

Water Distribution (Pipe) Network Analysis with WaterCAD

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Abstract - Pipe network analysis is the study of fluid flow through a network of pipes and their components that is composed of multiple interconnected branches of pipes. When performing a conventional pipe network analysis, it is often necessary to illustrate how to determine the flow rates and pressure drops in each individual component of the pipe network. Water utilities often rely on sophisticated software to automatically resolve these types of problems. Water from municipal water systems is usually routed through a water distribution network in order to reach a large number of customers. Using an example pipe network problem as a case study, we aim to explain how to analyze it and address its hydraulic design parameters using the WaterCAD software program.

keywords - Pipe Network, WaterCAD

I. INTRODUCTION

In both natural [1] and man-made environments, networks can be emerged or designed for connecting essential components together [1–5]. The study of networks is essential to understand and the development of their properties and design [1–5]. Engineers routinely employ to study networks to construct models of real-world systems in order to handle a variety of complicated challenges. Graph theory is a mathematical term that refers to the study of networks in many forms [1,4]. Networks, also known as graphs in formal mathematics, are the objects that are investigated by graph theory, which is a field of mathematics that investigates such things. When we think of networks, we commonly think of social networks and the Internet in particular, but network usage is extremely popular in the context of water supply and distribution [6,7]. Drainage/channel networks have long been a research area for natural water distribution networks [1,4,8]. In real life engineering, many software is used to model water distribution networks such as WaterCAD, StromCAD etc. In this article we aim to examine a simple man-made pipe network model, which is done with the use of WaterCAD widely available computer program [6].

II. NETWORK ANALYSIS

This network provides a distinct set of hydraulic design difficulties, with pipe network analysis serving as a common technique for resolving them.

Deterministic network analysis

The hydraulic parameters of the network, such as flow rates and head losses, can be explored in a deterministic manner using the pipe friction factors [7,9–11]. Specifically, in this scenario, it is necessary to find a solution for the steady-state flows on the network, which is based on the two assumptions listed below.

1. The total flow into a junction/node is equals to the total flow out of that junction (conservation of mass, or continuity equation) [10].
2. The head loss in any closed loop within the network must vanish (conservation of energy) [10].

The Hardy Cross method is a traditional method for solving these networks. Initial conditions are used in this method to generate guess values for the network's flows. The loop's flows are then adjusted by an amount calculated by the head loss formula (i.e., $h_L = KQ^n$) until loop-wise balance is achieved.

This technique assumes a network flow distribution that satisfies the continuity principle at each junction. After that, an adjustment to these assumed flows is calculated for each pipe loop in the network, until the correction is minimized to a tolerable level. The adjustment d is provided by if Q_a is the assumed flow and Q is the actual flow in the pipe (i.e., $Q = Q_a + d$). Then the head loss (H_L) can be expressed as $h_L = K(Q_a + d)^n$, neglecting higher terms head loss will be $h_L = K(Q_a^n + dnQ_a^{n-1})$. The sum of head losses around a closed loop must now be zero. As a result, $h_L = 0$, therefore, $\sum K * (Q_a^n + dnQ_a^{n-1}) = 0 \Rightarrow d = -\frac{\sum KQ_a^n}{\sum nKQ_a^{n-1}}$. The value of n is usually 1.85 for Hazen-Williams and 2 for Darcy-Weisbach [10].

Probabilistic network analysis

On the other hand, the number of known parameters such as flow rates and head losses that must be considered in order to obtain a deterministic solution in many practical water distribution networks in large cities will be extremely huge. Given the

fact that many of these variables are unknown, a probabilistic method for pipe network analysis has recently been developed to take these factors into consideration.

Analysis with software

When dealing with engineering challenges, water utilities often rely on sophisticated software to handle them automatically.

III. WATERCAD SOFTWARE

WaterCAD is a user-friendly hydraulic and water quality modeling application for water distribution systems that is easy to use. It has the potential to be a reliable, resource-saving, and simple-to-use decision-support tool for water infrastructure development. It is capable of assisting in the study, design, and optimization of water distribution systems, ranging from fire flow and water quality studies to energy cost management and pump modeling, among other things [6].

Example problem definition

The plan depicted in Figure 1 is for a proposed youth educational camp, a portion of which will be supplied with water via an above tank. We are offering this example to demonstrate how to use WaterCad to build the water distribution system for the subdivision to the left of the plan depicted in figure 1. The tank that will supply the subdivision has a bottom elevation of 700 feet and a top elevation of 730 feet. This is based on a daily demand of 40 gallons per minute [6,7].



Figure 1 Layout of a sample problem [6,7]

Program Execution

To begin, click on the WaterCad V8 icon and then on the pop-up menu that appears, pick Create New Project. Then, under the Tools menu, click Options, followed by Project. If necessary, pipe lengths can be rounded to the nearest foot. From the Drawing tab, select schematic drawing mode and change annotation multipliers such as symbol size and text height (set multiplier to 5). One can select the US system and then adjust the Unit system based on the units provided. Then, click OK to proceed and exit the Options window.

To begin building the model, prototypes can be picked from the View Tab. This will launch the Prototype Manager, which enables you to provide global characteristics to the model's elements. By right-clicking pipe and making a new prototype for the pipe components, we can resolve this issue. Additionally, we can click on properties: Enter a 6-inch diameter and choose PVC material with a Hazen-Williams [10] friction factor of 150 from the built-in materials library. We can pick "True" and close the window under the user-defined length for pipes.

Additionally, to pipe prototypes, by clicking on it, junction prototypes can be built. Select the necessary demand Collection, then right-click on the header of the base flow column and choose Global Edit. Then, choose Set as the operation and enter 40 as a global requirement allocated to all junctions. If necessary, click on the heading of the demand column again, select Units and Formatting, and change the global flow's units to *gal/min (gpm)*. Finally, the window and the Prototype Manager should be closed.

To schematize the model, click on Background Layers: NewFile in the bottom left column. Look for the configuration indicated in Figure 1. Click OK to retain the project's default properties and save it to the selected directory. You may need to zoom-extents to see the background layer. If the image looks to be too dark, increase the transparency.

Construct a pipe distribution system for the provided subdivision in accordance with the diagram. Utilize the Element toolbar to create a tank, pipelines, and connections. To bend a pipe, right-click it, select bend, add bends, and snap in the

desired location. Ascertain that all element labeling is selected beneath the element symbology and that the labels correspond to the labels on the diagram.

Due to the fact that we did not properly locate the tank or specify the pipe lengths, navigate to FlexTables, Pipe Table, and enter 410 feet for pipe 1. All pipes in our system should be lengthened to the values stated in table 1.

Table 1 Pipe Table

Length of the pipes	
<i>Pipe</i>	<i>Length (ft)</i>
P-1	410
P-2	560
P-3	300
P-4	545
P-5	560
P-6	600
P-7	280
P-8	560
P-9	280
P-10	545

Then, pick Junction Table from the FlexTables menu and enter the elevations for each junction in table 2.

Table 2 Junction Table

Elevation of the junctions	
<i>Junction</i>	<i>Elevation (ft)</i>
J-1	620
J-2	560
J-3	560
J-4	525
J-5	580
J-6	618
J-7	560
J-8	525

Double-click the tank, select the Physical heading, and enter a diameter of 60ft for the circular section. Then, under the Operating range header, enter 680, 715, and 730 feet as the minimum, beginning, and maximum elevations, respectively.

We are now prepared to run the model. To ensure that the data is correct, click the Validate icon; if there are no errors, we will get the "no problems were found" message box. To begin running the model, click the Compute (green →) icon. When the run is finished, examine the status log and then close the status log window.

Select FlexTables, Junction Table, and pressure and HGL values [6,7,10]. Similarly, examine the pipe attributes by selecting FlexTables, Pipe Table, and collecting the relevant design data. If necessary, save our work for DESIGN.

WaterCAD step by step

The above flow chart figure 2 depicts the step-by-step approach of building model in WaterCAD. Here, we direct all readers to the [6,7] for more information on each step.

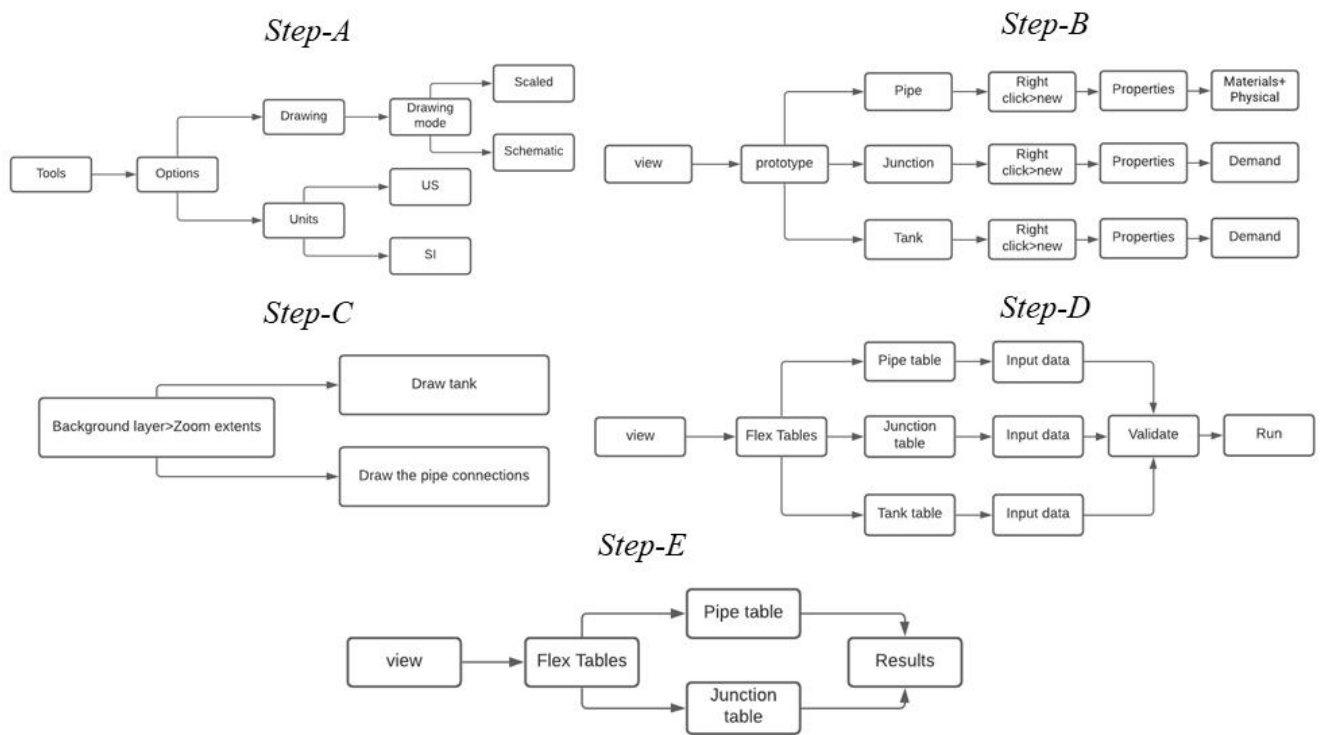


Figure 2 Flow chart depicts the step-by-step approach of WaterCAD [6]

IV. RESULTANT PIPE NETWORK LAYOUT

WaterCAD will automatically display the final network based on flow direction after validation and execution. The resulting layout for our example is shown in figure 3. Required parameter for design can also obtain from the FlexTables [6,7,10].

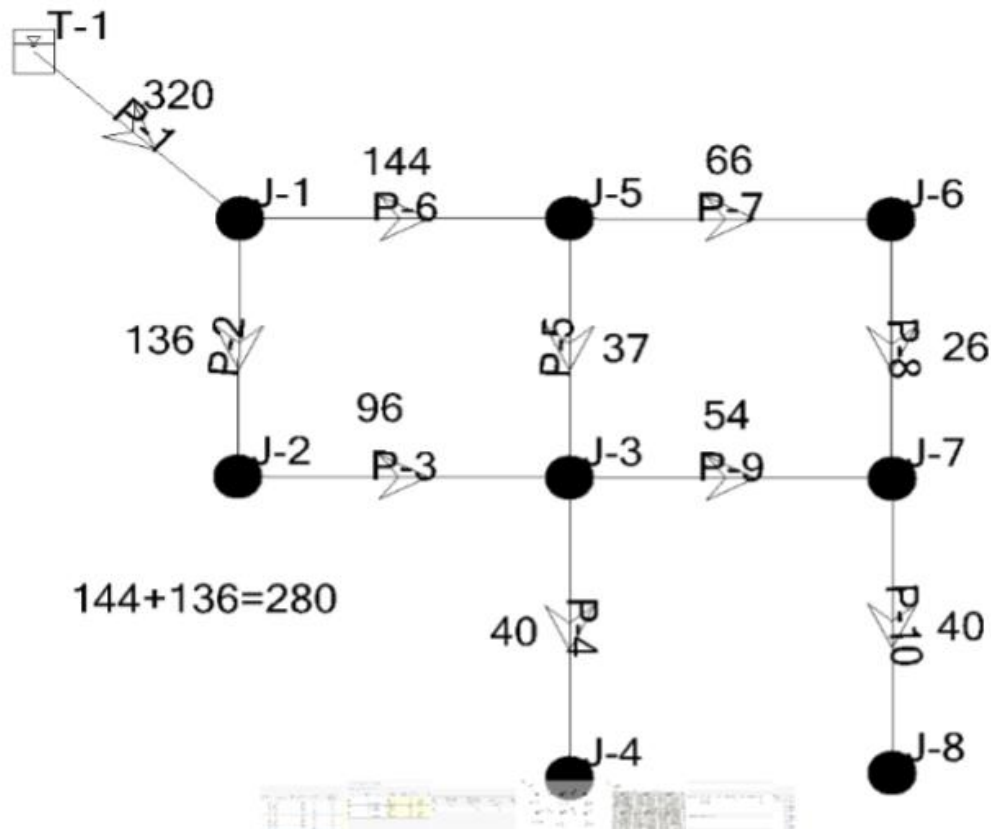


Figure 3 Resulting pipe network layout [6,7]

V. CONCLUSION

It can be concluded from the preceding explanation that the WaterCAD performs well for understanding water distribution network as well as solving real life engineering decision support tool.

VI. ACKNOWLEDGMENT

The author wishes to express gratitude to the Bentley (<https://www.bentley.com/en>) for providing student license for conducting WaterCAD simulations and UCF for selecting me as Teaching assistant to teach for Undergraduate Hydraulics Course.

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