# Pipe Network Design and Analysis: An Example with WaterCAD

Shiblu Sarker[1*]

[1]Department of Civil, Environmental and Construction Engineering, University of Central Florida, Orlando, Florida, 32816, USA; ORCID: 0000-0001-5580-2498
[*]Corresponding author: shiblu.buet@gmail.com

**Abstract**

Pipe network analysis is the analysis of the fluid flow through a network that containing several interconnected branches of pipes and their components. The common analysis of pipe network often demonstrates to determine the flow rates and pressure drops in the individual components of the pipe network. Water utilities typically use specialized software to solve these issues automatically. Municipal water systems frequently route water through a water supply network to reach a large number of users. In this paper we aim to demonstrate the use of WaterCAD software to solve hydraulic design parameter of an example pipe network problem.

## 1 Introduction

Networks can be found in both natural and man-made environments. The study of networks is fundamental to network theory. Engineers frequently use networks to develop models of real-world systems in order to tackle a variety of complex challenges. Graph theory is a mathematical term for the study of networks. In graph theory, a network is referred to as a graph in formal mathematics, and graph theory is the branch of mathematics that explores these objects. When we think of networks, we think of social networks and the Internet in particular, but network usage is extremely prevalent in the context of water supply and distribution. Drainage/channel networks have long been a research topic for natural water distribution networks Sarker and Singh (2017); Sarker et al. (2018, 2019a,b); Sarker (2021b). In this study, a simple man-made pipe network example is analyzed with the help of Software.

## 2 Network analysis

This network generates a unique set of hydraulic design issues, with pipe network analysis as a common solution strategy.

### 2.1 Deterministic network analysis

Based on the pipe friction factors, one can explore the network's hydraulic parameter such as flow rates and head losses Reza et al. (2014); Sarker (2021c,a) deterministic way. In this case the solution is sought for the steady-state flows on the network which based on the two following assumptions.

1. The total flow into a junction/node is equals to the total flow out of that junction (conservation of mass, or continuity equation)

2. The head loss in any closed loop within the the network must vanish (conservation of energy).

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. $h_L = K * Q^n$) 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 $h_L = K * (Q_a^n + d * n * Q_a^{n-1})$. The sum of head losses around a closed loop must now be zero. As a result, $h_L = 0$, therefore, $\sum K * (Q_a^n + d * n * Q_a^{n-1}) = 0$ $\Rightarrow d = -\frac{\sum K * Q_a^n}{\sum K * n * Q_a^{n-1}}$. The value of $n$ is $1.85$ for Hazen-Williams and $2$ for Darcy–Weisbach.



Figure 1: Layout of a sample problem Sarker (2021a)

## 2.2 Probabilistic network analysis

On the other hand, the number of known variables such as flow rates, head losses required to get a deterministic solution in many practical water distribution networks in large cities will be very enormous. Because many of these variables would be unknown, to account this, a probabilistic method for pipe network analysis has been developed recently.

## 2.3 Analysis with software

Water utilities typically use sophisticated software to tackle engineering issues automatically.

# 3 WaterCAD software

WaterCAD is a water distribution system hydraulic and water quality modeling application that is simple to use. It can be a decision-support tool for water infrastructure that is dependable, resource-saving, and easy to use. It is able to help in study, design, and optimize water distribution systems, from fire flow and water quality studies to energy cost management and pump modeling.

## 3.1 Example problem definition

The layout presented in figure 1 is a proposed youth educational camp, part of which will receive its water supply from an overhead tank. We are presenting this example to design the water distribution system for the subdivision to the left of the layout shown in figure 1, using WaterCad. The tank from which the subdivision will be fed has bottom and top elevations of 700 $ft$ and 730 $ft$ respectively. This is based on an average daily demand of 40 $gpm$.

## 3.2 Program Execution

To begin, click on the WaterCad V8 icon and select Create New Project from the pop-up menu. Then, under the Tools tab, choose Options, then Project. Pipe lengths can be rounded off to the closest foot if necessary. Select schematic drawing mode and adjust annotation multipliers such as symbol size and text height from the Drawing tab (set multiplier to 5). One can select the US system and adjust the Unit system from units. Then, to proceed, click OK and close the Options window.

Prototypes can be selected from the View Tab to begin building the model. This will activate the Prototype Manager, which allows you to give general properties to the model's elements. We can solve this issue by right-clicking pipe and creating a new prototype for the pipe components. We can also click on properties: enter 6-in diameter, select PVC material, associated with a friction factor of Hazen-Williams Sarker (2021c) of 150 from the build-in materials library. Under the user-defined length for pipes, we can select "True" and close the window.

In addition to pipe prototypes, junction prototypes can be created by clicking on it. Select the required demand Collection, then right-click on the base flow column's header and select Global Edit. Then, select operation as Set, and type in the value of 40 as a global demand assigned to all junctions. If necessary, click on the demand column's heading again, select Units and Formatting, and modify the global flow's units to $gal/min(gpm)$. Finally, close the window and the Prototype Manager.

To schematize the model, go to the bottom left column and click on Background Layers: NewFile. Look for the layout depicted in the figure 1. To preserve the project's default properties and save it to a specified directory, click OK. To see the background layer, you may need to zoom-extents.Increase the transparency to lighten the image if it appears to be too dark.

According to the diagram, build a pipe distribution system for the given subdivision. Create a tank, pipes, and junctions using the Element toolbar. To make a bend in a pipe, right-click on it, choose bend, add bends, and snap on the required spot. Make sure that all element labeling is clicked under the element symbology, and that the labels match the one on the diagram.

Because you didn't precisely locate the tank and give the pipes their exact lengths, go to FlexTables, Pipe Table, and give pipe 1 a user-defined length of 410 feet. Change the lengths of all pipes in your system to those listed in the table 1.

| Pipe | Length (ft) |
| --- | --- |
| 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 |

Table 1: Pipe Table.

Then, from FlexTables, select Junction Table and enter the elevations for each node from the table 2.

Double-click on the tank, select the Physical heading and give the circular section a diameter of 60ft. Then, select the Operating range heading and give minimum, initial and maximum elevations of 680, 715 and 730 ft respectively.

Now you are ready to run the model. Click on Validate icon to make sure the data is ok; if you have no errors you will get the "no problems were found" message box. Click on the Compute (green $\rightarrow$) icon to start running the model. When the run is complete, look at the status log and then close the status log box.

Select FlexTables, Junction Table, and examine the pressure and $HGL$ Sarker (2021c,a). Examine the pipe properties similarly by selecting FlexTables, Pipe Table, and recording the necessary data for design. Save

| Junction | Elevation (ft) |
|:---:|:---:|
| J-1 | 620 |
| J-2 | 560 |
| J-3 | 560 |
| J-4 | 525 |
| J-5 | 580 |
| J-6 | 618 |
| J-7 | 560 |
| J-8 | 525 |

Table 2: Junction Table.

your work for DESIGN if necessary.

## 3.3   WaterCAD step by step

The above flow chart figure 2 depicts the step-by-step approach of building model in WaterCAD. The Appendix section contains details about each step.
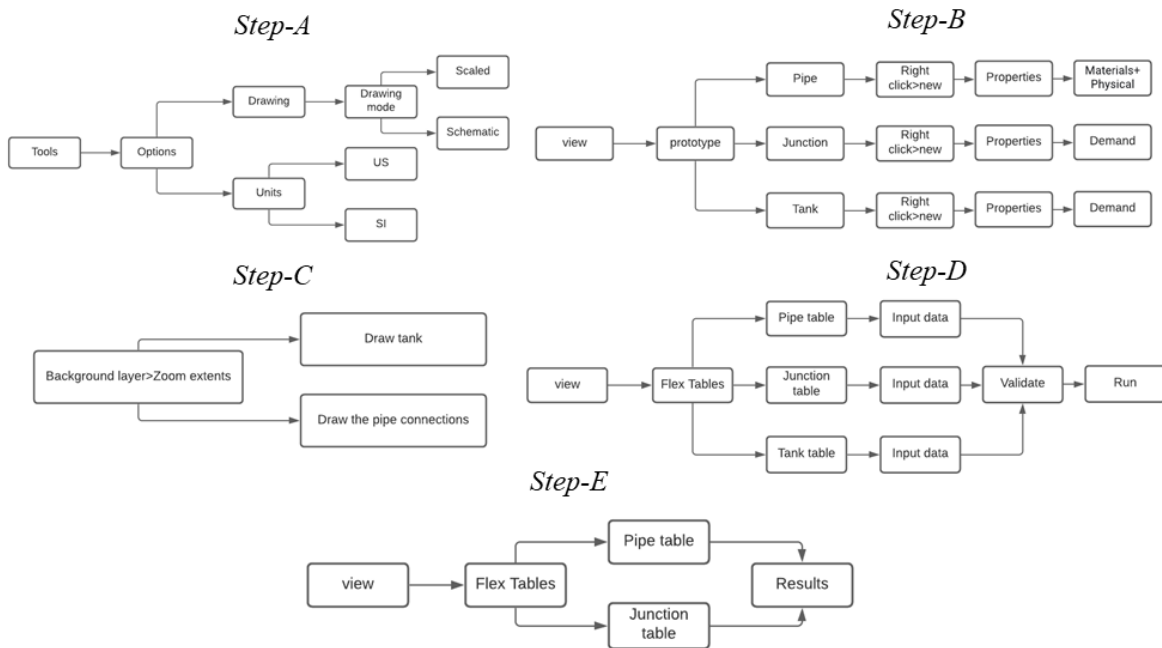


Figure 2: Flow chart depicts the step-by-step approach of WaterCAD.

## 3.4   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.
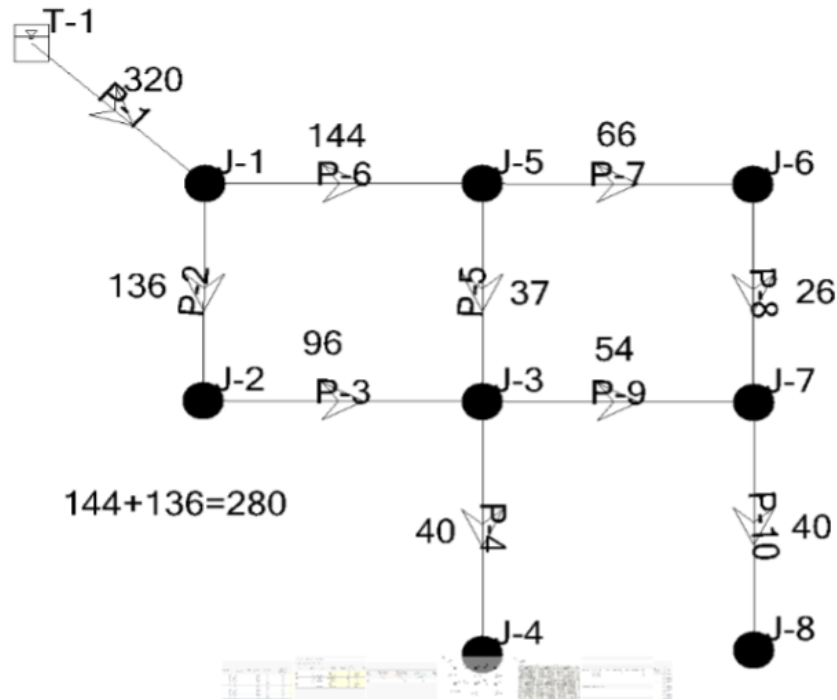
Figure 3: Resulting pipe network layout.

# References

Reza, A. A., Sarker, S., and Asha, S. A. (2014). An application of 1-d momentum equation to calculate discharge in tidal river: A case study on kaliganga river. *Tech. J. River Res. Inst*, 2:77–86.

Sarker, S. (2020). Pipe network design and analysis with WaterCAD. *Shiblu Sarker YouTube*.

Sarker, S. (2021a). Hydraulics lab manual. *engrXiv*.

Sarker, S. (2021b). Investigating topologic and geometric properties of synthetic and natural river networks under changing climatic. *UCF STARS*.

Sarker, S. (2021c). A short review on computational hydraulics in the context of water resources engineering. *engrXiv*.

Sarker, S. and Singh, A. (2017). On the topologic properties of river networks. *AGU Fall Meeting Abstracts*, 2017:IN33B–0128.

Sarker, S., Veremyev, A., Boginski, V., and Singh, A. (2018). On critical nodes in river networks. *AGU Fall Meeting Abstracts*, 2018:EP33D–2446.

Sarker, S., Veremyev, A., Boginski, V., and Singh, A. (2019a). Critical nodes in river networks. *Scientific Reports*, 9(1):1–11.

Sarker, S., Veremyev, A., Boginski, V., and Singh, A. (2019b). Spectral properties of river networks. *AGU Fall Meeting Abstracts*, 2019:EP51C–2107.

# 4   Appendix

Step 1: Tools > Options > Drawing > Drawing mode: Schematic

Step 2: Tools > Options > US

Step 3.1: view > prototype manager > Pipe (right click > new) + Junction (right click > new) + Tank (right click > new)

Step 3.2: Pipe Prototype-1 > right click > properties

5

Same for Junction data, Step 4.1: Right click > properties

Step 4.2: Demand collection > Right click

Step 4.3: Demand (base) ($gpm$) > right click Put 40 there!

Same for Tank data, Step 4.4: Right click > properties

Step 4.5: Demand collection > Right click

Step 4.6: Demand (base) ($gpm$) > right click Put 40 there!

Step 5.1: Select background layer

Step 5.2: New

Step 5.3: Select the path > open

Step 5.4: Zoom extents

Step 5.5 : Draw tank fist

Step 5.6: Draw the pipe connections

Note that the junction is automatically drawn

Step 6.1: Click View > Flex Tables > Pipe tables

Step 6.2: Click all the check boxes of 'Has user defined length'

Step 6.3: Put all the length assigned from the manual

Step 7.1: Click View > Flex Tables > Junction tables

Step 7.2: Put all the elevation assigned from the manual

Step 8.1: Click View > Flex Tables > Tank table

Step 8.2: Check the diameter, minimum, initial, maximum elevation

Step 9.1: Click validate

Step 9.2: Check the message that no problem were found

Step 10: Click run to complete

Step 11: Results can be checked from flex table

Finally, We recommended that readers watch the video on YouTube Sarker (2020).
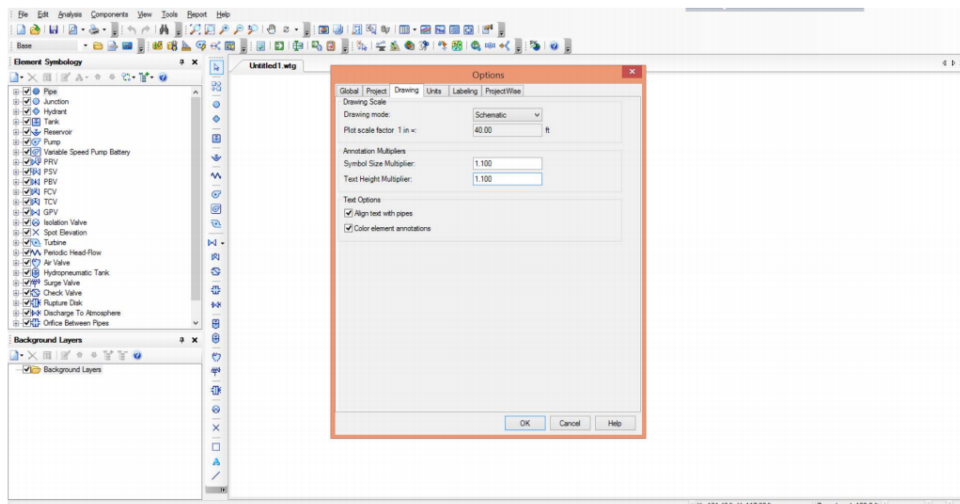


Figure 4: Step 1
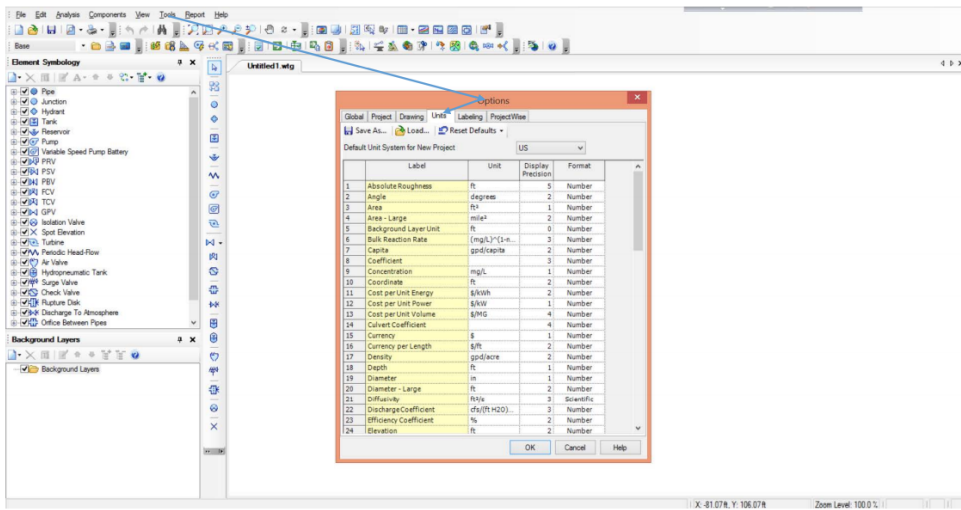
Figure 5: Step 2
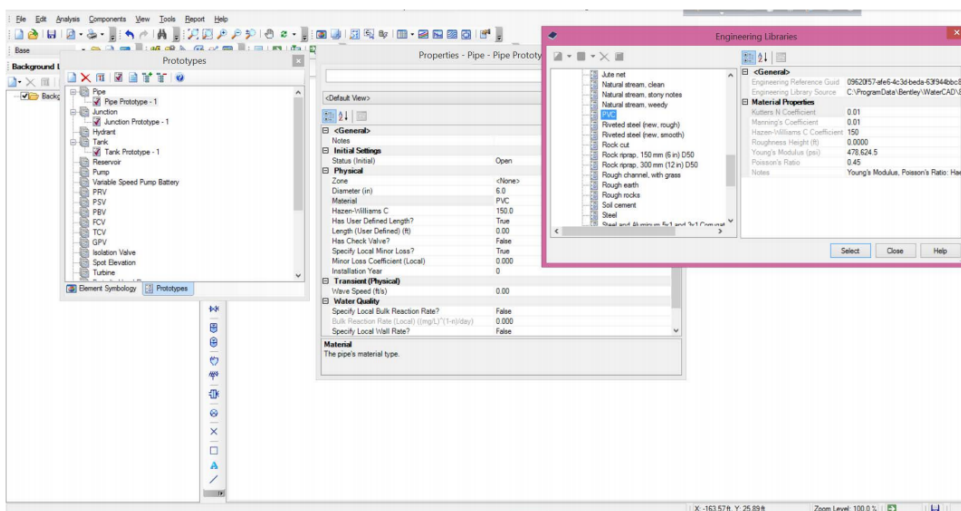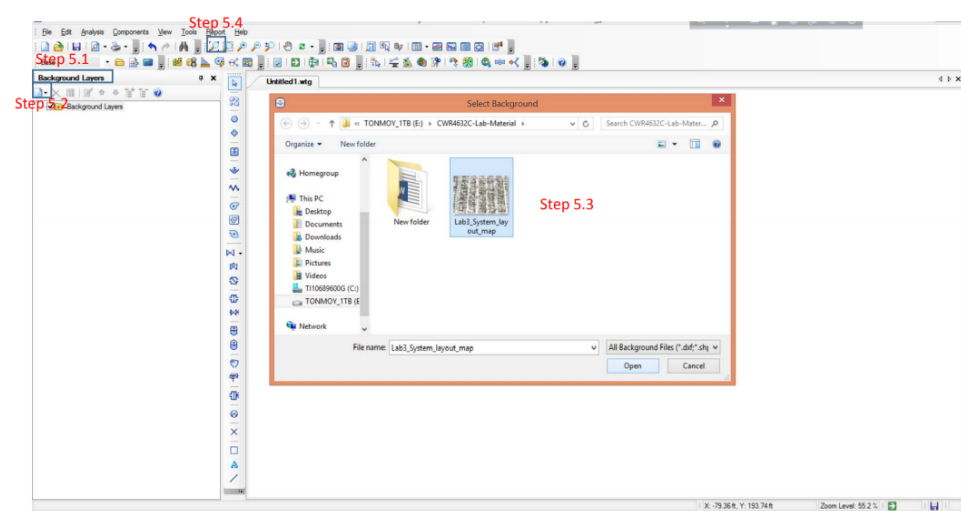


Figure 6: Step 3
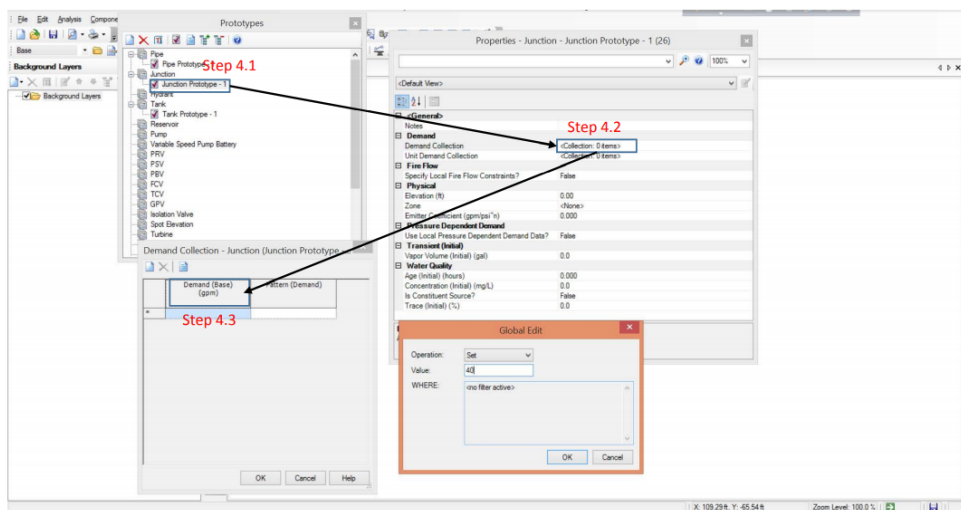


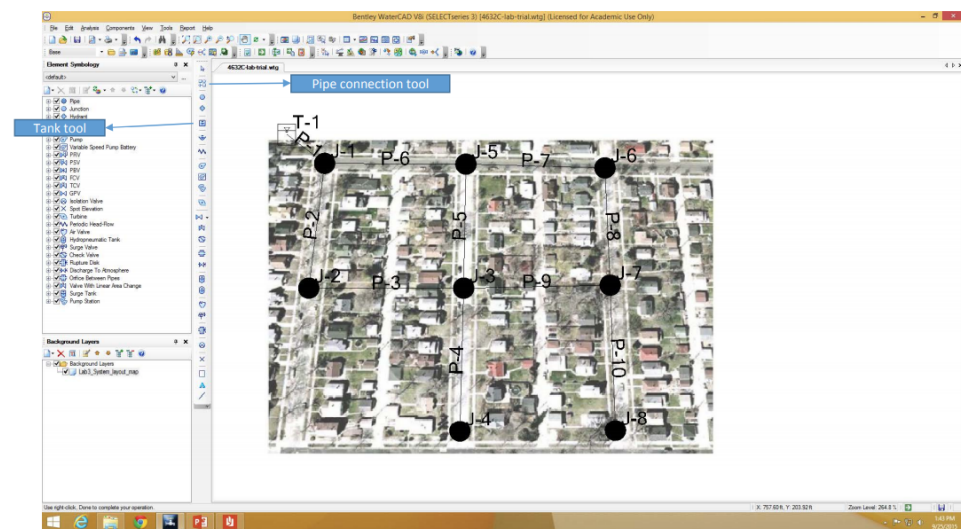Figure 7: Step 4a
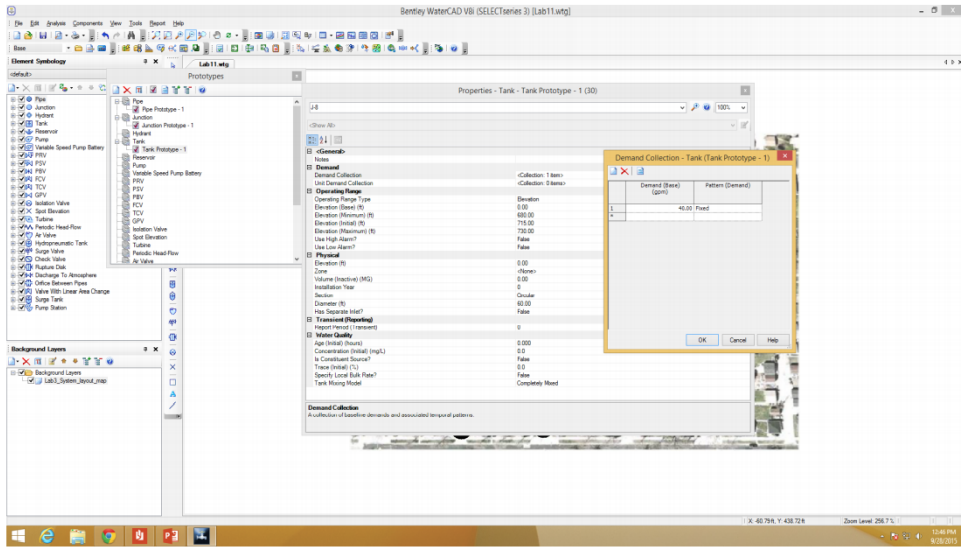
Figure 8: Step 4b
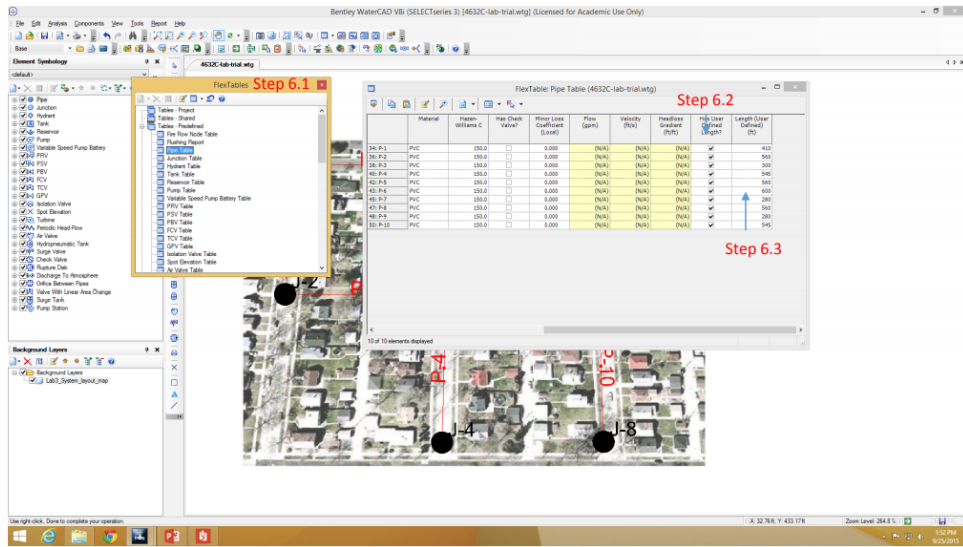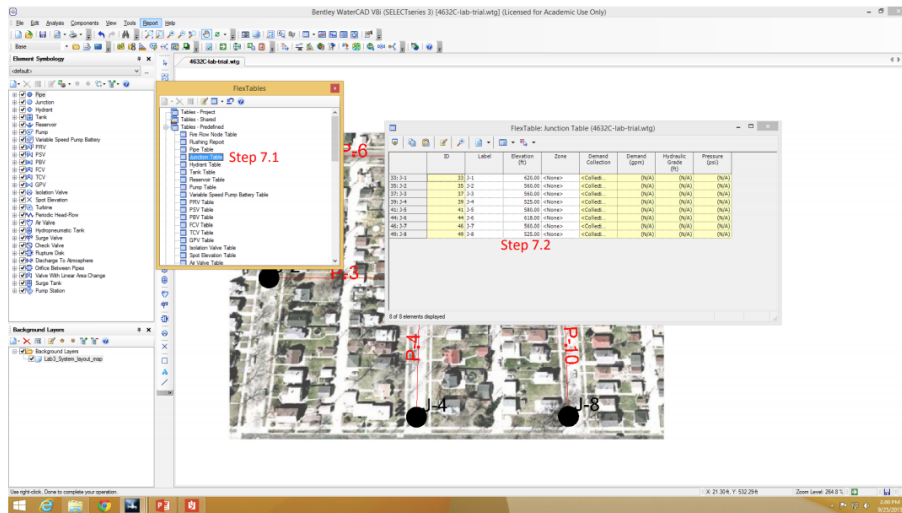


Figure 9: Step 5a



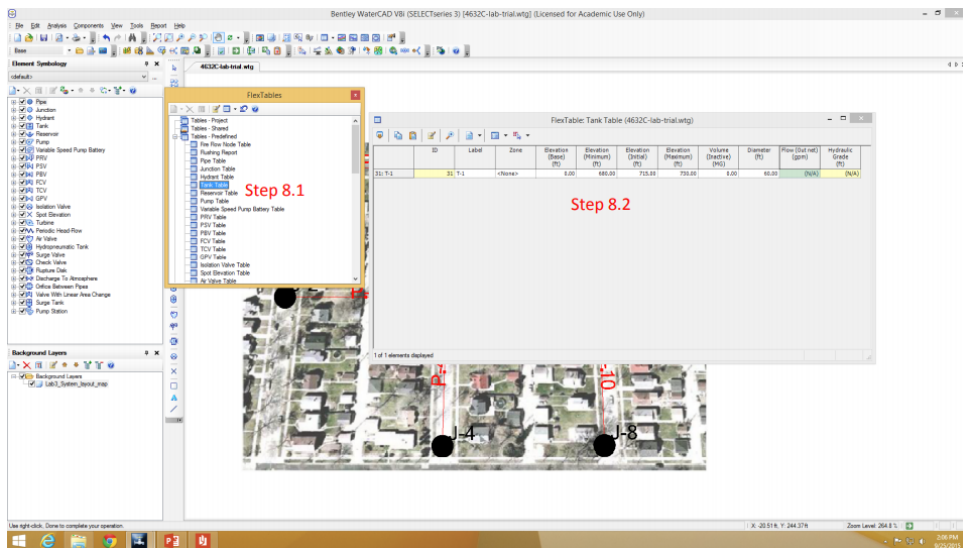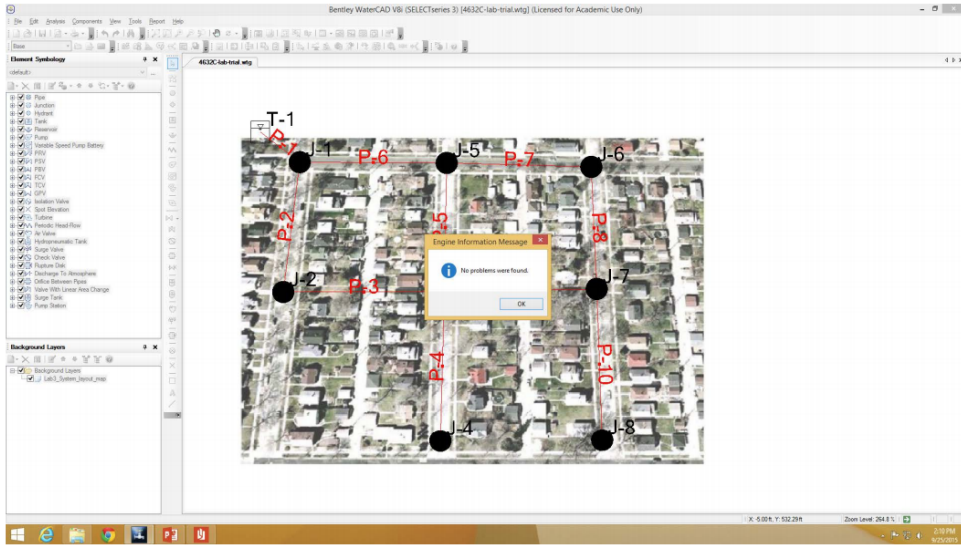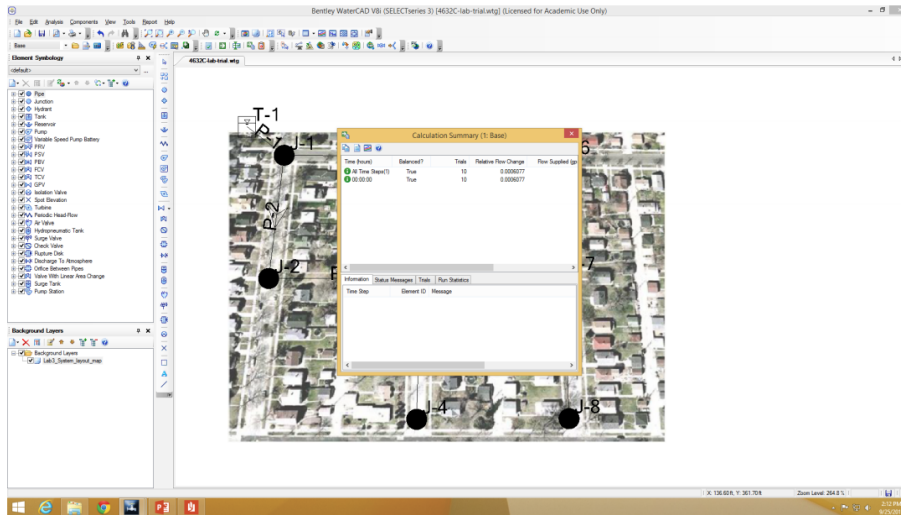Figure 10: Step 5b

Figure 11: Step 6



Figure 12: Step 7



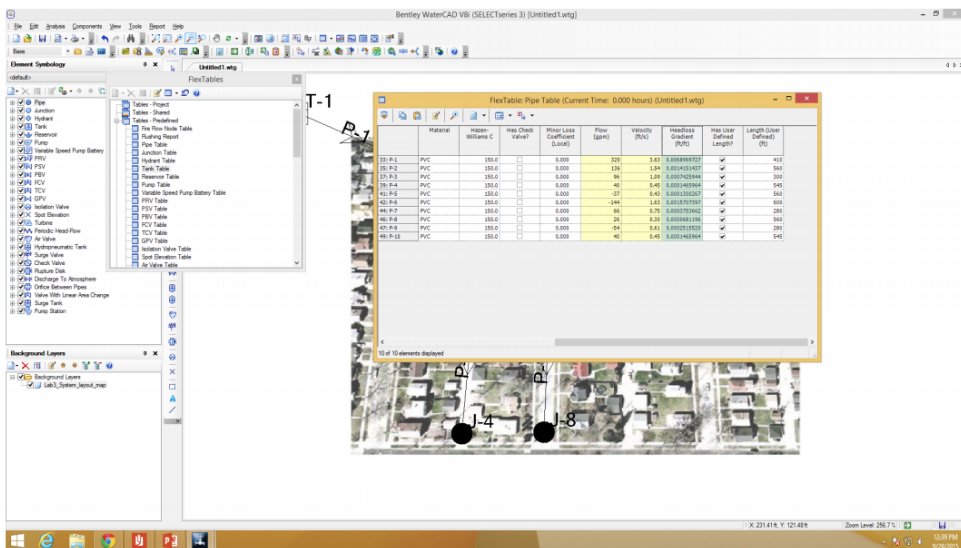Figure 13: Step 8

Figure 14: Step 9



Figure 15: Step 10



Figure 16: Step 11