WATER DISTRIBUTION SYSTEM ANALYSIS AND DESIGN FOR CROSBY, TEXAS

TEAM [redacted]

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EXECUTIVE SUMMARY

A water distribution network for a residential development in Crosby, Texas within Harris County has been designed. The distribution network satisfies demand across the development and adequate fire protection by the use of fire hydrants.

The analysis was completed by first determining parameters including minimum and maximum allowable flow pressures, elevations at each junction, and minimum pipe diameters depending on the number of junctions. The demand pattern used reflected average daily usage for typical Americans while the Hazen-Williams C value was assumed. Based on these assumptions and additional research, a model was generated in Environmental Protection Agency NET (EPANET), a software program that can be used to create and analyze closed conduit systems. Using EPANET, pressures, velocity, and flow rate were generated within pipes and junctions.

INTRODUCTION

Project Name and Purpose

The purpose of the "Newport Water Distribution System and Analysis for Crosby, Texas" is to create and analyze a water distribution system that can meet the demands of residents of single-family homes as well as of fire hydrants, using EPANET.

The objectives are to meet demand across the development, which means the water requirements of the development need to be met; and provide adequate fire protection to the newly annexed area, by providing enough water flow pressures in pipes.

Project Limits

The proposed development is located in Crosby, TX in Harris County within a neighborhood called Newport. The proposed development would be an addition to the Newport neighborhood bounded by N Diamondhead Blvd and Golf Club Dr, seen below in Figure 1.

Figure 1. Project limits in Crosby, Texas

Assumptions and Constraints

The limits of the project include: pressures of water flow inside the pipe must be between 35 psi and 80 psi under normal conditions with a maximum allowable velocity at peak house demand of 8 feet per second (fps) (Chanslor 2011), a minimum of 6 inch diameter pipes for less than 250 connections and 8 inches for more than 250 connections, and a minimum pressure of 20 psi for residual fire flow (Baker 2012). The minimum amount of backfill for pipes with a 12 inch diameter or smaller is 4 feet from the top of curb, with 3 feet absolute minimum (Lincoln).

To design the proposed development, some assumptions had to be made. The number of fire hydrants was assumed to be 28, due to each hydrant being spaced approximately 500 feet apart (Standard). The average demand was calculated to be 164 gcpd (gallons per capita per day) based on the average population and water use demand in Harris County (Pate 1987), so 200 gcpd was assumed to allow room for a greater capacity. Assuming Crosby, TX is generally a suburban area, the average number of residents per household is 3.10 (Houston 2014), thus 3.5 residents per household was assumed to account for possible increase in changes in population. The proposed development is assumed to be completely undeveloped, but lot lines have already been laid out, therefore lots were counted and 409 lots were assumed (Newport 2015). The lowest and highest elevations within the proposed development were assumed to be 39 and 50 feet respectively, based on previous surveys of the land.

A third party company does the pavement and construction, thus no costs are assumed for those portions of the project.

EXISTING CONDITIONS

Location and Topography

The proposed development is a neighborhood within Crosby, Texas located in southeast Texas in Harris County as seen in Figure 1. The topography is relatively level to gently undulating with elevations in the proposed development ranging between 39 ft and 50 ft. The slope from the most southwest corner to the most northeast is 0.161%. The slope from the most southwest corner to the highest elevation, which would be the northeast corner, is 0.301%. These values have been determined by the elevation of the nodes, shown in Figure 3, and the linear distance between them.

Land Use

The current land use for the proposed development is currently forestland. It is undeveloped and is covered by trees, bushes, and thick grass. The soil is mostly clay loams and clays.

HYDRAULICS

Analysis Objective

Using EPANET, a water distribution system for the proposed development was designed to meet the necessary flow demand and pressure requirements. For this subdivision of 409 residential homes, a single water line entering the subdivision from the southwest must provide adequate water pressure and flow at any given moment during the day, including fire flow during peak usage.

Hydraulic Methodology

EPANET allows the user to create a model using junctions and links that can be adjusted to fit design requirements. Data, including elevation, base demand, and pipe length and diameter, can be inputted into the model in addition to components, such as pumps, reservoirs, and valves, in order to calculate outputs such as flow and pressure.

The first step to creating the model was to set the defaults, which in this case were: the use of the Hazen-Williams loss model, units of gallons per minute, a diameter of 10 inches for the pipes, and a roughness coefficient of 100.

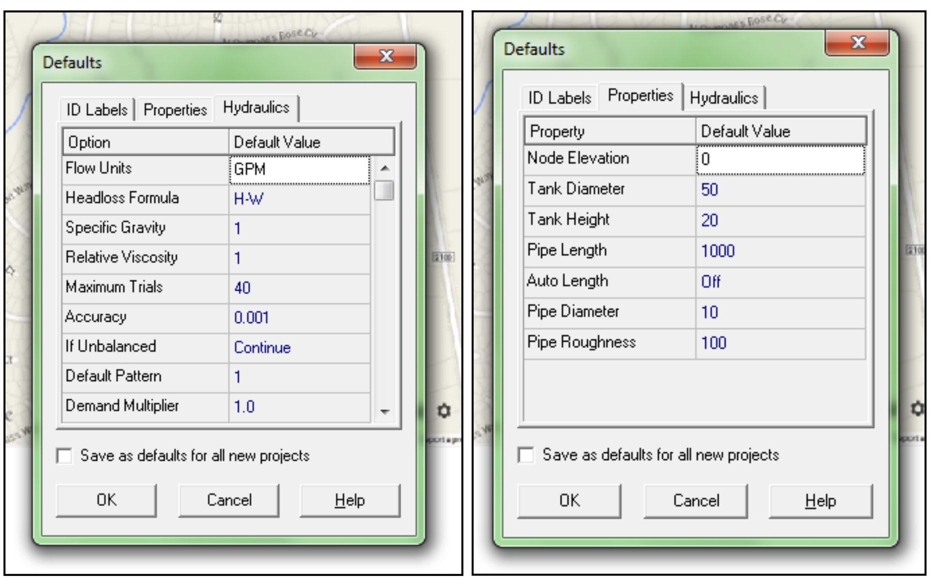

Figure 2. Defaults for EPANET Model

In order to create the model, an image of the proposed development was saved as a bmp file and then uploaded as a background. The image allowed the design engineers to draw the water distribution system using the planned roadways and house lots as guidelines. The first step in drawing the model was to input a reservoir, which acted as the source of water for the development. In this case, the source was the Luce Bayou, which entered the subdivision from the southwest and had an elevation 46 feet below the lowest elevation in the subdivision. In order to determine the lowest elevation in the subdivision, a topographical map created from prior surveying was used from which an elevation of 39 feet was found. Therefore, the elevation for the reservoir was inputted as -7 feet. The elevations for each node can be seen in Figure 3.

The next step to creating the model for the water distribution system was to determine where nodes or junctions would be located. The water necessary to meet the demand for the houses comes from these nodes, and they also serve as turning points since pipes are not curved but some streets are. Using the image of the proposed development, nodes were placed at approximately every seven houses and at road intersections, as every house does not require a node and the node should not be overloaded. The layout of pipes and nodes is shown in Figure 9. The subdivision was then divided in order to determine which nodes would serve which houses. This grouping of houses according to node entered in EPANET can be seen on Figure 4.

The locations of the fire hydrants was based on the hose length, therefore they were dispersed about 500 feet apart throughout the subdivision. A total of 28 hydrants for the neighborhood have been established. They are marked by a red circle on Figure 4. Each hydrant serves approximately six houses.

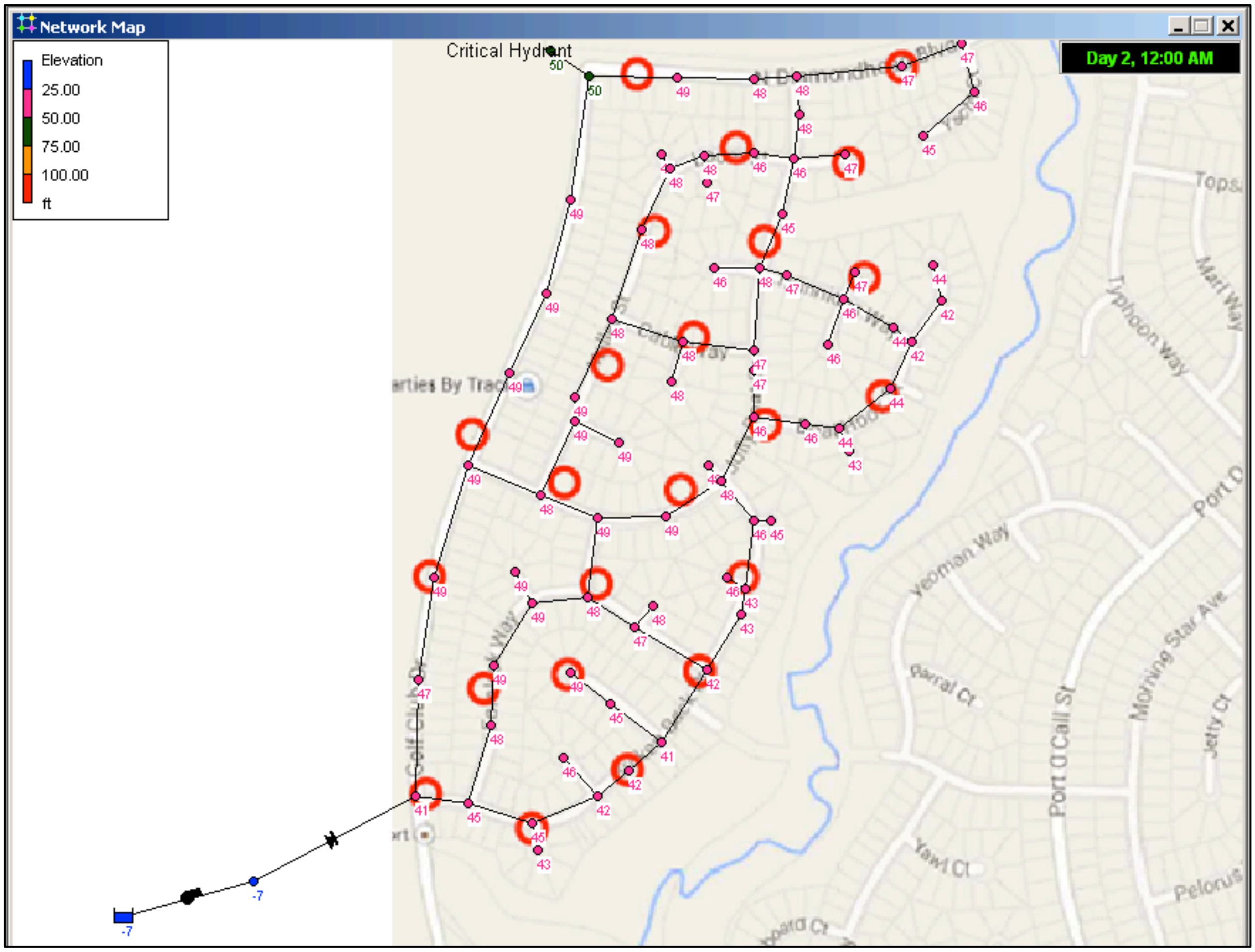

Figure 3. Node Elevations

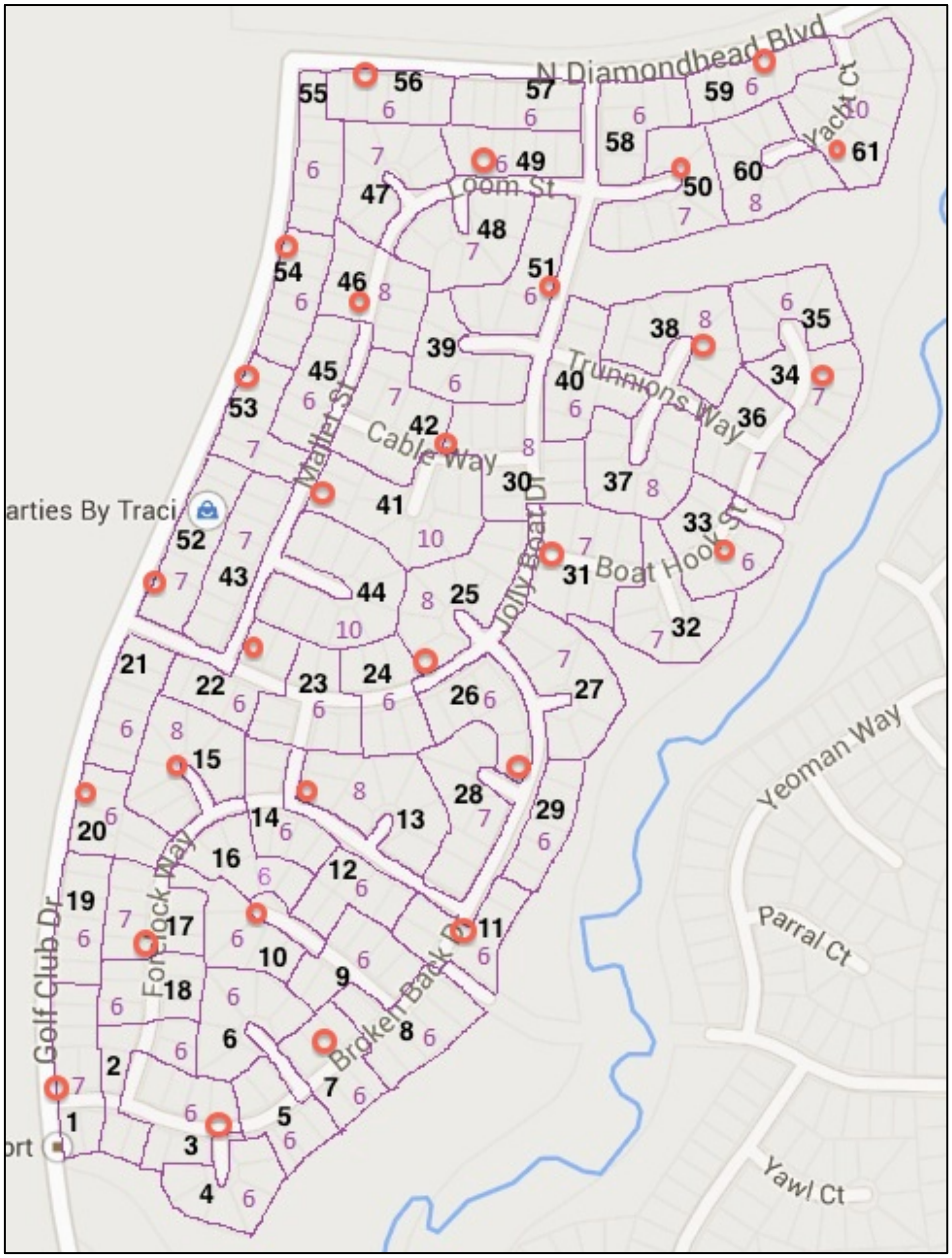

Figure 4. Houses to Corresponding Nodes with Fire Hydrants

It was estimated that each person uses approximately 200 gpd and each house has an average of 3.5 people living in it. With the number of residential homes, this means there is an estimated demand of 286,200 gpd for the entire subdivision. In order to determine the demand for each node, the number of houses it served was multiplied by the number of people per house and the amount of water each person used per day. These calculated demands were inputted as base demands for each node. If a node did not serve any houses and acted only as a junction between pipes, the base demand was entered as zero. These base demands are shown in Figure 5. Additional information needed for the nodes was the elevation of each node, which was determined using a topographical map, and inputted at each node. Values are shown in Figure 3.

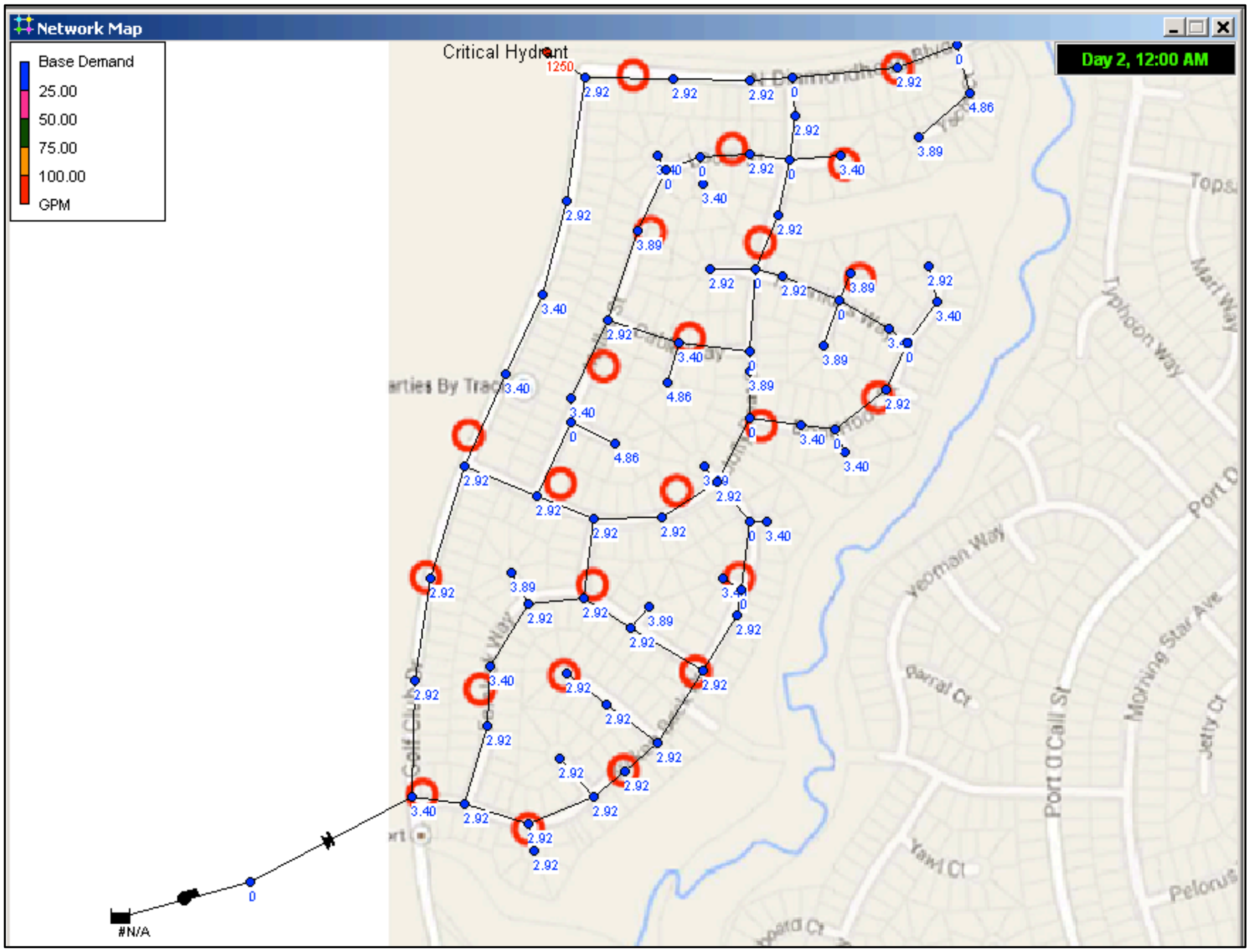

Figure 5. Base Demands as Entered in EPANET

The next step was to determine the length of the pipes connecting the nodes. These distances were estimated using the distance measurement tool on Google Maps. The distances determined by this process are shown in Figure 6.

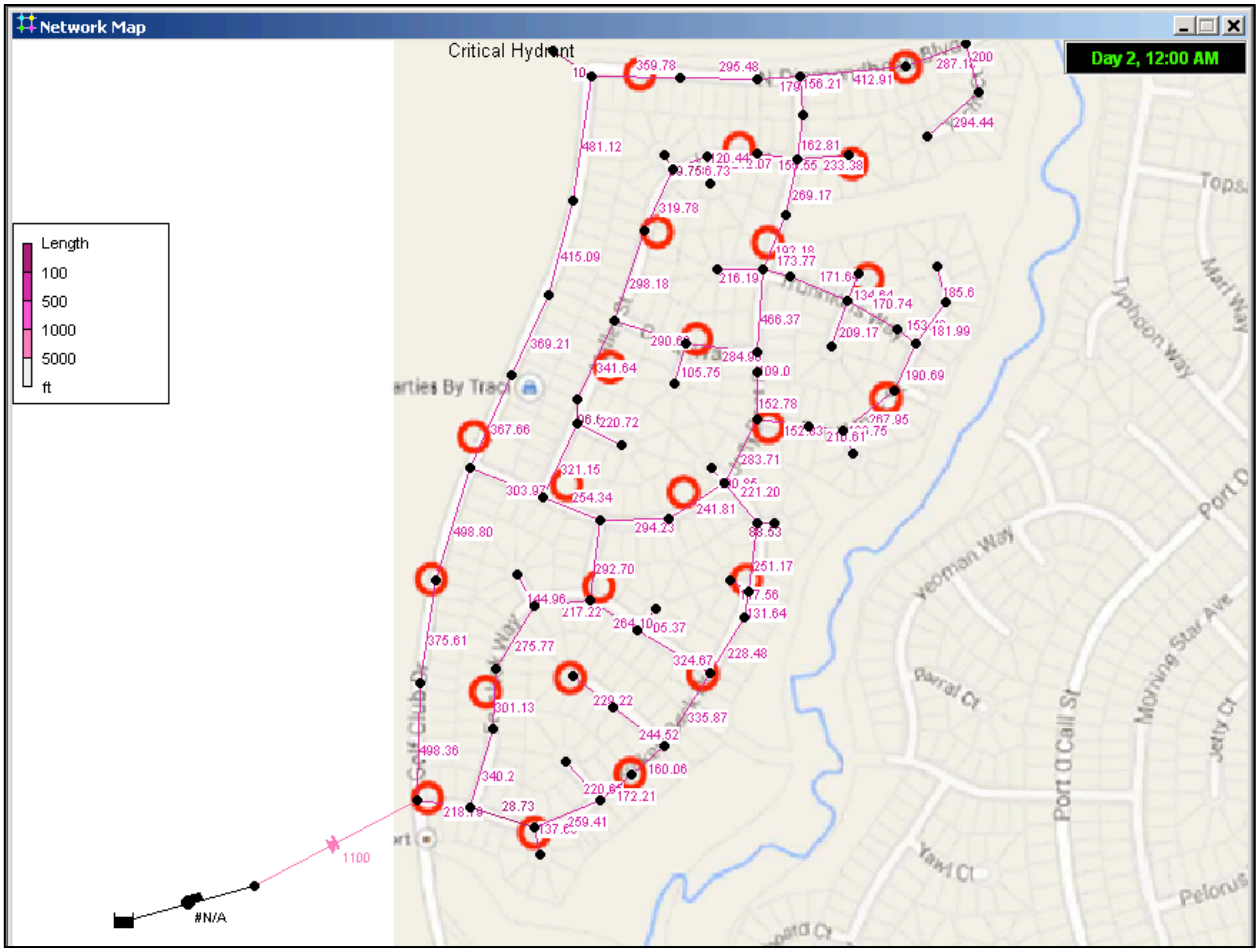

Figure 6. Pipe Lengths

Since the elevation of the reservoir was below the elevation of the development, a pump was included in the design. As pumps are links in EPANET, a node was placed outside of the development and the pump was connected between the reservoir and this node. The elevation at this node was equal to that of the reservoir, -7 ft, and the base demand was zero. In order to connect the pump to the subdivision, a pipe with a diameter of 12 inches and a length of 1100 feet was used, according to the distance from the Bayou to the subdivision. Pump curves were created using given performance curves from Cornell Manufacturing Company and were linked to the distribution model in order to run the program and observe each pump's performance.

As previously stated, the pressure in the pipes must be between 35 and 80 psi at all times of the day to maintain proper functionality and prevent contamination of water or breaches. This is assuming there are no fires. Target pressures in the distribution lines are between 50 and 65 psi. Also, velocity of water in the pipes should not exceed 8 fps to prevent pipe degradation.

In order to retain the water pressure at required levels and keep the water from flowing backwards, a check valve was added to the model. To do this, the pipe connecting the pump to the neighborhood was selected and the Initial Status was changed to CV. The setup of this valve relative to the pump and reservoir is shown in Figure 7.

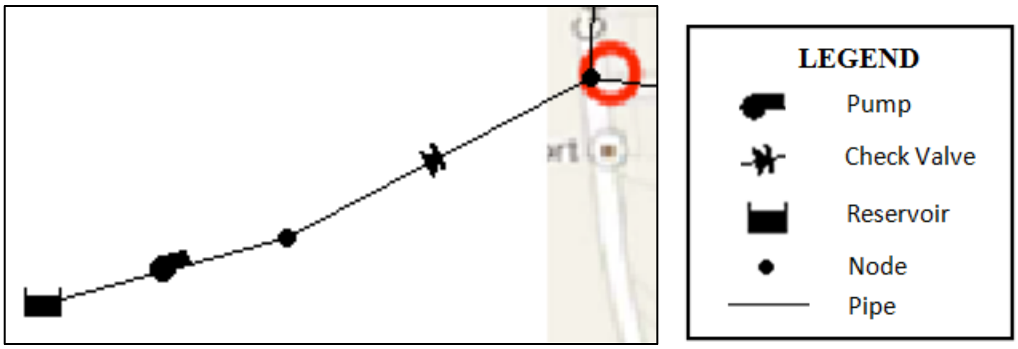

Figure 7. Reservoir, Pump, and Valve System

A pattern for water usage during different times of the day was established based on the likelihood of people using water for that set time. To illustrate, there is much less water demand at 2 AM, because most residents will be sleeping. However in the afternoon, around 7 or 8 PM, demand increases because most residents are doing things around their homes that require water. This pattern is represented in Figure 8. These peak factors are the percentage of the average demand for that hour of the day.

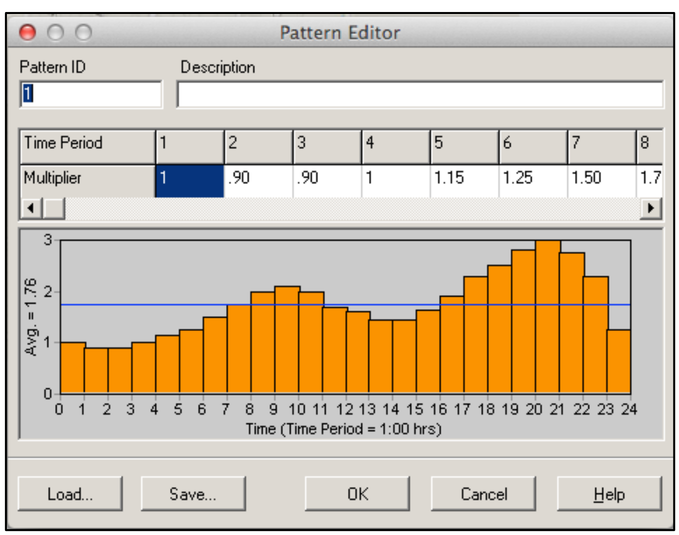

Figure 8. Demand Pattern

It was necessary to model fire flow for the neighborhood to ensure that proper pressures would be maintained. Fire flow at every node at all times of the day was not needed, since it would be highly unlikely that the whole subdivision would be on fire and that it would take a full day to put out. Fire demand was therefore modeled for the hydrant placed furthest away and at the highest elevation. The location of this “critical hydrant” can be seen in the top left corner of the system layout as it is shown in Figure 3.

The demand at this critical hydrant was modeled by standard fire flow criteria using a class factor of 1.5 for wood frame construction in the neighborhood, an estimate of the total square foot area of the largest floor in the building, and a percentage of the total area of the other floors. The average fire flow demand was found to be 1250 gpm for this subdivision. The system was tested with a fire at this location, and with the regular hourly demands at each node.

RESULTS AND RECOMMENDATIONS

Description

The basic network of proposed pipes for the area can be seen below in Figure 9.

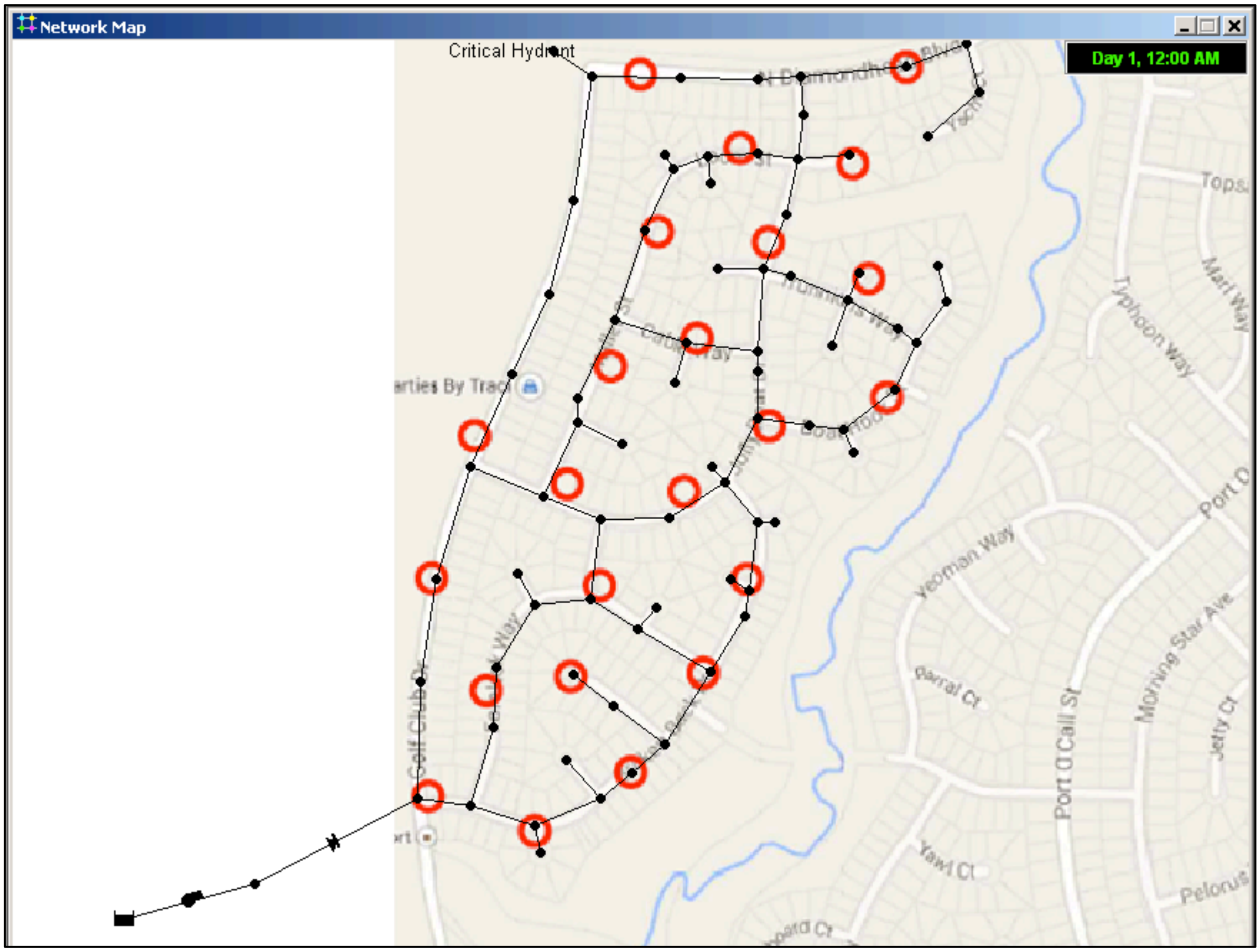

Figure 9. Proposed Pipe Setup

As stated, they are set up to follow the places were roads will be built to facilitate any necessary maintenance. A total of 79 junctions and 85 pipes will be used as described in the cost estimation portion of the report. The red circles on Figure 4 mark the location of the 28 fire hydrants, which will be spread throughout the neighborhood.

The pump chosen was a design by Cornell Manufacturing Company; the model was 5RB-D. This allowed for the smallest pressure to be 23.16 psi at the location of the critical hydrant twenty hours into the simulation if there is a fire that needs to be put out. The smallest pressure would be 60.17 psi, also at that node, without a fire in the neighborhood. As can be seen by the demand pattern shown in Figure 8, this time, around 8 PM, is when the greatest demand on the system takes place. These lowest pressure values are both above the minimum required pressure; therefore pressure will be sufficient for the daily demand as well as for possible fire requirements. The pressures at each node during this hour of highest demand are show below in Figure 10 and Figure 11.

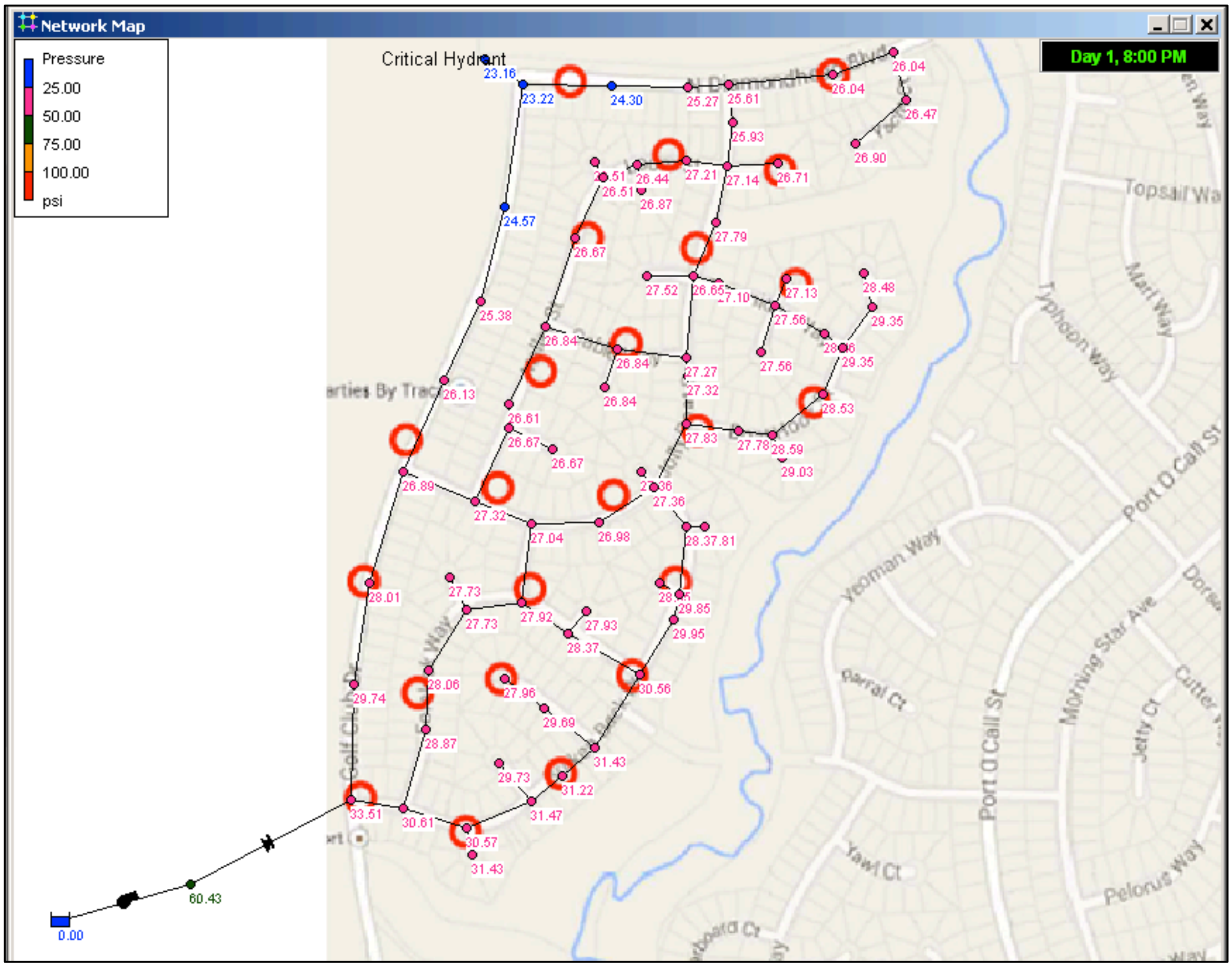

Figure 10. Smallest Pressures with Fire Flow Requirement

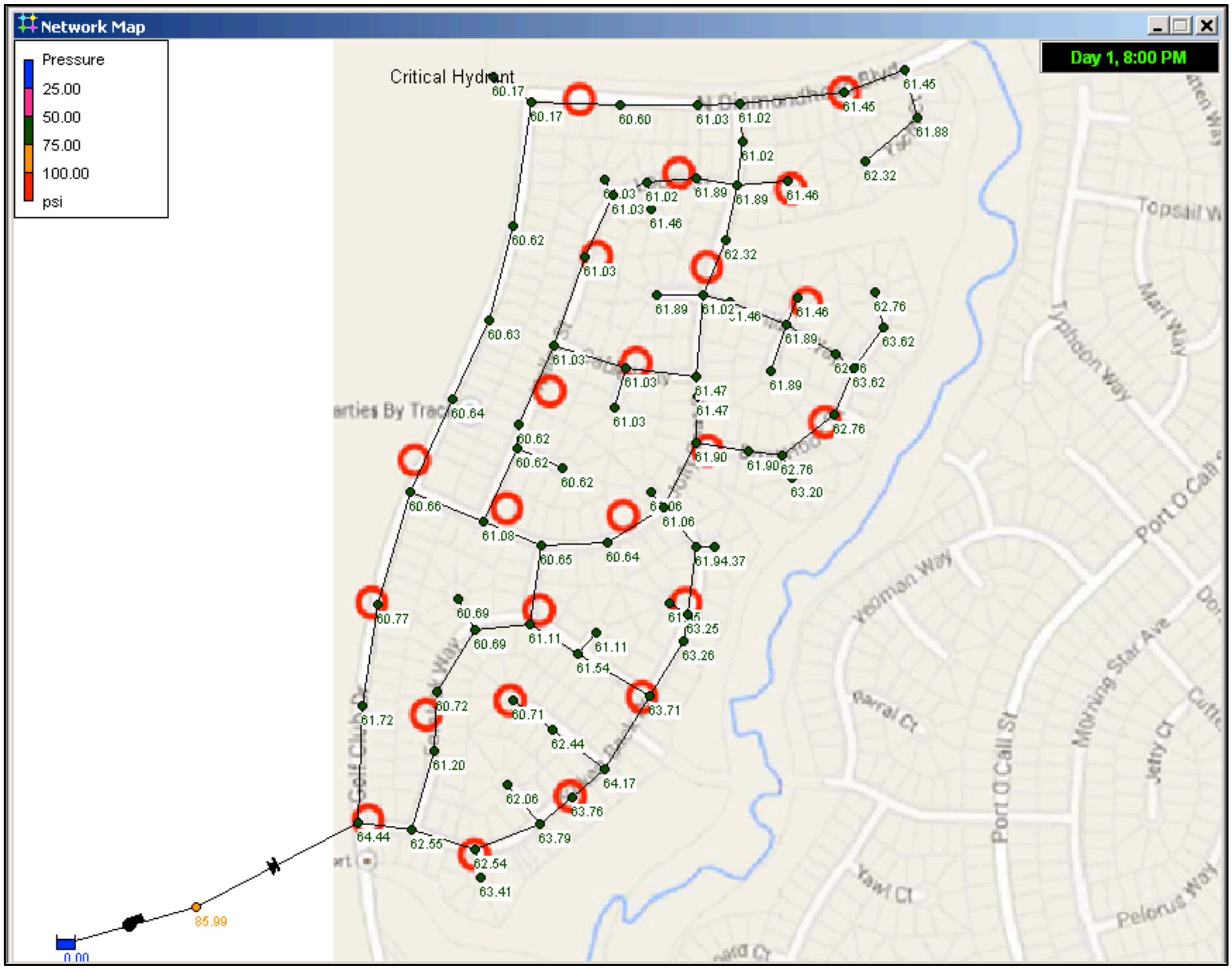

Figure 11. Smallest Pressures without Fire Flow Requirement

The simulations showed that the largest pressure in the pipe system would be 50.65 psi, at the node closest to the pump, for a situation that required fire flow. The highest without a fire requirement would be 65.77 psi at the same location. These high pressures both occur around 2 AM when, as can be seen on the demand pattern in Figure 8, the residents of the neighborhood would use very little water. These largest pressure values are both below the maximum allowable pressure for the pipe system; therefore no damage will be inflicted on the system. The pressures at each node during these hours of low demand are displayed in Figure 12 and Figure 13.

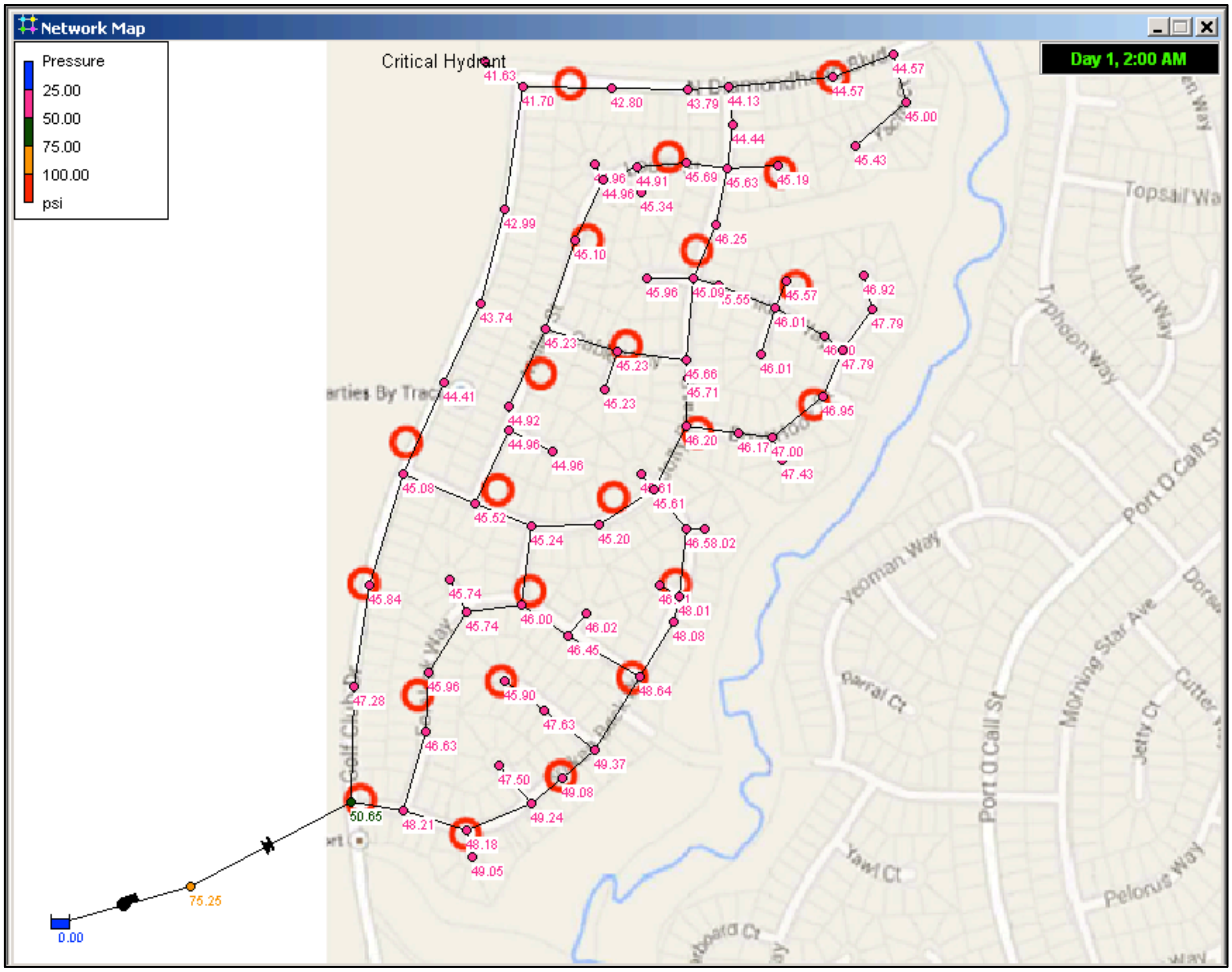

Figure 12. Largest Pressures with Fire Flow Requirement

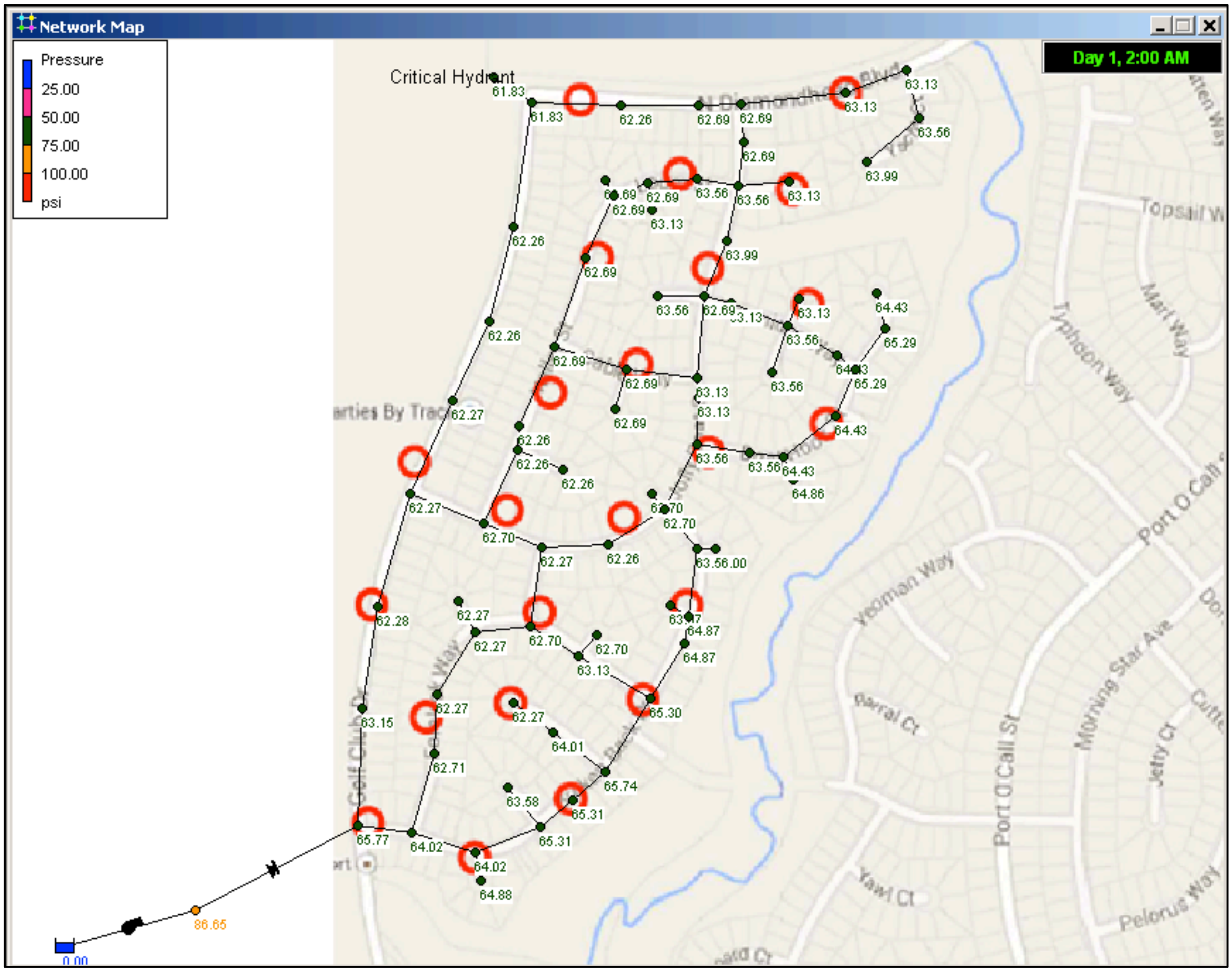

Figure 13. Largest Pressures without Fire Flow Requirement

Hydraulic Analysis

For the proposed system, the pressure at the pump and details of the pipe can be found in the table in the Appendix of this report. This represents both situations that were modeled with EPANET: with a fire flow requirement in the neighborhood and without.

The pump pressure remains steady throughout the day and sufficient discharge and flow is supplied to the system to accommodate the variant amount of water usage and maintain pressures within the range required.

It should be noted that water pressure and velocity are highest at this point of the system. This is expected due to the fact that all the water from the reservoir is being pushed through this node and pipe before it is dispersed throughout the system. The higher pressures at this location, along with the control valve in case of flow disruption, prevent backflow of the system.

Recommendations

For the proposed project, the pipes should follow the path of the roads in the neighborhood, with their respective length as seen on Figure 6. These pipes should all be of a 10-inch diameter, with the exception of the pipe with the valve, which will have a 12-inch diameter. The valve suggested is model 12-33F-CB2 by Newco. There will be 28 hydrants in the area, as marked by red circles on Figure 4. The pump recommended for this layout is by Cornell Manufacturing Company, model 5RB-D. These choices ensure proper function of the system in Harris County, since all requirements are met.

Cost Analysis

The total land area is 121 acres. Purchasing the land will cost approximately $18,500 per acre. It will have to be cleared and grubbed, which will cost approximately $4,500 per acre since it is a heavily wooded area.

Excavating will cost $42 per linear foot and backfill will cost $7 per linear foot.

The 10-inch diameter pipes will cost $88 per linear foot and the 12-inch diameter pipe will cost $128 per linear foot. Pipe lengths for the distribution system are shown in Figure 6. A Swing Check Valve made of carbon steel will be used. This valve is model 12-33F-CB2, designed by Newco, and has a 12-inch diameter. The cost for this valve is $4,327.32.

Hydrants used for the subdivision will be Clow Medallion F2545 Fire Hydrant (AWWA - ULFM). As previously stated, there will be a total of 28 each priced at $4,592. The trench depth for the hydrants should be six feet.

The pump chosen for the system is Cornell Pump Co.'s model 5RB-D. It will cost $7,500.

The cost of pavement was not included in this analysis because that is to be subcontracted out.

Overall, the project will require funds of $7,591,300.

Table 1. Preliminary Cost Estimate

LAND					
	Description	**Unit**	**Qty.**	**Unit Cost**	**Total Cost**
	DEVELOPMENT AREA	AC	121	$18,500.00	$2,238,500.00
	Subtotal Development Area				**$2,220,000.00**
	CLEARING AND GRUBBING	AC	121	$4,500.00	$544,500.00
	Subtotal Clearing and Grubbing				**$544,500.00**
	EXCAVATION	LF	20,374	$42.00	$855,708.00
	Subtotal Excavation				**$855,708.00**
	BACKFILL	LF	20,374	$7.00	$142,618.00
	Subtotal Backfill				**$142,618.00**
UTILITIES					
	Description	**Unit**	**Qty.**	**Unit Cost**	**Total Cost**
	WATER SUPPLY:				
	10-inch Waterline	LF	19274	$88.00	$1,696,112.00
	12-inch Waterline	LF	1100	$128.00	$140,800.00
	Check Valve		1	$4,327.00	$4,327.32
	Fire Hydrants		28	$4,592.00	$128,576.00
	Pump		1	$7,500.00	$7,500.00
	Subtotal Water Supply				**$1,977,315**
				SUBTOTAL	$5,740,100
				Contingencies (15%)	$861,000
				Engineering (15%)	$990,200
				TOTAL	**$7,591,300**

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APPENDIX

Appendix A. Pump and Pipe Measurements

Appendix A. Pump and Pipe Measurements

Hour	With A Fire Flow Requirement			Without A Fire Flow Requirement		
	Pump	Pipe		Pump	Pipe	
	Pressure (psi)	Flow (gpm)	Velocity (fps)	Pressure (psi)	Flow (gpm)	Velocity (fps)
0:00	74.73	1448.90	4.11	86.64	198.90	0.56
1:00	75.25	1429.01	4.05	86.65	179.01	0.51
2:00	75.25	1429.01	4.05	86.65	179.01	0.51
3:00	74.73	1448.90	4.11	86.64	198.90	0.56
4:00	73.91	1478.73	4.19	86.63	228.74	0.65
5:00	73.35	1498.63	4.25	86.62	248.63	0.71
6:00	71.86	1548.35	4.39	86.59	298.35	0.85
7:00	70.26	1598.08	4.53	86.54	348.08	0.99
8:00	68.54	1647.80	4.67	86.48	397.80	1.13
9:00	67.82	1667.69	4.73	86.45	417.69	1.18
10:00	68.54	1647.80	4.67	86.48	397.80	1.13
11:00	70.59	1588.13	4.51	86.55	338.13	0.96
12:00	71.23	1568.24	4.45	86.57	318.24	0.90
13:00	72.17	1538.40	4.36	86.60	288.41	0.82
14:00	72.17	1538.40	4.36	86.60	288.41	0.82
15:00	70.91	1578.19	4.48	86.56	328.19	0.93
16:00	69.24	1627.91	4.62	86.51	377.91	1.07
17:00	66.32	1707.47	4.84	86.38	457.47	1.30
18:00	64.74	1747.25	4.96	86.29	497.25	1.41
19:00	62.22	1806.92	5.13	86.13	556.92	1.58
20:00	60.43	1846.70	5.24	85.99	596.70	1.69
21:00	62.65	1796.97	5.10	86.16	546.98	1.55
22:00	66.32	1707.47	4.84	86.38	457.47	1.30
23:00	73.35	1498.63	4.25	86.62	248.63	0.71
24:00	74.73	1448.90	4.11	86.64	198.90	0.56