efforts have been taken to facilitate GIS as a tool for decision making on water supply network system through automation of the whole system, analyzing the existing coverage, delineation of suitable locations for new *overhead* tanks (OT) with dynamic digital mapping and interactive models.

The objective of the study is to demonstrate the capabilities and potentiality of GIS to automate and analyze the existing water supply systems (identifying served and deprived zones) in a *Pourashava* area, which needs information based planning for future expansion. The service area of the existing overhead tank has been delineated using GIS (Network-Allocation) technology, which shows optimal and alternative paths for the movement of resources through a network. This method has been widely and successfully used in other countries for emergency resource planning [DWP (2000)]. The potential location for setting up new *overhead* tanks were delineated using Weighted Overlay application (MODEL BUILDER) of GIS based on a number of location influencing factors and landuse based water demand. The method was used because of its excellent capabilities to analyze results with respect to various influencing factors and rank the output for optimum decision making.

### Advantages of GIS based Water Supply System

Now safe drinking water is a provocative question in the developing countries. Though up-to-date technology and GIS based infrastructural management is frequent in developed countries, but it is new to the developing world. This study is a very preliminary endeavor done to add a force in the planning field. It implies a substantial scope for changing the traditional water supply management system in the country. Following are the advantages of the new system over practical one:

(a) The traditional system is to keep record of water services on paper files. It takes more space and can be damaged at any time. GIS based integrated and automated database for water supply network would be a great resource for different institutions and developers In addition it helps to locate the problem segment very quickly, which is really a time consuming process in the traditional system.

(b) In Bangladesh, network line design is done manually, which is always susceptible to error. Automation of pipe network creates an organized database for quality supervision.

(c) Development of database of pipe network system as well as clients' location would help to run the system efficiently through minimizing the system loss and update facilities to the service holders when required.

(d) Delineation of existing water supply coverage will help the related authority to demarcate the future expansion zone.

(e) Suitable location for the construction of new reservoirs will help planning the potential distribution zone and technical decision making for water sources.

## Site Location

Gopalgonj *Pourashava* (*Upazila* and district headquarters) is situated about four miles east of the Modhumati River (active), in the district of Gopalgonj that lies in the southern western part of Bangladesh (Fig. 1), covering about 14.40 sq. km It is a district town under Dhaka division and is well connected by the national highway to Dhaka and the nearby Khulna city.

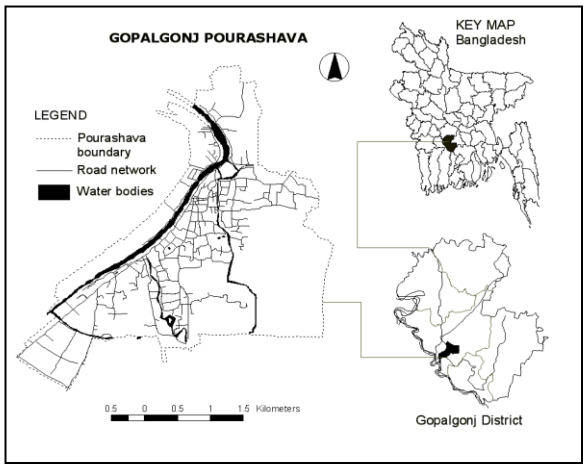


Fig.1 Location map of the study area.

Statistical data reveals that the population of Gopalgonj *Pourashava* was recorded 18,118 in 1981 with a growth rate of 3.90% per annum. According to the Population Census 1991, the total population of Gopalgonj *Pourashava* was 25,007 (after the inclusion of 3.1 sq. km of new area). The land surface of the study area is very flat and can be divided into two broad categories, namely high/raised land and very low-lying and *beel* areas lying between 0.2 m and 2 m above MSL (mean sea level). Major areas are subjected to flooding during high floods. The topography of the *Pourashava* is almost flat with fertile alluvial soil. Over the years, the area of the *Pourashava* has been developed through earth filling of cultivable lands, which were mostly low-lying plain soil. Despite earth filling for raising the foundation of homesteads, filling also occurred due to repeated inundation during the monsoon. Due to the abandonment of old courses by the Modhumati River some depressions and stagnant pools of water have been crated in the western part of the *Pourashava*.

## Existing Water Supply System of Gopalgonj

***a) Water sources:*** It was found that only 40% of domestic and non-domestic holdings have access to *Pourashava* water supply system and a large majority of about 60% has no access to that facility. About 680 $m^3$ of water is supplied per day to about 13,385 consumers through 1043 house connections and the water demand of approximately 20,175 citizens are met through 630 shallow hand tube wells. Another 2597 get their supply through 10 street hydrants and some 24 ponds, rivers and canals are used by the rest of the population [DPHE (1999)]. The only overhead tank was constructed in 1973. The height of the tank is about 25.2 m from the ground level. It has a capacity of 680 $m^3$. Among 15 production wells, 7 are abandoned and 3 tube wells are operating partially. Only five wells are now running properly and operated for 12-14 hours daily [Field Survey (2001)]. The wells pump water to the distribution network through the Iron Removal Plant and overhead tank. The Iron Removal Plant (IRP) was constructed in 1991 under, Dutch aided

Department of Public Health and Engineering “12-District Towns Water Supply Project” having a design capacity of 140 $m^3hr^{-1}$. Although removal efficiency is still satisfactory, the treatment capacity and filtration have been reduced significantly due to frequent clogging of the filter bed.

***b) Distribution network:*** The distribution pipe with 100 mm diameter constitutes the longest length (16.83 km) and 300 mm pipe constituted the shortest length (0.03 km). Most of the pipes are made of PVC (Polyvinyl Chloride). According to Gopalgonj Pourashava (2000), there are about 1043 water supply service connections which range from a diameter of 13 mm (1/2″) to 25 mm (1″). The number of 19 mm pipe service connections is slightly higher than that of 13 mm pipe connections in domestic water use. In commercial use, water service is provided only by 25 mm pipes.

***c) Water consumption pattern***: The consumption pattern of domestic household shows that 43.57% of the total volume is consumed for bathing and 28% for washing. Others uses include cooking (10.12%) and drinking (5.76%) (DPHE, 1999). Water supplied by distribution pipes and Department of Public Health and Engineering deep tube wells are manly used for bathing purpose (50.46% and 68.13% respectively). The water of street hydrants and river or pond water is used for washing purpose (76.17% and 30.48% respectively).

***d) Waterborne diseases****:* A household survey conducted by DPHE in 2000 (in Gopalgonj *Pourashava* and adjacent areas) revealed that about 40.29% of the total population suffered from waterborne diseases. A major portion of the people suffered from Cholera and Dysentery (35% and 37% respectively). Hepatitis and skin diseases also cause suffering to the people in this area.

***e) Water demand assessment:*** A tentative water demand was estimated by the DPHE, Gopalgonj for the year 1999 based on the population of 1998, which was 39,950 $m^3day^{-1}$. The total demand was estimated as 3487 $m^3day^{-1}$ for the study area (used for GIS analysis in this study). The total water demand is 3487 $m^3day^{-1}$ in Gopalgonj *Pourashava*. A large portion of population (14,000) is served by common yard connection and only 8000 people get the opportunity of house connection.

## Materials and Methods

***Delineation of served and deprived zones of piped water supply system using GIS network analysis:*** To identify the served and unserved zones for water supply the ALLOCATE function of PC NETWORK (PC ARC/INFO 3.5.1) has been used. The allocate function is used to assign each link in the network proximal center, thereby defining service areas. Allocate illustrates the model of how resources are distributed between centers (e.g., reservoirs and pumps) and their surrounding arcs (e.g., road network). Each center has a resource capacity (e.g., total volume of water). Resource along with the linear features of the network is assigned to a center based on its capacity and variety of additional criteria such as the distance or time from a center and its total capacity is used to delineate served and deprived zones.

In this analysis, location (represented by node) of overhead tank is considered as resources center and the roads (represented by arcs) to the consumers are used as distribution network. The tank’s water capacity, maximum service area, arc-wise demands are also considered.

***Delineation of Suitable Sites for New* Overhead *Tanks Using Weighted Overlay Methods:*** Analysis has been made to delineate suitable areas for construction of new overhead tanks to meet optimum water demand. This analysis has been done on the basis of some influencing factors and results of the previous analysis. In this respect, a new technology has been used called Model Builder *(Spatial Analyst 2.0)*. It helps to create and manage spatial models that are automated and self-documenting.

***Data analysis and presentation tool*:** PC ARC/INFO, ARC View, Spatial Analyst (Model Builder) were used for GIS analysis. Microsoft Office 2002 was used for documentation and database maintenance.

## Results

***Delineation of served and deprived zone of piped water supply system*:** To identify the area served by the existing overhead tank, tank location (center) map, road map (arcs) and settlement map (demand calculation) have been used. Two different demands have been calculated for Network analysis. The attributes and unit used for demand, capacity and impedance are given in the Table 1.

Table 1. List of attributes and units used in the analysis.

| Item /attributes | Demand ($m^3$) | Capacity ($m^3$) | Impedance (m) |
|---|---|---|---|
| Description | 1. Equal water demand for all road<br>2. Actual water demand of each road considering different landuse | Reservoir water capacity | Length of the road |

***a) Attributes used in network-allocation analysis:***

(i) Overhead tank capacity (Center capacity) = 680 $m^3$ [DPHE (1999)];
(ii) Arc-wise water demand (described later) = water demand of each road segment as it flows along road;
(iii) Impedance (one way) = Road length (from tank to consumer only as reverse flow does not happen); and
(iv) Impedance limit = 3000 m (the tank is able to supply water to the consumer up to 3000 m with the gravity flow along the road).

When arcs (road) are allocated to center (overhead tank), the demand (water-demand) of each allocated arc is accumulated until the center's capacity is reached. If the demand of an arc causes the capacity to exceed, that arc is not allocated to the center. The allocation continues until the maximum impedance limit (3000m along road) is reached along all the paths allocated to the center, or until the center's capacity (680 $m^3$) is met by the cumulative demand from all links allocated to the center which occurs first.

***b) Water demand calculation for network analysis:*** The water demand is calculated by adding all the demand of settlements (households, shops or offices) near each road. NEAR command of ARC/Info identifies which household, shops or offices is nearer to which road. Two types of water demand (along road) were applied as demand attribute in the network analysis, which are as follows:

a) Assume equal water demand for each arc/road length;
b) Actual demand for each arc/road length based on different water demand for various land use.

Assume equal water demand for each arc/road length (considering equal number of settlements is located near each road). In this concept following equation was used,

$D = S \times L$……… (1)

Where,
$D$ = demand for a road segment (arc)
$S$ = demand density for each unit of road length
$L$ = length of the road (arc)
In this relation, $S$ = (Total water demand in the study area) / (Total road length)
Here,
Total water demand in the study area is about 3487 $m^3$ and total road length = 55986 m (calculated from road coverage)
Therefore, $S$ = (3487/ 55986) m3 = 0.062 $m^3$
Then, from the equation (1), we can get,
D = 0.062 x length of that road segment (arc) = 0.062 x $L$

***Actual demand for each arc/road length based on different water demand for various landuse:*** To carry out this task, first NEAR command has been used in ARC/Info to transfer the settlements to their nearest arc. NEAR computes the distance from each point in a coverage to the nearest arc, point, or node in another coverage [ESRI (1992)]. The distance and the internal ID of the closest feature are saved as new items in the input point coverage's feature attribute table. It was used to identify the demand of different settlement types (residential, commercial, office, education, and health) on the nearest road segment. It ensures the execution of the analysis considering actual demand through the network. After executing NEAR command, internal ids of arcs (roads) and distance between arc and point are added automatically as new items against their allocated settlement. Then total number of settlements with ids (allocated to a particular road segment) has been identified to calculate total demand of that arc. To calculate the water demand for a particular use "Bangladesh Water Consumption Standards" has been followed (Table 2).

Table 2. Settlement type and average water consumption per day.

| Settlement type | Average water consumption (demand) per unit use (in $m^3$ per day) |
|---|---|
| Household<br>(Ave. household size = 8) | 0.15 X 8 = 1.2 |
| Commercial | 0.04 |
| Office buildings | 0.06 |
| Education institution | 0.09 |
| Hospital | 0.590 per bed |
| Mosque | 0.065 |

Source*:* Aziz (1975).

Therefore, total water demands of an arc segment = (number of settlements allocated to the arc X water demand ($m^3$) of settlements based on their use) + (number of settlements allocated to the arc X water demand ($m^3$) of settlements based on their use) + - - - - -- - - -

***c) Network allocation analysis:*** The Network analysis has given the following results for existing overhead tank using above criteria and different concept of water demand (Table 3).

Table 3. Result of Network-Allocation analysis using different water demand.

| Demand category | Served arc (%) | Un-served arc (%) |
|---|---|---|
| Equal demand | 21 | 79 |
| Actual demand | 61 | 39 |

When equal demand is considered, it gives a restricted service area (21% of total water distribution path) against present pipeline coverage. On the other hand, the analysis by taking actual demand has given comparatively true result (61% of total water distribution path) related to the present situation. For this reason the service area of the overhead tank derived from actual demand based on use variation of settlements has been accepted and the other is rejected. To get spatial zone, existing service area of the overhead tank has been delineated by joining the end node of the allocated arc manually. It has been used as an important factor for the next suitable location analysis. Therefore, existing coverage of the overhead tank (OT) is 3821408 $m^2$ (27% of the *Pourashava* area) and total unserved area is found to be 10178592 $m^2$ (73% of the *Pourashava* area). The service area of the existing overhead tank delineated by network analysis is shown in the Fig. 2.

## Delineation of potential areas to setup new overhead tank

This analysis has been conducted based on some influencing factors related to location decisions and results of the previous analysis (Network Allocation). In this respect, Model Builder (a tool in the ARC VIEW Spatial Analyst 2.0 extension) is used. It helps to create spatial models of geographic areas.

To delineate suitable land, analysis has been done using the above coverage considering influencing criteria (Model Builder) and minimum area required to construct tank and pump house. Final output has been derived from vector data in ARC/VIEW.

***a) Location suitability modeling for new* overhead *tank:*** In the weighted overlay analyses the following geographical features and facilities have been considered: accessibility/road, electricity line, location of structures with different use, land elevation, population density, service area of existing overhead tank, active production well and distance from proposed water treatment plant, to be constructed by DPHE. To incorporate the above criteria, the following vector coverages of the study area have been brought to the analysis (Table 4).

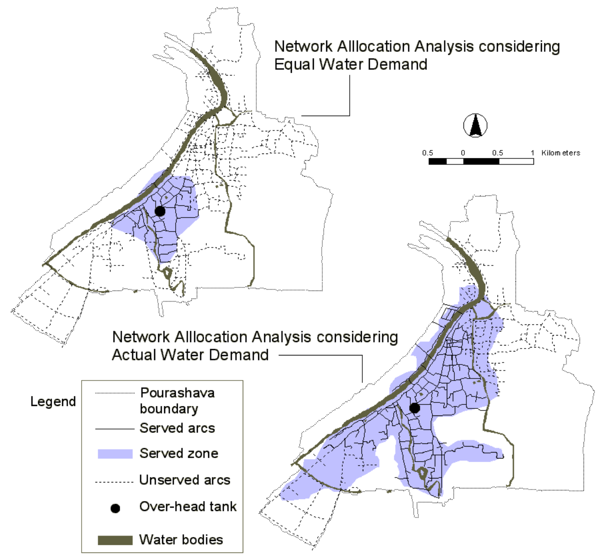


Fig. 2. Delineation of served and deprived zone by Network allocation analysis.

Table 4. Details of coverage used in suitability analysis.

| Sl No. | Map Contents | Feature class |
|---|---|---|
| 1 | *Pourashava* boundary | Polygon |
| 2 | Road network | Line |
| 3 | Location of structures/settlements | Point |
| 4 | Land elevation map | Polygon |
| 5 | Population density map (zones) | Polygon |
| 6 | Electric power line | Line |
| 7 | Location of production well | Point |
| 8 | Existing coverage of the overhead tank | Polygon |
| 9 | Location of active production wells | ARC VIEW Shape File (point) |
| 10 | Location of proposed water treatment plant | ARC VIEW Shape File (point) |

Model Builder can analyze only raster data. Therefore, at first all the themes were converted into grid in the model builder. Then different buffers have been added to the themes as required on specified logic, which influences location decisions. It is assumed that the potential sites will be outside the coverage of the existing overhead tank, outside the homestead and far enough from settlements, far from the river bank and road but not in an inaccessible area. Electricity facility must be at hand and the land must be stable. A site having moderate population density area and potential expansion zone are considered as well. These criteria have been fulfilled using different buffers or multi-buffers of coverage (Table 5, 6 and 7) or directly applying them to the overlay analysis.

Table 5. Detail of buffers created for structures/settlements.

| Number of buffer/s | Buffer distance (m) | Purpose |
|---|---|---|
| 5 | 0-15 | Homestead area and restricted for construction of tank |
| | 15-300 | Get superior flow of water from tank located in this area from the settlement |
| | 300-800 | Get less flow than the above |
| | 800-1500 | Get less flow than the above |
| | 1500-3000 | Get less flow than the above |

Suitable locations for overhead tank are expected at the 3000m distance from the settlements because the tank can serve the consumer up to this distance by gravity flow of water [DPHE (1999)]. The description of road buffer is shown in the Table 6.

Table 6. Details of buffers created for road network.

| Number of buffer/s | Buffer distance (m) | Purpose |
|---|---|---|
| 4 | 0-15 | Restricted for construction of tank because it is too close to road |
| | 15-300 | Very much suitable area because easy accessible but not too close to road |
| | 300-1000 | Less accessible than the above |
| | 1000-1500 | Less accessible than the above. Area outside 1500m from any road is considered not accessible for the supply of construction materials of the tank |

The description of buffer for river, electric line, production wells and newly installed treatment plant are given in the Table 7.

Table 7. Detail of buffers created for river, electric power line, active production wells and treatment plant.

| Themes | Number of buffer/s | Buffer distance (m) | Purpose |
|---|---|---|---|
| River | 1 | 0-15 | Area within 15m distance is not suitable for heavy construction (PWD, Gopalgonj). So, it is restricted zone. Outside of this distance construction can be done |
| Electric line | 1 | 0-500 | Area within 500 m of existing electric line, electricity can be available for the pumping works of the tank (PDB, Gopalgonj) |
| Production wells | 1 | 0-1500 | Pumps of the production well are able to supply water within this distance (Department of Public Health and Engineering, Gopalgonj ) |
| Treatment plant | 1 | 0-400 | Pumps at the proposed treatment plant will be able to supply water within this distance (Department of Public Health and Engineering, Gopalgonj ) |

The description of grid themes applied directly in overlay (non-buffer) operation is listed in the Table 8.

Table 8. Details of grid themes applied directly in overlay (non-buffered).

| Themes | Purpose |
|---|---|
| Existing coverage of the overhead tank | The suitable area must be out side the existing coverage of the tank, which has got by connecting the endpoint of the served arc (delineated in the previous analysis). Therefore, served polygon shows the restricted zone. |
| Population density map (zones) | High-density areas are almost served by the existing tank. So, moderately dense area and future expansion zone has been emphasized |
| Land elevation map | Heavy construction like overhead tank requires high and stable soils. |

***b) Weighted overlay analysis:*** This analysis is based on the relative weightage (percentile importance value) of themes in location-decisions, distribution of buffers (accessible and restricted zone), function of non-buffering themes and evaluation scale value to rank the suitable sites.

The list of all percentile importance values assigned to each theme and evaluation scale values are preserved in the weighted overlay table panel of MODEL BUILDER. It is shown in the Table 9. The Model used for location suitability analysis is also given in the Fig. 3. The model includes the flowchart of data conversion process, respective buffering process, weighted overlay process and final output in a sequential order.

Table 9. Weighted overlay table panel (Model Builder-Spatial Analyst 2.0).

| Input theme | Theme type | % of influence | Buffer (m)/them values | Scale value (rank) |
|---|---|---|---|---|
| Land elevation map | Non-buffered | 25 | very high land | 3 |
| | | | moderately high | 2 |
| | | | high | 1 |
| | | | low | 1 |
| | | | Agri-land | Restricted |
| | | | No data | Restricted |
| Electric power line | Buffered | 1 | 0-500 | 3 |
| | | | No data | Restricted |
| Population density map (zones) | Non-buffered | 8 | 0.001 persons/ha | 2 |
| | | | 0.002 persons/ha | 3 |
| | | | 0.003 persons/ha | Restricted |
| | | | 0.004 persons/ha | Restricted |
| | | | No data | Restricted |
| Road Network | Buffered | 15 | 0-15 | Restricted |
| | | | 15-300 | 3 |
| | | | 300-1000 | 2 |
| | | | 1000-1500 | 1 |
| | | | No data | Restricted |
| River | Buffered | 1 | 0-15 | Restricted |
| | | | No data | 3 |
| Location of structures/settlements | Buffered | 35 | 0-15 | Restricted |
| | | | 15-300 | 3 |
| | | | 300-800 | 2 |
| | | | 800-1500 | 1 |
| | | | 1500-3000 | 1 |
| | | | No data | Restricted |
| Existing coverage of the overhead tank | Non-buffered | 1 | Served area | Restricted |
| | | | Unserved area | 3 |
| | | | No data | Restricted |
| Location of proposed water treatment plant | Buffered | 1 | 0-4000 | 3 |
| | | | No data | Restricted |
| Location of active production wells | Buffered | 13 | 0-1500 | 3 |
| | | | No data | 1 |
| Sum of influence | | 100 | | |

Table 9 shows that location of structures/settlement poses the most important role because consumers must be located within the distance where water reaches through gravity flow. Therefore, it has been given 35% importance. On the other hand, a tank should not be located in a personal courtyard and that is why 15 m buffer around settlements was marked as restricted during the analysis. This same restriction has also been considered for river and road networks. The next important factor is land type (25% of influence value), which is essential for sound construction. Then road-network is an important factor (15%) for accessibility to carry the construction materials. Population density (8%) has moderate influence to locate the tank near the future expansion zone but excluding the place, which is presently served by the tank. Existing service area of the tank has been marked as restricted. Supply of water to the overhead tanks is another important issue. The proposed treatment plant will be able to supply water up to 4 km distance area. It covers almost all the area of the *Pourashava*. Therefore, suitable sites have been located considering the plant location as well. The quality grade of the sites was also determined through the location of the active production well (13%). Sites near the production well (1500 m) have been considered as highly suitable.

Though served area of the existing tank, water body locations factors are important as well and their buffers have been used to eliminate non-suitable areas directly or to include suitable areas for consideration. So, they are given less weights. Ultimately, location has been determined outside of the existing served area, inside the zone with electricity supply and outside of water bodies. The whole process of analysis is shown in Fig. 3.

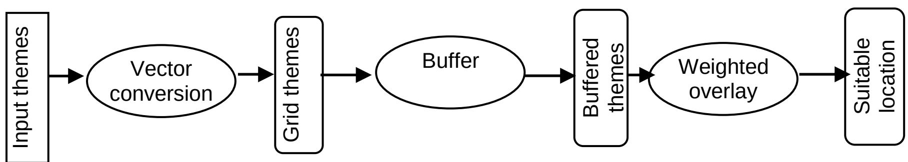


Fig. 3. Simplified model used for this analysis.

Using the above model (Fig. 3), influencing factors and restricted values, Model Builder has given the preliminary suitable sites and ranked them on the basis of the evaluation scale described in Table 9. These primary suitable sites (Fig. 4) include areas where there is more than enough space for overhead tank construction and also too small space to be constructed. To delineate minimum desired area for tank construction and pump house, the smaller space units are needed to be excluded. It has been successfully done by using ARC View sub-menu to get final output.

***c) Suitable sites having minimum desired area:*** According to DPHE (1999), 1600 sq. m (40x40) $m^2$ area is required for an overhead tank, its service room and pump house. To identify polygons with areas greater and equal to 1600 $m^2$, request was made to the Query Builder sub menu of ARC View, which has provided the following calculation results:

(i) Total area of potential sites is 1028132. 549 $m^2$ (13% of the *Pourashava* area) in all scale value.

(ii) Total area of suitable sites are 162081.4137 $m^2$ (6.58% of all delineated areas) in scale value 2.

(iii) Total area of highly suitable sites is 369234.32 $m^2$ (93.42% of all delineated areas) in scale value 3.

(iv) There is no area in less suitable category in scale value 1.

The locations of suitable sites with desired minimum area (actually suitable for overall construction) are shown in the Fig. 4. From the final output sites it can be seen that most of the areas are located along the belt of future expansion zone of the *Pourashava*. Some suitable areas are located in the south portion of the study area, which has a great potentiality to be expanded in future due to its proximity to Gopalgonj University (under construction). Delineation of existing water supply coverage will also help concerned authorities to delineate the future expansion zone and provide future urban facilities.

## Conclusion

GIS is a popular technology, which can be efficiently applied to water supply system in order to automate the whole system, analyze the existing coverage and to delineate suitable sites for overhead tanks. This could make a great change in the development planning horizon of

Bangladesh. Here, network allocation method of GIS has been applied with two water demand categories. Equal water demand for the whole study area shows that only a little area is served by the existing overhead tank (21% of total water distribution path). The real picture of piped water supply coverage is much different. So actual demand estimated from Bangladesh Water Consumption Standards is applied through near method of ARC/INFO. It provides an acceptable result (61% distribution path) close to the existing coverage through water pipe line. ARC View Model Builder has been used to delineate the potential sites for constructing new overhead tanks. The model is executed in search of three categories of suitable sites. It has been identified that 1028132 $m^2$ (13% of the *Pourashava* area) in different locations is suitable for constructing new tanks. Among potential locations, about 93% area is identified as highly suitable and near 7% as suitable sites.

Suitable location for the construction of new reservoirs will help planning the potential distribution zone and technical decision making for water supply sources. By the integration of geographic and attribute data GIS can evaluate any service network very efficiently. It can be applied in analyzing of community facilities like, community centers, sport centers, shopping and many others [Hossain (1998)]. It can also be used in emergency route planning like, bus network, firefighting route planning etc. These automated methods should be applied in all service giving departments of Bangladesh for providing best service to the consumers.

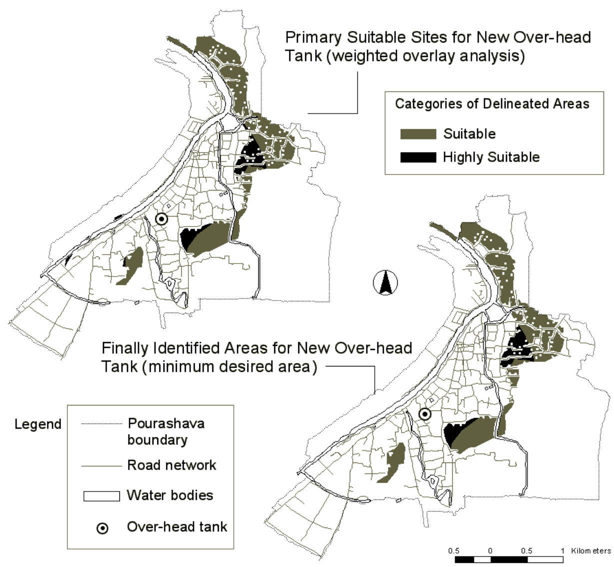


Fig. 4. Delineated areas for new overhead tank.

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