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EPAnet Demand Calculation Methods and Implications

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Abstract: ***Water distribution network analysis depends largely on demand representation at nodal points irrespective of pattern of distribution network i.e. grid method or dead end method. Uncertainty in projected nodal demands and estimated pipe roughness coefficients of each year of operation is the major cause of fluctuation in pipe flows and nodal pressures of the Water distribution network (WDN). Allocation of wrong demand to nodes lead to failure of system either by generating negative pressures due to high velocities due to small diameter pipes or due low velocities and subsequent deposition of silt due to larger diameter of pipes. Since WDN is one of the most important and expensive components of water supply systems, Allocation of proper demand is the aim of water agencies or authorities dealing with design, maintenance, and the operation of WDNs. EPANET is the one tool for design of distribution network and demand allocation is an important step while designing. Present paper discuss about the calculation of demands to nodes by different methods and limitations of each.***

Keywords: water distribution network, demand allocation, GIS, EPAnet

1. Introduction

Fresh water is one of the most essential needs for residential and non-residential sectors of any society. To supply water for different users, water is collected from the sources, and then transferred and distributed among the users after treating to the appropriate standards at the water treatment plants. It is then transported through a water distribution system at sufficient flow and acceptable pressure. The design phase of the WDN involves choosing the characteristics of the components of the system so they can meet the requirements of the WDN. Therefore, the main task of WDN design is to determine the material and diameter of pipes so that nodal demands are met at sufficient pressure and minimum cost. There are two sets of variables in the procedure of WDN design: decision variables, known as "design variables", which are pipe diameter, material and its characteristics and "state variables", which are pressure at nodes and flow rates in pipes. The main design parameters, based on which design variables are chosen and which state variables are controlled, are the water nodal demands. The major sources of uncertainty during the operation of a WDN come mainly from water nodal demand. Population growth, climate conditions, socio-economic factors, public behavior, life style and standard of living are the causes of demand uncertainty.

The aforementioned uncertainties in nodal demands can lead to the hydraulic failure of a WDN during its service life. The hydraulic failure at a consumption node of a WDN is defined as a nodal pressure drop below the minimum required pressure[4]. If actual demands exceed projected demands, and/or actual pipe roughness coefficients exceed the estimated roughness coefficients, the dissipated energy within the pipes increases, and thus a hydraulic failure may occur at the nodes[5].

The main aim of this study is to study the reliability of the demand allocation to the nodes and the network for design of water distribution network under uncertainty in nodal demands. The impact of uncertainty in projected nodal demands is assessed using failure of nodal pressure, which is the most common criteria of hydraulic performance of WDN.

2. Literature Review

Water distribution networks (WDNs) are built to supply water in urban areas. The main function of WDNs is to transfer high-quality water to meet the demand of different consumers. A water distribution network is an important part of the water supply system, as it contributes to nearly 70 percent of the total cost of the water supply system[6]. Because of the huge expenditure of water distribution networks and their critical role in supplying water, the reliability of WDNs has attracted much interest in recent decades.

Analysis of water distribution system includes determining quantities of flow and head losses in the various pipe lines, and resulting residual pressures. In any pipe network, the following two conditions must be satisfied:

1) The algebraic sum of pressure drops around a closed loop must be zero, i.e. there can be no discontinuity in pressure.
2) The flow entering a junction must be equal to the flow leaving that junction; i.e. the law of continuity must be satisfied.

The widely used method of pipe network analysis is the Hardy-Cross method.

Hardy-Cross Method

This method consists of assuming a distribution of flow in the network in such a way that the principle of continuity is satisfied at each junction. A correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.

If Qa is the assumed flow and Q is the actual flow in the pipe, then the correction d is given by

d=Q-Qa; or Q=Qa+d

Now, expressing the head loss (HL) as

HL=K.Qx

we have, the head loss in a pipe

=K.(Qa+d)x

=K.[Qax + x.Qax-1d + ...negligible terms]

=K.[Qax + x.Qax-1d]

Now, around a closed loop, the summation of head losses must be zero.

SK.[Qax + x.Qax-1d] = 0

or

SK.Qax = - SKx Qax-1d

Since, d is the same for all the pipes of the considered loop, it can be taken out of the summation.

\ SK.Qax = - d. SKx Qax-1

or

d =-SK.Qax/ Sx.KQax-1

Since d is given the same sign (direction) in all pipes of the loop, the denominator of the above equation is taken as the absolute sum of the individual items in the summation. Hence,

d =-SK.Qax/ S l x.KQax-1 l

or

d =-SHL / x.S lHL/Qal

where HL is the head loss for assumed flow Qa.

The numerator in the above equation is the algebraic sum of the head losses in the various pipes of the closed loop computed with assumed flow. Since the direction and magnitude of flow in these pipes is already assumed, their respective head losses with due regard to sign can be easily calculated after assuming their diameters. The absolute sum of respective KQax-1 or HL/Qa is then calculated. Finally the value of d is found out for each loop, and the assumed flows are corrected. Repeated adjustments are made until the desired accuracy is obtained.

Since this is an iterative method number of simulation models are available for analysis. EPANET is one among them.

EPANET models a water distribution system as a collection of links connected to nodes. The links represent pipes, pumps, and control valves. The nodes represent junctions, tanks, and reservoirs. Junctions are points in the network where links join together and where water enters or leaves the network.

The basic input data required for junctions are: i) elevation above some reference (usually mean sea level) ii) water demand (rate of withdrawal from the network) iii) initial water quality.

The output results computed for junctions at all time periods of a simulation are: i) hydraulic head (internal energy per unit weight of fluid) ii) pressure iii) water quality

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different formulas. Each formula uses the following equation to compute headloss between the start and end node of the pipe:

$$h_L = Aq^B$$

where h_L = headloss (Length), q = flow rate (Volume/Time), A = resistance coefficient, and B = flow exponent.

Water demand allocation in Epanet is most important step in designing water distribution networks. Allocation of wrong demand to nodes causes failure of system. Sometimes negative pressures are generated due to small diameter pipes where as in other areas due to larger diameter of pipes leads to low velocities and subsequent deposition of silt in pipes. In this paper two methods are discussed, one based length pipe of each node represents and another area of node each node represents.

3. Case Study

3.1 Case I

Chakra Dwara Bandham is a small urban out growth near Rajahmundry, Andhra Pradesh, Hyderabad. It is recently merged into Rajahmundry Municipal Corporation. Population of this hamlet as per census is 2015, 2986, 3974 in 1991, 2001 and 2011 respectively. Projected populations are 4340, 5281 and 6294 in 2017, 2032 and 2047 respectively. Total road network is 7700m. This area is selected because the population is uniformly distributed all over the area. Population density in area is low.

3.2 Case II

Another hypothetical area with uniform grid pattern (Similar to a planned layout) was taken and demand calculation methods by both methods applied on the same. The results are presented in results section.

4. Methodology

In the first method line topology is generated and total length generating from node to other nodes is determined .Half of above length is taken as representative length for that node. Demand for each node is calculated by multiplying as representative length and demand per meter length .Demand per meter length is calculated by q = Q/total network length, where Q is total demand of concerned area.

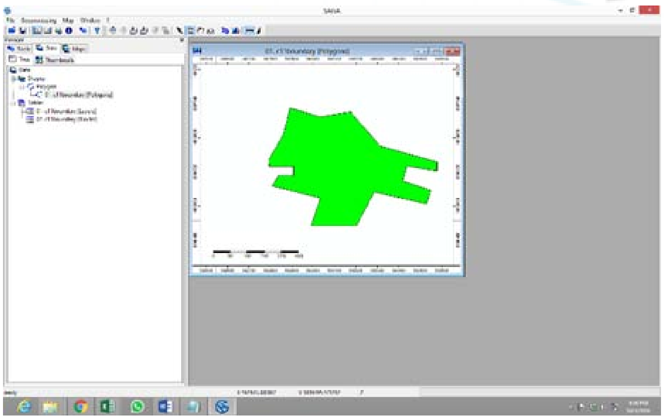
In second method thiessen polygons are generated using public domain software SAGA GIS .The procedure is as follows.

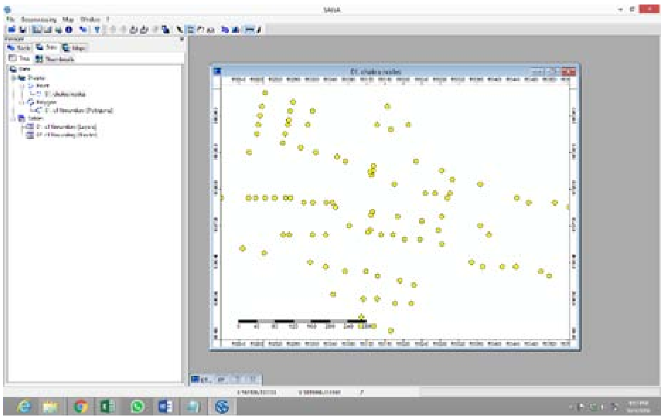
1) From Epanet file x,y ,id text file is extracted with help of Microsoft excel.
2) Boundary of area (town) is drawn in autocad and exported in DXF format.
3) Points are imported into SAGA GIS from import shape command.
4) Boundary is imported into SAGA GIS from import DXF command.
5) Thiessen polygons are generated for points using create thiessen polygons command.
6) Thiessen polygons are clipped with area boundary.
7) Shape file index is created for above polygons using command create shape file index.
8) Attribute table of shape file index is opened in Microsoft excel to know the area and to calculate demand of each node by multiplying area of polygon, population density and per capita consumption.

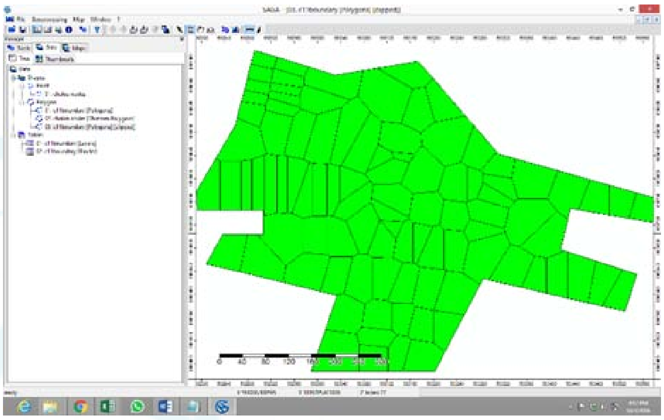
5. Result Analysis

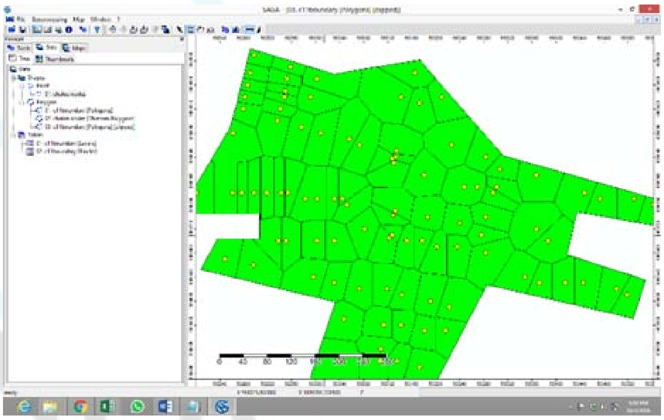
5.1 Case I

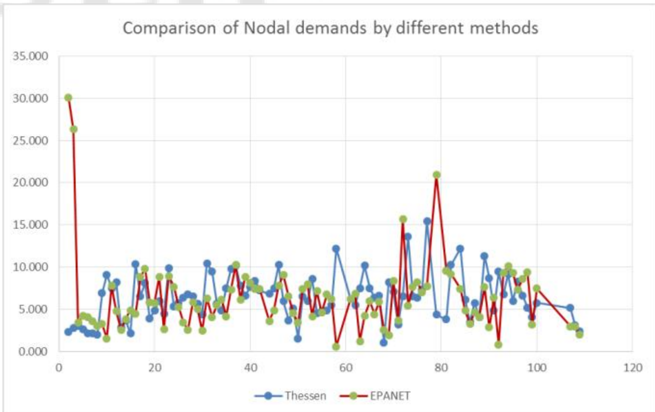
Figures 2 to 5 shows the outputs during the process. Figure 6 indicates the nodal demands calculated by standard EPAnet method and Theissen polygon method. This is clear from the figure that there is no clear correlation existing between these two methods. At certain points these two methods are giving same values where as when moving towards the boundaries the deviation is more and more.



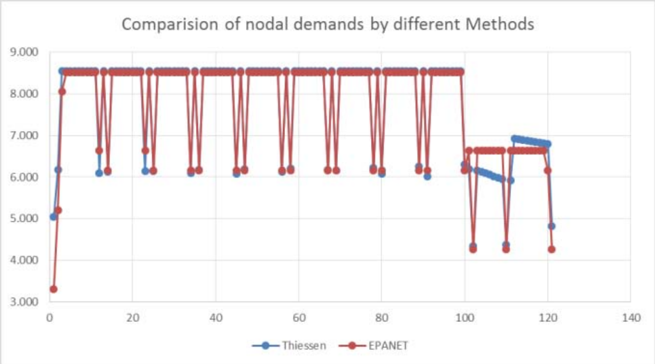








Case II:
Same analogy was applied to grid iron pattern network. The results are as follows.



From the above figure it can be very seen that the both the methods are giving the same nodal demands.

6. Conclusion

1) Different methods are available for estimating nodal demands for water network analysis
2) Comparing EPANET method and Theissen method for haphazard growth of city even though population density is same, showing no correlation between two methods.
3) Comparing EPANET method and Theissen method for Grid type of cities/ Planned system cities if the population density is same, a perfect correlation is existing except at boundaries.
4) Hence theissen method using SAGA GIS can be used for planned developed city for calculating nodal demands which will save the time.

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