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GIS Mapping in Urban Slum Water Supply

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Abstract Water supply in slum area has been one of the most complicated tasks owing to a complexity in land tenure and rapidly changes in geography, population growth, and the uncertainties in the parameters influencing the time series and also due to the non-availability of adequate supply. Recently, geographical information system (GIS) has become quite popular and widely applied in various fields. This paper demonstrates the use of GIS to water supply in urban slum area to help and improve their quality of life (QoL). In particular, use of GIS technology to build a water supply management model in slum area. At present, in Chittagong city there are no proper water supply networks to supply the water in slum area. To illustrate the applicability and capability of the GIS, the Chittagong city, Bangladesh, was used as a case study. It is envisaged that, the proposed system can save much time, cost, and minimize the mistakes in managing operation and maintenance systems for water distribution networks.
Keywords *Geographical Information System (GIS); Quality of Life (QoL); Water Supply in Slum Area*

1. Introduction

In developing country like Bangladesh, water supply systems represent an important part in the urban infrastructure and critical factor of public health issue and economic development. The effectiveness of any resource management depends upon the nature of a sequence of measures preceding the decision. Information regarding location, at any given point of interest is necessary in the analysis and design of several resources management projects such as dam construction, pipe-lining, water reservoir operation, water distribution and wastewater disposal (Johnson, 2009).

Water is a scarce commodity, getting scarcer day by day. The humanitarian crises are not just the quantity of water available but the basis on which distribution networks are worked out. In the developing nation, most of municipalities distribution networks are have been grossly over stripped by rapid growth population. Neither the quantity of water available, nor the supplied mode is adequate for the inhabitants of these cities. The people who bear the brunt of this, however, are the poor. People living in over-crowded shanty towns are not supplied an assured or clean supply of water. A primary impact is threats to life through diffusion of infectious diseases including anaemia arsenicosis, ascariasis diarrhea, cholera, typhoid, scabies (Pond, 2005). Other impacts includes reduces benefits for recreation, diminished health of aquatic ecosystems, could open the door to door corruption and increases violence between water user due to water scarcity, pricing and uncertainty. Water supply in the slum area is not financially beneficial for organization in developing country due to very low cost and at time free of cost. In this circumstance, authorities in every town of the developing world need to devise systems of water supply and distribution that accommodate the needs of the growing number of urban poor.

In recent years, geographic information system (GIS) is a widely used tool in the field of engineering, environmental science and related discipline. GIS is rapidly changing the ways that engineering planning, design, and management of resources are conducted (Johnson, 2009). Water resources system can analyze mathematical model. However supply system are complex involving both physical and human dimensions, thus may not be defined accurately by mathematical method. GIS analysis and linked mathematical models can provide wide-ranging capabilities to examine plans and designs because of mapping visualization help to connect complex information. The goal of this study is to design a GIS based water distribution system to deliver potable water especially in slum areas in required quantities and in satisfactory level to improve the quality of life. This may introduce a significant advantage in water consumption in slum area.

This paper consists of five sections. Section 2 describes some related works on GIS based water supply, section 3 is about propose model, section 4 is about analysis of simulation result and finally section 5 concludes the paper with summary.

2. Related Work

2.1. Geographical Information System

The introduction of geographical information system technology brings with it a period of change. This is common with information systems and other innovations that changes working practices. Maguire (1991) suggested that by the end of the century everyone in the developed world would use GIS every day for routine operations. Truly, the range of application of GIS has increased in last two decades, in response to the expansion of the necessity for GIS and applications to which it has been applied.

GIS based analysis of the pattern of urban development over the demographic change and land use modifications has indicated that urban growth has mainly taken place linearly (Carver, 1991; Straume, 2014). This tools widely used in urban landscape planning and design (Yi-chuan and Li-fang, 2008; Mirats Tur et al., 2009; Zunying et al., 2010; Sihua, 2011). Sundararaman et al. (2012) explained the demand of sewerage network and scarcity of water supply system using remote sensing and GIS techniques.

Application of GIS technology in the emergency monitoring of sudden air pollution accident is proposed by Chen and Suozhong (2010). The research helps to respond sudden air pollution accident more rapidly for the emergency monitoring staff. Research also done on application technology of GIS data in intelligent transportation system (Xin-hai and Yu-juan, 2010), development of railway asset management systems (Guler and Jovanovic, 2004), and fire prevention supports (Higgins et al., 2014). Moreover, GIS technology has been applied in support of decision-making in the petroleum exploration by Lian and Yan (2010).

2.2. Water Supply in Chittagong

According to Chittagong water supply improvement project interim report (2012), the total water production capacity of 219,000 m^3/d, which caters about 47 percent of the present demand in the Chittagong city corporation area. The sector development plan (FY2011-25) estimates that in Chittagong, 41 percent of the population is served by a piped water supply, which is increased to 46 percent if supply via water points is included. The Atlas of poor settlements in Chittagong City Corporation notes that only 31.6 percent of the poor households in Chittagong have access to water (Chadder, 2013). However, in many cases this water is obtained from contaminated hand-dug wells or other unprotected sources, has high iron concentrations and salinity and can take considerable time to collect and convey to home. Many of these water sources may also be illegal connections to the Chittagong WASA (CWASA) distribution system. As noted above, the current rules and regulations of CWASA do not allow piped connections to customers without land tenure or notarized permission from the owner. However, over last decade and through intervention of a number of national NGOs, CWASA has started to supply water to low income communities (LICs) without land tenure on the provision that the connection is, at least initially, in the name of the NGO.

Although this is a positive development but progress is slow and in last five years only 26 connections has been made. Referring to CWASA bills for these connections indicates that the average monthly amount charged is BDT 364. This is equivalent to 60 m^3 per month or 2 m^3 per day per connection. For the 26 working connections the total volume of water provided per day is therefore 52 m^3. Considering that CWASA produces in the order of 219,000 m^3 per day this amount is negligible, yet it has transformed the lives of many people. It is understood that approximately half of the connections have now been transferred and are under the name of the concerned community based organization (CBO).

2.3. Low Income Communities Population and Characteristics in Bangladesh

The slums of urban Bangladesh, mapping and census (2005) estimated that there were a total of 9,048 slums in six cities; Dhaka, Chittagong, Rajshahi, Khulna, Sylhet and Barisal of these 1,810 or 20 percent, were located in Chittagong. It was estimated that 35 percent of the population of these six cities lived in slum areas on only four percent of the available city land. Population density in the slums was estimated at 205,000 people per square kilometer, which is 200 times the average figure for Bangladesh. Other key findings included:

- Approximately 40 percent of the slums had 10 to 20 households
- 80 percent were on private land
- 40 percent of the slums identified in 2005 were established before 1981
- 80 percent of the slums were at least 10 years old, and
- All slums were single stored

In the case of Chittagong it was estimated that the total slum population was 1.46 million, although this was also reported as being 35.4 percent of the population of the city, which does not tie in with current population estimation. If 35.4 percent is correct then the population living in the slums was probably closer to 878,000. This can be explained to some degree by the fact that estimates of the Bangladesh population for the period 2001 to 2011 were considerably higher than the preliminary results given by the 2011 census. It also found that 42 percent of Chittagong slums had no support of an NGO, which was the worst situation in any of the six cities studied.

The WHO/UNICEF joint monitoring programme 2010 (JMP) estimated that the population of Bangladesh to be 149 million of which 28 percent or 41.7 million were classified as urban. Access to improve sources of drinking water during the time is summarized in Table 1.

***Table 1:** Improved Water Supply in Bangladesh in 2010 (Chadder, 2013)*

Facility	Urban (%)	Rural (%)	Total (%)
Piped	20	1	6
Other improved	66	79	77
Improved total	85	80	81
Unimproved	15	20	19

3. Methodology

This research focuses on to investigate a reliable GIS based water supply model in Chittagong city to ensure water in the urban slum area. The methodology presented here is in the form of a general model for the analysis and specification of GIS requirements. Figure 1 presents the overall workflow of the proposed model.

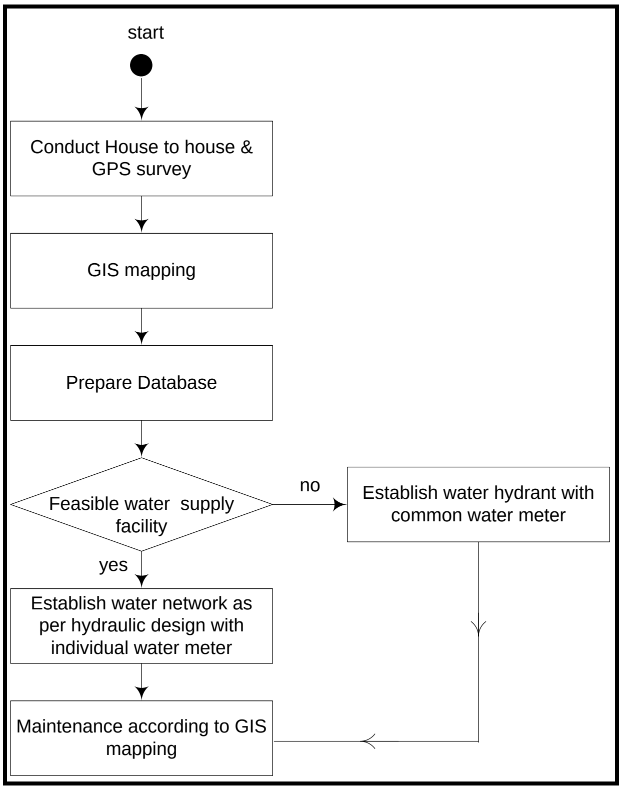

***Figure 1:** Workflow of Proposed GIS Based Water Supply Model*

Step 1: Global positioning system (GPS) and house to house survey

A survey should be conducted to determine the capabilities of GIS system. For GIS implementation there needs two types of survey: (a) Field verification survey by GPS, and (b) House to House survey.

(a) Field Verification Survey by GPS

The GPS is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the earth, where there is an unobstructed line of sight to four or more GPS satellites. The main objective of GPS survey is to clarify conflicts among the drawings which are collected, and to identify current situation because the information was not present. To identify exact position of planned distribution network and its facilities in real world, for example: gate valve, reducer, T-connection, hydrant etc. Moreover, to establish the GIS based digital mapping and database for operation and maintenance work. In GPS survey the steps are following:

- Prepare pre survey map
- Identification of pipe lines interventions and water service facilities
- Marking and fix up the points
- Taking GPS reading
- Submit the survey data for GIS mapping
- Recheck the transferred data and mapping
- Distribution network drawing and database design

(b) House To House Survey:

House to house surveys are to identify the exact location of CWASA customers. The identification of proper location of water meter installation because the information has not been present. The Work flow of house to house survey includes:

- Prepare an image map
- Marking and fix-up the plot in image map
- Collection of data and
- Transfer for GIS mapping

Step 2: GIS Mapping

For GIS mapping "Arc GIS 10" has been used. Survey form data digitized on GIS map using two features: (1) Line feature, for structure and proposed service line; and (2) Point feature, only for proposed water meter connection. Steps for GIS mapping are:

- Preparation of initial GIS datasets by editing work
- Preparation of ground control points (GCP) between CWASA coordinate system and satellite image
- Transform GIS data to WGS1984 coordinate system
- Spatial adjustment to correct strong distortions in GIS data on image data on WGS1984 coordinate system update GIS data.

Step 3: Prepare Database

Microsoft access / Excel and post SQL can be use as backend database. Database contains spatial data which is connected to GIS software. And software display different attributes of water supply facility like water meter, pipe lines, valve etc.

Step 4: Feasibility Checking

Based on considered factors including landscape, population density, nearest water supply network, cost effectiveness the authority can make decision on whether they establish new water networks for water supply with individual water meter or they establish water hydrant with common water meter.

Step 5: GIS based Maintenance

GIS is the prime tools for maintenance of water supply networks. It is easy to locate the service area; it may count individual structure and calculate water consumption by using GIS tools. Future system capabilities also depend on GIS map. GIS records enables repair, replacement and analysis the inspection results also information about new facilities can be entered into the GIS when that facilities are repaired and rename. We are totally ignored about water supply for slum area due to absent of GIS and spatial data.

4. Simulation Result and Discussion

4.1. Data Collection

To understand the views of poor communities in Chittagong, here worked alongside Chittagong WASA. For survey have visited forty one (41) settlements (ward) of the urban poor and spoke to representatives of the communities. They were asked from where they collect water, how far this are from their settlements, how much time have spent in the process, how much they collects each day, where they stored the water, what are the quality of the water obtained, how much they have to pay for it, and how much they feels they would ideally like. Furthermore, discussed to officials in the WASA, obtained all the available data of water supply and distribution and the schemes devised for the urban poor.

The study estimated that in the 2010 population of Chittagong was 2.7 million living in 562,000 households. The study also estimated that there were 5,778 LICs in Chittagong containing 301,527 poor households. The study therefore concluded that 53.6 percent or 1.45 million of the total population of Chittagong are poor. The reported classification is presented in Table 2.

Table 2: *Distribution of Households by Ward*

Ward Ref.	Ward Name	No. of Households				
		Extremely Poor	Very Poor	Moderately Poor	Marginally Poor	Total Poor
1	South Pahartali	3,580	888	1,411	1,077	6,956
2	Jalalbad	4,379	4,728	7,945	3,940	20,992
3	Panchlaish	2,349	2,754	4,065	2,186	11,354
4	Chandgaon	1,670	3,830	3,400	2,601	11,501
5	Mohara	4,621	5,230	3,125	1,632	14,608
6	East Sholakbawar	814	2,330	1,924	363	5,431
7	West Sholakbawar	28,172	3,018	1,320	755	33,265
8	Sholakbawar	1,880	3,494	2,024	1,036	8,434
9	North Pahartali	7,951	3,065	1,124	69	12,209
10	North Kattali	5,710	506	363	652	7,231
11	South Kattali	115	612	1,906	7,248	9,881
12	Saraipara	25,170	2,055	13,147	2,737	43,109
13	Pahartali	3.993	4,604	2,152	3,686	14,435
14	Lalkhan Bazar	2,006	1,631	1,727	297	5,661
15	Bagmoniram	281	299	380	102	1,062
16	Chanik Bazar	219	73	132	349	773
17	West Bakalia	5,023	2,599	1,007	1,333	9,962
18	East Bakalia	4,417	1,032	1,613	293	7,355
19	South Bakalia	2,989	2,418	1,840	765	8,012
20	Dewan Bazar	322	25	20	0	367
21	Jamalkhan	629	96	654	48	1,427
22	Enayet Bazar	2,036	4	183	608	2,831
23	North Pathantuli	330	131	295	226	982
24	North Agrabad	58	582	1,699	1,620	3,959
25	Rampur	498	607	1,211	203	2,519
26	North Halishahar	88	130	905	448	1,571
27	South Agrabad	2,988	988	181	0	4,157

28	Pathantuli	1,295	2,250	1,250	280	5,075
29	West Madarbari	223	347	311	16	897
30	East Madarbari	1,404	1,561	382	601	3,948
31	Alkaran	10	5	138	300	453
32	Anderkilla	35	34	122	170	361
33	Finghee Bazar	155	85	305	1,809	2,354
34	Patharghata	852	1,258	740	907	3,757
35	Boxirhat	7,358	198	7	0	7,563
36	Gosalldanga	1,035	935	169	86	2,225
37	Halishahar Munir Nagar	317	120	374	593	1,404
38	South Middle Halishahar	3,332	3,022	413	138	6,905
39	South Halishahar	3,920	339	396	245	4,900
40	North Patenga	1,421	1,478	1,939	1,579	6,417
41	South Patenga	950	1,535	1,678	1,061	5,224
Total		**134,595**	**60,896**	**63,977**	**42,059**	**301,527**

All LICs are classified as (1) extremely poor, (2) very poor, (3) moderately poor or (4) marginally poor. LICs are generally inhabited by industrial labourers, rickshaw pullers, waste pickers etc. It has been found that there are now over 500,000 garment workers in Chittagong, many of whom live in the LICs. Table 3 illustrates the survey result of LIC of the population of Chittagong.

Table 3: *LICs of the Total Population of Chittagong*

Type	Settlements		Households		Population	
	No.	**%**	**No.**	**%**	**No.**	**%**
Extremely Poor	1,574	27.2	134,595	44.6	645,450	44.6
Very Poor	1,360	23.5	60,896	20.2	292,330	20.2
Moderately Poor	1,561	27.0	63,977	21.2	306,810	21.2
Marginally Poor	1,283	22.2	42,059	14.0	202,610	14.0
Total	**5,778**	**100.0**	**301,527**	**100.0**	**1,447,200**	**100.0**

4.2. GIS Database Design

According to survey data, GIS database has been designed. In this research Arc GIS 10 has been the input data including settlement ID, settlement name, FID, shape, perimeter, area, slum id, ward, zone, category and settle_Id etc. Figure 2 illustrates the output information about the proposed model.

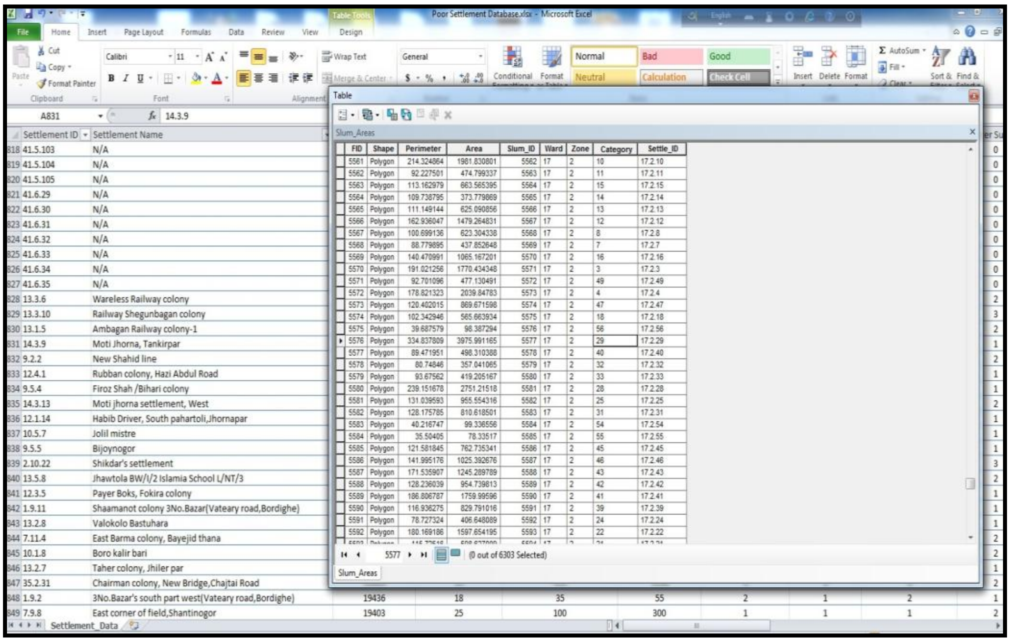

Figure 2: *Attribute Table of GIS Data*

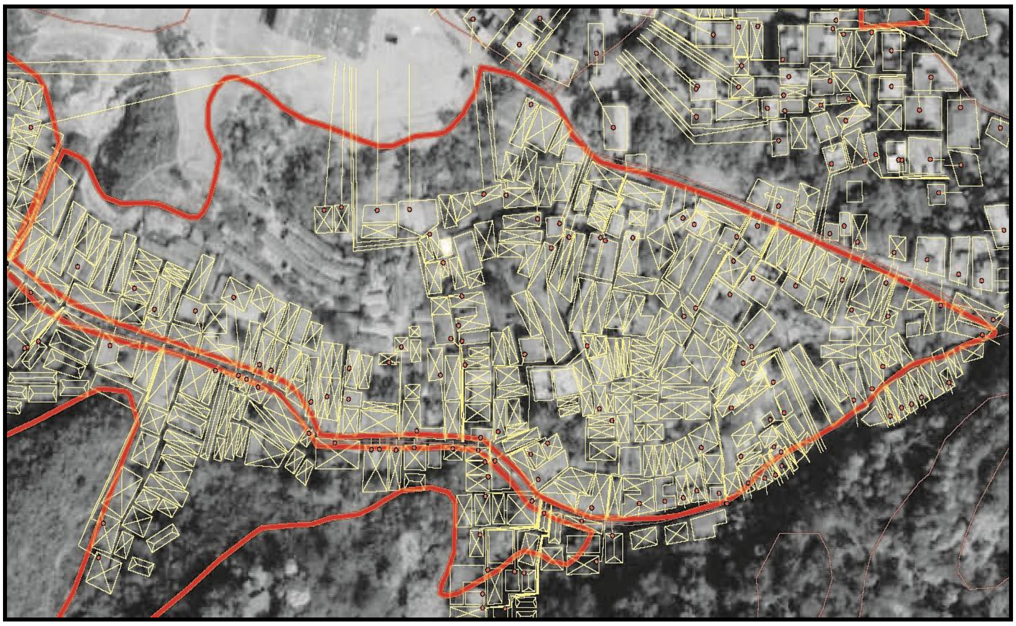

Figure 3: *GIS Based Water Supply Model (Output map)*

The Figure 3 displays overall mapped information about a household or proposed meter. The information including shape of structure, proposed service connection (pipe lines) and water meter.

4.3. Discussion

Another name of water is life. Pure drinking water is basic rights of the entire citizen. The peoples of slum area suffering many hydrant diseases including skin diseases due to poor quality water used. To ensure minimum pure water is only option to release those diseases. Some NGO takes the water distribution as a business. Therefore, slum peoples suffering and government losses their revenue, GIS can enhance the maintenance and management. In summary, GIS implementation has a list of effect including:

- Will more easily to inspection, repair, replacement and evaluation
- Future system capabilities
- Income of distributed water company will increase
- Quality of life of slum area will improve due to potable water

5. Conclusion

GIS concept and tools plays an important role in all aspect of data collection and archiving, support for condition assessment through display and modeling and message dissemination. Water is a scarce commodity for the urban poor, partially due to the inequity of water distribution within the city. The contribution of this study is to ensure potable water demand for peoples of slum area in legal way. Knowledge of population density and establishment of mapping promise for ensure supply as demand thereby greatly aided to improve the quality of life in slum area. The result shown that comparing with traditional methods, this research helps to respond operation and maintenance water supply more rapidly for the emergency monitoring staff.

The study covers vital aspects on the issue of water supply and distribution for poor communities in a large urban city Chittagong, Bangladesh. There are many more aspects of water supply, quality and distribution that need to be studied in greater depth. For instance, the local authorities should need to take the responsibility for their maintenance.

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