Simulation of Hydraulic Parameters in Water Distribution Network Using EPANET and GIS

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Abstract—Water supply system is a system of engineered hydrologic and hydraulic components which provide water supply. The major objective was to generate satellite based thematic layers, town and ward boundary maps and Geospatial Information System based census data and to estimate water demand, design of transmission lines and main pipe lines to meet the requirement of future demand. GIS has been used to integrate and estimate quantity of earth work to be excavated in terms of cutting and filling through Digital Elevation Model (DEM). The pipe network system is simulated to understand its behavior for different inputs using EPANET 2.0. In the present study, both single period and extended period simulation were carried out for distribution network system for one ward. Simulation has been carried out for hydraulic parameters such as head, pressure and flow rate. Total Energy Line and Hydraulic Gradient Line were prepared for the simulated results.

Keywords—EPANET, GIS, Pipe network, Simulation, Water supply.

I. INTRODUCTION

DESIGN of surface water supply system concerns the locations and capacities of diversion works and storage, as well as the operations of these to meet multiple purposes and objectives [11]. Therefore in order to ensure the availability of sufficient quantity of good quality of water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes [5, 12], which may provide potable water to the various section of the community in accordance with their demand and requirements. Due to the advent of Geographical Information Systems (GIS), it possible to visualize, and model the entire cycle of water supply network from source to household [5, 8]. The network system must be modeled, analyzed, and its performance [10] is evaluated under the various physical and hydraulic parameters or conditions [2, 4]. This process is called as “Simulation” [12]. EPANET [3, 6] is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks [9]. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps.

A. OBJECTIVES:

Objectives of the study are as follows.

- Generation of thematic layers for Alnavar town using GIS based census data.
- Design of pipe network for the future demand (for town level and ward level).
- To find alternative alignments for main pipe line from source to OHT using DEM.
- Simulation of the water distribution network system for various hydraulic parameters
- Comparison of Hydraulic Gradient Lines and Total Energy Lines.

II. STUDY AREA

Alnavar is a taluk panchayat (sub-district) of Dharwad district, Karnataka state, India lies between 15°26’N 74°44’E and 15.43°N 74.73°E an average elevation of 563 m above MSL rainfall of 930 mm. The total area considered is 165 km² which covers 29 villages around Alnavar town for which water supply system is designed and pipe network has to be simulated. This study was carried out as part of part of ongoing project of Karnataka Urban Water Supply and Drainage Board (KUWS & DB), Bangalore, India. The total population of the town is 16,290 as per the Census 2001. The town consists of 15 administrative wards. The data used in the present study are listed in the table 1 with description.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite data</td>
<td>Regional Remote sensing Centre-Bangalore</td>
<td>CARTOSAT-1; dt: 15/03/2009; 2.5m Resolution; IRS LISS-IV, dated 02/02/2008; 5.8 m resolution.</td>
</tr>
<tr>
<td>CARTO DEM</td>
<td>Regional Remote sensing Centre-Bangalore</td>
<td>Spatial resolution of 20 m was generated from stereo pairs using Leica photogrammetric suite.</td>
</tr>
<tr>
<td>Topo sheets</td>
<td>Survey of India</td>
<td>Used as base map.</td>
</tr>
<tr>
<td>Census data</td>
<td>Census of India</td>
<td>Used to project water demand.</td>
</tr>
<tr>
<td>Autocad map</td>
<td>City Administration</td>
<td>To design pipe network.</td>
</tr>
</tbody>
</table>
III. METHODOLOGY

The methodology (figure 1) was developed by conceptualized the water supply system. Ortho rectified Cartosat-1 images, rectified LISS IV images and topo sheets are masked and extracted for the required area using ArcGIS software. The ward wise census data is attached to the database of the Alnavar wards boundary layer. Future Population was estimated using following three methods. The methods used in this project are mentioned below.

Arithmetic Increase Method: \[ P_n = P_0 + n \times x^* \] (1)

Geometric Increase Method: \[ P_n = P_0 (1 + r/100)^n \] (2)

Incremental Increase Method: \[ P_n = P_0 + n \times x^* + \left[ n \left( n+1 \right)/2 \right] y^* \] (3)

Where \( P_n \) = Prospective or forecasted population; \( n \) = Number of decades;

\( r \) = Assumed growth rate in %; \( x^* \) = Average increase of population of known decades; \( y^* \) = Average of incremental increase of the population of known decades.

Hulikere Lake is selected as potential water source for drinking situated at a distance of 6.5 Km. Transmission pipe and Main pipe lines are designed based on the required discharge and the velocity of flow using discharge and Manning's hydraulic equations.

Discharge equation \[ Q = A \times V \quad m^3/s \] (4)

Mannings equation \[ V = \left( \frac{1}{n} \right) R^{2/3} S^{1/2} \] (5)

Where \( V \) = Average velocity of water in m/sec; \( R \) = Hydraulic mean depth; \( S \) = Bed slope \( (V: H) \) in m; \( n \) = Manning roughness coefficient; \( A \) = Cross sectional area of the pipe in m².

IV. SIMULATION

The network is simulated for both present demand scenario and future demand scenarios using GIS and EPANET [1]. In this study, an AutoCAD map (figure 2) was converted to GIS file format and overlaid on CARTOSAT-1 imagery. Pipe network and nodes are created on the map and water demands at each junction were provided. EPANET’s hydraulic simulation model was used to compute junction heads.

Fig 1. Flowchart of methodology
The head loss was estimated using equation (6) and total energy line and hydraulic gradient line were drawn for the simulated results. Total time duration considered for the extended period simulation is 72 hours with a reporting time step of 1:00 hr.

Darcy-Weisbach formula. 

\[ H_L = f \frac{Lv^2}{2gd} \]  

(6)

Pressure at each node \[ P = \rho gh \]  

(7)

Where \( H_L \) = head loss in m/1000 m; \( g \) = acceleration of gravity; \( L \) = pipe length in meters; \( d \) = pipe diameter in meters; \( v \) = flow velocity in m/sec; \( f \) = friction factor (Assumed 0.25 for new pipes); \( \rho \) = Density of water =1000kg/m\(^3\); \( g \) = Acceleration due to gravity = 9.81 N/ m\(^2\); \( h \) = height of the point from free surface.

V. ANALYSIS AND RESULTS

IRS P6 LISS-IV and IRS P5 Cartosat-1 images were ortho-rectified geo-referenced to geographic co-ordinates and WGS 84 datum using the Rational Polynomial Coefficients in Lieca Photogrammetric suite and DEM’s with the resolution of 10m. The main distribution pipe line was designed by considered future population at rate of 135lpcd using continuity and Mannings equation. The required peak discharge was estimated to be 0.0045m\(^3\)/s. Earth work excavation for alignment 1 and 2 are 5436.9 m\(^3\) and 3218.15 m\(^3\) respectively.

Hydraulic simulation: After a network has been suitably described, water demand at each junction was provided. Hydraulic analysis [12] at 9.00 hours for head and pressure head were carried out to understand the performance and behavior network and results are tabulated in table 2. The results of present and future demand were compared for extended period hydraulic simulation. The time instance used for drawing HGL and TEL is at 9:00 hrs. At this time, water level in the tank is 3.46 m. Similarly, total head is computed for all nodes using EPANET and hydraulic equations and the results are tabulated in table 3 (only selected nodes are presented).

VI. CONCLUSIONS

The following conclusions were drawn from this study.

- The satellite image and DEM have shown in effectively in selection of alternate alignment and quantity of earth work estimation.
- This paper has demonstrated an application of stochastic simulation for reliability analysis of water distribution systems using EPANET 2.0, taking into account the hydraulic considerations such as pressure, head, velocity etc...
- The results of the simulations are checked using hydraulic equations. This showed that the results are correct and can be used for modeling water supply system.
• This study would help the water supply engineers in saving time as it this process is fast, less tedious, easy to incorporates the changes etc under one umbrella.

REFERENCES


