WATER DISTRIBUTION SYSTEM RELIABILITY STUDY

CITY OF MARINE CITY
ST. CLAIR COUNTY, MICHIGAN

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1.0 EXECUTIVE SUMMARY

The purpose of this Water Distribution System Reliability Study is to determine the water system's capabilities, identify deficiencies within the system, and develop a list of recommendations to improve the water system for Marine City. As part of the Reliability Study update, a hydraulic network model of the City's water system was created to account for the entire distribution system and to accurately simulate the existing flows and characteristics of the system. The model was then used to identify specific deficiencies in the system, examine future demands, and develop recommendations to improve the system based on requirements set forth in this report. This report will assist the City in verifying that future improvements to the water system will adequately address the present and projected needs of the system. It will also serve as a resource for planning future development and expansions to the water distribution system.

Marine City obtains their water through an intake station at the St. Clair River. This water is pumped to a water treatment plant (WTP) that is located on the southeast corner of South Water Street and Jefferson Street. The water is filtered and chemically treated to eliminate or reduce contaminants to safe levels before it is pumped into the distribution system.

The existing distribution system consists of approximately 28 miles of water main that range from 1 inch to 16 inches in diameter. The water system consists primarily of 4-inch, 6-inch, and 8-inch mains along residential streets, and 10-inch, 12-inch, and 16-inch pipe along the arterial roads. The water main installed over the past three decades has been primarily ductile iron pipe, consisting of approximately 95% of the entire system, while much of the other pipe throughout the system is asbestos cement (transite) pipe. Also, some PVC and HDPE pipe have been installed over the last 20 years.

The hydraulic network analysis reflects the w`ater consumption throughout the system for 2019. The water demands incorporated into the model account for billed water use and unaccounted for water that may occur due to pipe losses, fire flow use, customer meter inaccuracies, and unauthorized consumption. Water use data was determined from City billing records and WTP reports. The average water use was determined by calculating the average daily amount of water delivered to the City during 2019. The minimum pressure requirements are based on the Michigan Department of Environment, Great Lakes, and Energy's (EGLE) generally accepted Ten States Standards for Water Systems. Fire demand requirements are based on the recommendations of Wade Trim.

Projections for future water needs throughout the system are based on estimates of population growth and projected future developments. The Southeast Michigan Council of Governments (SEMCOG) has predicted a 6.6% decrease in Marine City's population (from 2020 to 2045). Since there are no large future developments planned, the projected water use was spread uniformly throughout the water system.

The above information was used in developing the hydraulic network model to accurately simulate flow characteristics of the existing water distribution system in Marine City.

Information pertinent to the water distribution system was entered into the water network computer model. The accuracy of the model has been verified through the comparison of fire hydrant flow tests to computer simulations of the actual tests.

The computer model was then used to test the system's abilities to provide adequate fire flows and maintain system pressure requirements under average day, maximum day, and peak hour scenarios. The modeling indicated that pressures were maintained system-wide above EGLE's minimum requirement of 35 psi for each scenario. The pressures across the system hardly changed between the average day and peak hour scenarios. This can be attributed to the low demands in the system and the WTP and storage tanks' abilities to supply the necessary water demands.

Several areas throughout the City cannot currently deliver water flow that meets the recommended minimum fire flow requirements for the maximum day scenario. The locations that are not capable of providing required fire flows are all located on dead-end lines, many of which are undersized. The areas with the lowest available fire flows in the water system are generally serviced by four-inch diameter mains.

A list of 11 recommendations has been made for improving the City's water distribution system. The recommended improvement projects consider immediate, short-term, and long-term impacts, and are based on meeting minimum pressure and fire flow requirements, potential water quality issues, and overall reliability and redundancy of the system. Most of the recommendations are for upsizing undersized mains and looping dead-end lines to adjacent mains. These recommendations are further described in Section 7. The approximate present-day cost to complete all the improvements is $2,461,000.

2.0 INTRODUCTION

2.1 GENERAL

The City of Marine City is in southeastern St. Clair County in southeast Michigan. Marine City is bordered by East China and China Township to the north. To the south and west, the City is bordered by Cottrellville Township. On the east, the City is bordered by the St. Clair River. Two portions of Cottrellville Township are also within the borders of Marine City.

Marine City contains 2.2 square miles within its limits and has a population of 4,051 per SEMCOG records. The St. Clair River, which is a major commercial shipping channel that connects Lake Huron to Lake St. Clair, runs along the eastern border of the City.

The ground surface elevations in Martin City ranges from 575 feet along the St. Clair and Belle Rivers to 587 feet near the King Road and West Boulevard. The City generally experiences a rise in elevation from southeast to northwest.

2.2 PURPOSE

The purpose of this Water Distribution System Reliability Study is to develop a comprehensive model for determining the existing and future water systems' capabilities, identifying deficiencies within the system, and developing a list of recommendations to improve the water system for Marine City. This report is intended to assist the City in verifying that future improvements to the water system will adequately address the present and projected needs of the system. It will also serve as a resource for planning future development and expansions to the water distribution system. The Reliability Study meets the water system requirements of EGLE and complies with the Michigan Safe Drinking Water Act (PA 399).

The Safe Drinking Water Act requires ten-year projections of water use to be performed, evaluation of the existing water supply system for its ability to supply these needs, and identification of cost-effective system improvements to eliminate system deficiencies in the water supply system. In order to comply with these requirements, a hydraulic network analysis of the existing water distribution system was performed. The hydraulic network analysis included development of a comprehensive computer model of the City's water distribution system. The model was then used to evaluate the ability of the existing system to meet both the existing and future water demands of the system.

Several water distribution deficiencies were identified through the analyses and have been used to develop a list of future capital improvement projects. Future updates to the hydraulic network analysis are recommended every five years and more frequently if major changes in estimated system demands and/or improvements are made to the system. The computer model can be easily updated and utilized to address these future issues.

2.3 SCOPE

The scope of the Reliability Study consisted of eight major components. These components are summarized as follows:

1. Data Collection

   The City's water use records and WTP records were reviewed, analyzed, and organized for use in the Water System Model. Water billing records were obtained for 2019 and were compared with the corresponding WTP records.

2. Evaluate Source Water Pressure

   Supply pressures from the WTP and elevated the storage tank were evaluated and incorporated into the model.

3. Develop and Calibrate the Water Distribution System Model

   Using existing water system maps, water use records, and the United States Geological Survey (USGS) elevation data available, the water distribution system model was developed and calibrated. As part of the calibration effort, 19 hydrant flow tests were conducted throughout the water system.

4. Evaluate Water Use for Future Ten-Year Scenarios

   Using forecasted population projections, water use was estimated throughout the City for scenarios based on projected system conditions ten years into the future.

5. Run the Model for Existing and Future Water Uses and Identify System Improvements

   The calibrated model was run to evaluate the water system's ability to meet existing and future water needs. Average day, maximum day, peak hour, and maximum day plus fire flow scenarios were evaluated for existing and future conditions. System improvements were identified from these scenarios.

6. Develop Planning Level Cost Estimates for the System Improvements

Planning level cost estimates were developed for each system improvement. The improvements were also prioritized based on input from DPW personnel.

7. Review the Findings and Recommendations with the City

The findings and recommendations of the evaluation were shared with the City prior to releasing the final version of the report.

8. Submit Final Report to EGLE

The final report will be submitted to EGLE upon approval by the City.

Marine City

St. Clair County, Michigan

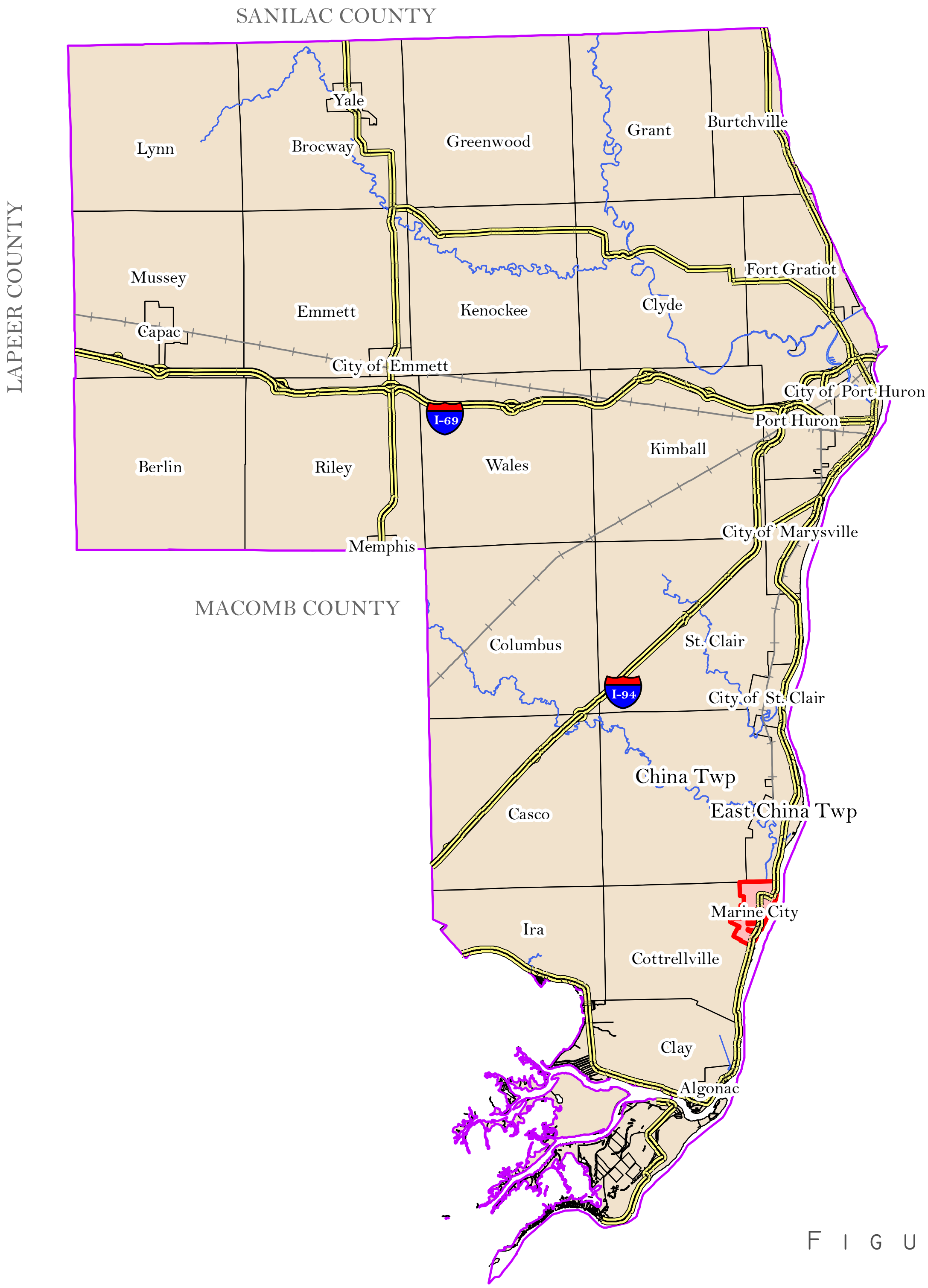

FIGURE I

0 15,000 30,000 Feet

LEGEND

- State Roads
- Railroad
- River
- St. Clair County
- Marine City
- Cities, Townships, Villages

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3.0 EXISTING WATER SYSTEM

3.1 WATER TREATMENT PLANT

The existing WTP was initially constructed in 1936 with an addition in 1968. The plant has also seen a rehabilitation in 2005, which modernized much of the facility. The Marine City WTP is built at an elevation of approximately 580. The current capacity of each element of the water treatment system are as follows:

- Intake: 4.25 MGD
- Raw water supply: Low service pumps total capacity 4.0 MGD, firm capacity 2.3 MGD
- Treatment process: Filter total capacity 2.1 MGD, firm capacity 1.4 MGD
- Finished water supply: High service pumps total capacity 3.2 MGD, firm capacity 2.0 MGD

Based on these rated elements of the treatment process, the firm capacity of the Marine City WTP is currently 1.4 MGD.

3.2 TRANSMISSION SYSTEM

Marine City's flow is delivered to the water distribution system via 12-inch and 10-inch mains branching off from the WTP. A 16-inch main also follows South Parker Street to supply the southern portion of the City. One 10-inch main and two 12-inch mains extend to East China Township where interconnects are placed in case of emergency or maintenance. These interconnects are typically closed.

3.3 DISTRIBUTION SYSTEM

The existing distribution system consists of approximately 28 miles of water main that range from 1 inch to 16 inches in diameter. The water system consists primarily of 4-inch, 6-inch, and 8-inch mains along residential streets, and 10-inch, 12-inch, and 16-inch pipe along the arterial roads. The water main installed over the past three decades has been primarily ductile iron pipe, while much of the older pipe throughout the system is asbestos cement (transite) pipe. Also, some PVC and HDPE pipe have been installed over the last 20 years.

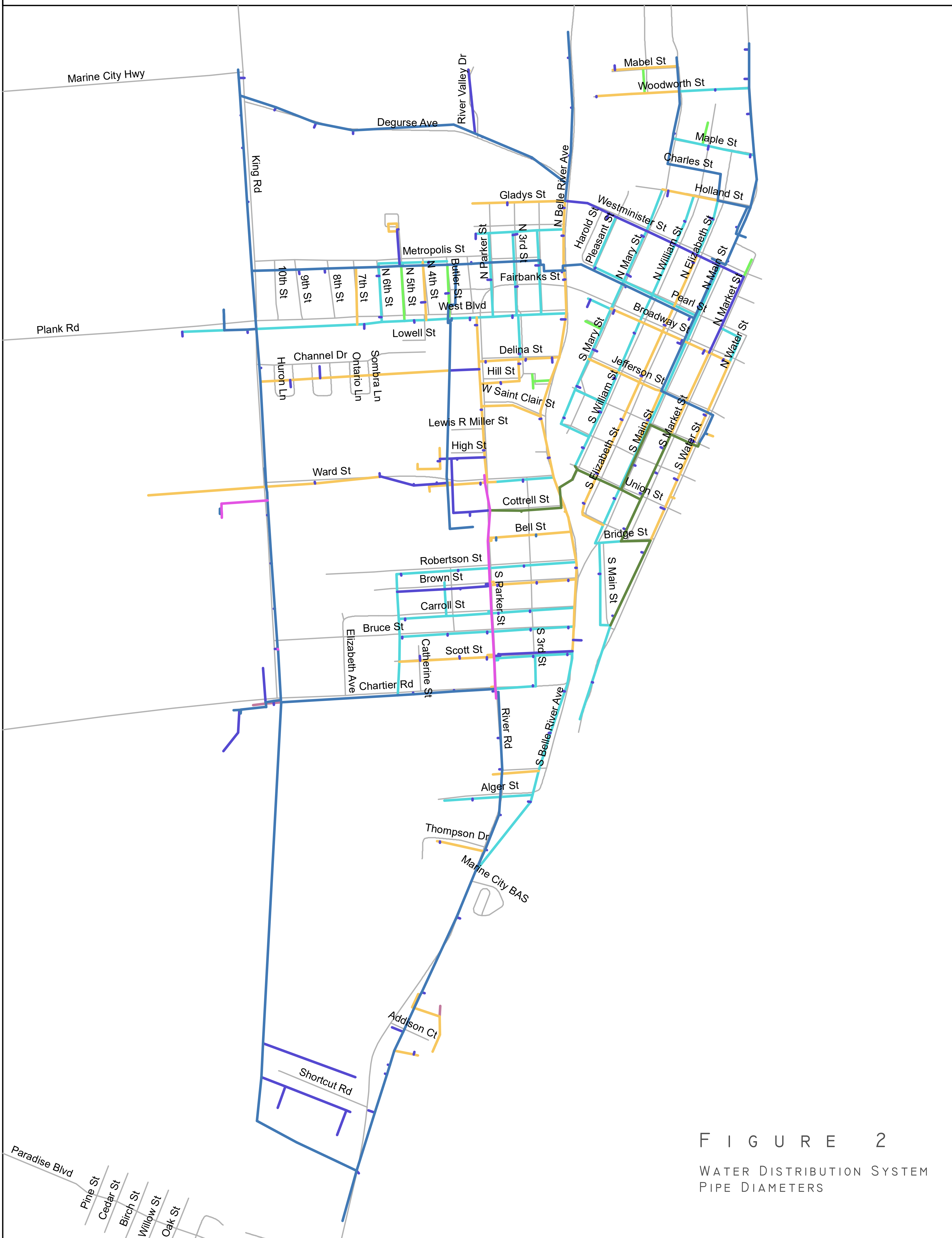
There are currently no valves known to be closed in the water distribution system; however, closed or partially closed valves may still exist throughout the system.

3.4 STORAGE TANKS

One water tower exists in Marine City which provides approximately 0.98 million gallons of water to the storage for the system. The water tower is approximately 127 feet in height with about 40 feet included in that is the head range for storage. The tower is also 64.67 feet wide.

Marine City

St. Clair County, Michigan



F I G U R E 2

WATER DISTRIBUTION SYSTEM
PIPE DIAMETERS

LEGEND

- Roads
- Railroad
- WTP Water Treatment Plant
- T Storage Tank
- River

Pipe Diameter

- 1-inch
- 2-inch
- 4-inch
- 6-inch
- 8-inch
- 10-inch
- 12-inch
- 16-inch

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F I G U R E 3

WATER DISTRIBUTION SYSTEM
PIPE MATERIALS

0.15 Miles

LEGEND

- Roads
- Railroad
- WTP Water Treatment Plant
- T Storage Tank
- River

Pipe Material

- Asbestos Cement
- Cast Iron
- Ductile Iron
- PVC or HDPE
- Steel

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Marine City

St. Clair County, Michigan

FIGURE 4

GROUND ELEVATIONS AND TOP WATER USERS

LEGEND

- Roads
- Railroad
- Water Main
- WTP Water Treatment Plant
- T Storage Tank

Ground Elevation (ft)

- 575 - 580
- 580 - 585
- 585 - 590

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4.0 WATER CONSUMPTION

There are several components that affect the distribution of water consumption within the water system. These components are water usage, system peaking factors, system losses, and fire protection demands. The proper representation of these components throughout the network is vital to the analysis. Each of these components is discussed in the following sections.

4.1 EXISTING WATER USE

Water billing records were obtained for Marine City for a three-year period from 2016-2019. Water demands were applied equally in each of Marine City's three billing sections. A portion of Cottrellville Township is also serviced by Marine City and a separate higher flow was applied at the intersection of Chartier and King Roads where Cottrellville is connected. Top water users were also obtained for Marine City, but upon analysis of the data had a negligible impact on the model so a uniform demand was utilized for each section.

4.2 FUTURE WATER USE

Water system hydraulic analyses typically extrapolate historical population growth as a method of estimating future water demands. Since no large future developments are planned within the water system network, the projected water use of future residents was the principal factor in determining future water use. The population of Marine City was 4,051, respectively, per 2020 SEMCOG estimates. A population forecast prepared by SEMCOG estimates that the City will have 3,783 residents by the year 2045.

4.3 PEAKING FACTORS

Maximum day and peak hour conditions were evaluated for this Reliability Study. The demands associated with maximum day scenario were characterized by applying a multiplication factor to the average daily use. The WTP reports from 2019 were evaluated to determine the maximum day water use and its corresponding peak factor. Since hourly data was not available to determine the peak hour water use in the system, a conservative peak hour factor of 4.0 was suggested for use in this study. The following table indicates the water use and maximum day peaking factor for 2019.

Table 1. 2019 Water Use

Month	Total Flow (mil gal)	Daily Flow Rate (mgd)	
		AVG	MAX
January	12.688	0.41	0.622
February	10.334	0.36	0.428
March	11.198	0.36	0.481
April	11.487	0.38	0.512
May	14.052	0.45	0.611
June	15.931	0.53	0.621
July	19.233	0.62	0.815
August	19.421	0.63	0.807
September	14.762	0.49	0.731
October	12.273	0.40	0.507
November	10.659	0.36	0.459
December	11.023	0.36	0.430
TOTAL	163.061	0.44	0.815

Table 1 indicates a maximum day demand of 0.815 mgd and a yearly average day demand of 0.44 mgd. The day experiencing the largest water use during 2019 was factored over the average day water use during the same year in order to determine the max day factor (1.83) used in this study. Since the population of the City is not anticipated to increase, using the 1.83 max day factor for future demands is both conservative and appropriate.

4.4 SYSTEM LOSSES

System losses in a water distribution system are defined as any unmetered discharge of water caused by firefighting, flushing of hydrants, inaccurate meters, system leakage, water main breaks, and other unknown uses. Typical system losses generally range from 10-15%. The American Water Works Association (AWWA) recommends that unaccounted water be limited to less than ten percent of total usage. Water loss is calculated based on the difference between the quantity of water produced at the WTP and the quantity of water sold by the City. The percentage of total water loss is calculated as follows:

$$\text{System Losses} = \frac{\text{Water Treated} - \text{Water Billed}}{\text{Water Treated}} \times 100\%$$

The calculated water system losses are shown in the following table.

Table 2. System Losses

Year (July 1 - June 30)	Amount of Treated Water (mil gal)	Amount Sold to City Users (mil gal)	Municipal Usage (mil gal)*	Amount of Unaccounted for Water (mil gal)	Loss Percentage
2018-2019	140.891	113.046	16.695	11.15	7.91%
2019-2020	149.324	115.205	16.695	17.424	11.67%
*Municipal Usage for 2018-2019 estimated match that of 2019-2020					

Table 2 indicates that the water loss experienced in the water distribution system falls below or within the typical 10-15% range that many water systems experience. The modest water loss that the City is experiencing is likely due to water main breaks and hydrant flushing. The older pipes in the network are more likely to experience a break than the newer pipes in the system. Multiple water main breaks will result in increased water loss; however, the magnitude of a main break is a more important factor in determining the volume of water lost. A list of water main breaks since 2018 is included in the Appendix.

Methods of further investigating water loss throughout the system include inspecting valves for leaks and to ensure that they are fully functional, conducting a leak detection program, and/or testing/replacing dysfunctional home/business meters. Replacement of aging or poorly functioning infrastructure would also decrease the water loss experienced by the distribution system.

For the computer model database, the system losses were equally distributed over the system in addition to the billed customer demands.

4.5 FIRE PROTECTION

The design of a supply system to meet fire demand involves consideration of:

1. Volume of water to extinguish a fire
2. Rate of required water application to extinguish a fire
3. Type of building
4. Pipe requirements
5. Cost of pipe requirements
6. Insurance premiums
7. Acceptable community risk

Each of these factors must be carefully considered and weighed before a final decision can be made by the community as to the needed supply system. Usually the community must decide if the required improvements to the water distribution are cost-effective and affordable in relation to the acceptable risk. The most widely used guide for calculating fire demand needs is published by the Insurance Service Office (ISO).

The method used in calculating the required fire flow is detailed in the ISO publication "Fire Suppression Rating Schedule." The term used to describe the fire flow requirement is Needed Fire Flow (NFF). This is the rate of flow considered necessary to control a major fire in a specific building. It is intended to assess the adequacy of a water system as one element of an insurance rating schedule. It is not intended as criteria for design.

Ideally, a water supply system should be capable of providing the maximum NFF within its service area. However, the relatively high rates of flow required to meet the NFF requirements, compared with all other demand situations (e.g., maximum day, peak hour) require a significant increase in pipe size and associated cost. For example, a commercial area already adequately served by a 10-inch line for supply purposes would require a 20-inch diameter pipe to fully meet a 5,000 gpm NFF requirement. As a result, a major portion of the distribution system would have to be reconstructed to meet these relatively high NFF requirements. It is unusual for an existing water distribution system to be capable of providing every NFF within its service area.

A compromise is often made by the community to meet a percentage of the NFF requirements at an affordable cost. In designing a new water distribution system or for improvements within an existing distribution system, the community typically decides to provide for a portion of the NFF within the design area.

The criteria for establishing deficiencies due to fire flow demand was reviewed and discussed with City DPW personnel. A minimum flow value of 1,000 gpm was established for residential areas and a minimum flow of 2,500 gpm was desired for commercial and industrial areas. These are common fire flow requirements that are used by many communities in southeast Michigan. The residential flow values exceed the minimum value of 500 gpm recommended by EGLE.

Table 3. Fire Demands

STRUCTURAL TYPE	WATER SYSTEM MINIMUM CRITERIA (GPM)
Residential	1,000
Commercial	2,500
Industrial	2,500

5.0 HYDRAULIC NETWORK MODEL

5.1 COMPUTER PROGRAM

The computer software utilized for this Reliability Study is WaterGEMS, CONNECT Edition Update 2. WaterGEMS is a water network analysis program developed by Bentley Systems, Inc. to perform water distribution system studies. This program is capable of analyzing fluid flows in a complex distribution network containing pumps, check valves, pressure-regulating valves, storage tanks, meters, fittings, etc. for a number of different scenarios including average day water usage, fire flow simulations, and extended period simulations. Complete output can be generated which includes pressures, demands, elevations, and hydraulic grade lines at all junctions, head losses, flows, and velocities in water main lines and various pump information. Output can be presented in numerous formats such as tabular, numerical, or graphical.

5.2 BASE MODEL PREPARATION

Water is supplied to the Marine City distribution system at operating pressures typically between 45 psi and 55 psi. These pressures result in hydraulic grades varying between 699 feet and 701 feet. Table 5 displays the modeled hydraulic grade at the Marine City WTP.

The elevations of the water main used in the model are important since they affect the predicted pressures. Water main constructed across uneven terrain will show higher pressures at low points and lower pressures at more elevated locations in the system. Since determining the exact profiles of the existing water main is often difficult and time consuming, it is common practice to assume that the water main profile mirrors that of the ground above it. The node elevations in the model were generated from a digital elevation model (DEM) file for St. Clair County that was obtained from the Michigan Geographic Data Library on the official State of Michigan website. The latest DEM file was generated in 2000 and provides horizontal elevations at 30-meter (98.4 feet) intervals. The vertical accuracy of the data is approximately ± two feet, which would correspond to approximately ± 0.9 psi.

5.3 CALIBRATION

A water model must be calibrated before the computer program can be used to confidently analyze the various effects simulated conditions will have on the distribution system. Calibration is the process of making the WaterGEMS hydraulic computer model mimic the actual behavior of the communities' water system. To calibrate the model, strategic locations throughout the system were selected to test fire hydrant flows and obtain pressures at each testing location. The field test data allowed the model to be verified by simulating the same flow conditions measured in the field with the computer program.

Hydrant flow tests were performed by Marine City staff on September 12, 2014, under the following guidelines:

1. Locations for testing were chosen based on their accessibility, diameter of pipe, and location within the system. The locations were selected so that a variety of common pipe sizes and materials were tested.

2. The objective of each hydrant test is to measure the static pressure at each location, as well as the residual pressures when a neighboring hydrant is being flowed at a known rate.

3. Each test site was chosen so three consecutive hydrants existed along a stretch of water main where no lateral water main connections occurred (i.e., no other mains were either providing or drawing water between the three hydrants).

4. At the start of the hydrant flow test, the three hydrants were flushed to clear the line of sediments. Once the line was cleared, a static pressure reading was taken and recorded at the two outside hydrants while the middle hydrant remained closed. Once the static pressure readings were obtained, the middle hydrant was fully opened. After the system stabilized, the flow rate from the middle hydrant and the residual pressures at the end hydrants were recorded.

Nine locations were chosen for fire hydrant flow tests to calibrate the model. These areas reflected locations evenly distributed throughout the water network. Although the tests are dated, the responsiveness of the water system is likely the same or very similar to what it was in 2014. The calibration results appear to be very consistent leading us to believe that the data is good, and the calibration is valid. The results of the hydrant flow testing are presented in the Appendix.

The average flow during the testing day (September 12, 2014) was compared to the average day flow used for the model and the demands at each node were adjusted uniformly to coincide with the flows during the test date. Each individual flow recorded during the flow tests was imposed on the model, then various system parameters were varied until the static and residual pressures in the model resembled the corresponding pressures recorded during the field tests. The adjusted flow conditions were simulated, and the model was calibrated to obtain results within a generally accepted criterion of ten percent of the field measurements.

The computer analyses of the water network are based on the Hazen-Williams Pipe Flow Formula, which requires pipe roughness coefficients (C-factors) to be assigned to each pipe. The roughness of a pipe represents the condition of the inside of a pipe (i.e., the friction factor) and is the largest unknown in preparing the model. The friction factor of a pipe, coupled with the pipe’s size, has a large influence on the amount of flow passing through a pipe, which ultimately affects the resulting pressures and flows within the system.

The hydrant flow tests generally impact the C-factors in the model more than any other parameter. It is common practice to alter the characteristics of all similar pipes throughout a system since it is impractical to perform a flow test on every segment of pipe in the system. The C-factors for this analysis range between 60 and 150 based on pipe material, size, and age. The C-factors assigned to various pipe classifications are shown in Table 4.

Table 4. C-Factors Determined through Calibration

Material	Diameter	Hazen-Williams C-Factor
Asbestos Cement	4" – 12"	130
Cast Iron	4" – 8”	60
Cast Iron	16”	90
Ductile Iron	6” – 16"	130
HDPE	10”	140
PVC	8" – 12”	150

The HDPE and PVC pipes are represented in the water model with roughness coefficients (Hazen-Williams C-factors) of 140 and 150, respectively. The ductile iron and asbestos cement pipes have C-factors of 130. 4-inch to 8-inch cast iron pipes have C-factors of 60. The majority of pipes in the system are ductile iron and asbestos cement pipes with C-factors of 130. Essentially, lower C-factors represent an actual reduction in pipe diameter due to tuberculation and corrosion or the presence of a partially closed valve(s) in the area. Pipes with lower C-factors are typically older pipes that are more susceptible to breaks, decreased flows, and lower water quality due to residual build-up within the pipes over time.

Another adjustment for calibrating the model included setting the water level at the elevated storage tank to 700 feet. This resulted in a water depth of 29.5. No valves were closed in this water distribution system.

The static and residual pressures at all nine testing locations were calibrated within ten percent of the field results.

The hydraulic grade line (HGL) at the source of the water supply generally forms a boundary condition for the model. The HGL at this location can be determined through known elevations and pressures. While elevations remain constant, the pressures may fluctuate over time. Table 5 displays the pressure and HGL at the WTP that was used to calibrate and model the water distribution system.

Table 5. Existing Boundary Condition Modeled

Supply	Ground Elev.	Pressure	HGL
Source	(ft)	(psi)	(ft)
WTP	586.00	45.0	700

6.0 HYDRAULIC COMPUTER ANALYSIS

6.1 INTRODUCTION

The calibrated model was used to evaluate existing and projected future conditions. Analyses consisted of four different scenarios: average day water use conditions, maximum day water use conditions, peak hour water use conditions, and maximum day water use plus fire flow conditions. Maximum day and peak hour conditions are achieved by applying the peaking factor for each condition to each node demand. Fire flow modeling is completed by setting fire demand criteria and adding that to the maximum day scenario. The computer model is capable of simulating fire flow conditions at each node throughout the system. Each computer simulation tested, verified, or analyzed some component of the system to evaluate the distribution system's ability to meet the water demands of today and the future.

6.2 CRITERIA FOR SYSTEM EVALUATION

System criteria were established to evaluate the distribution system's ability to meet existing and future water demands, as well as the recommended standards of EGLE. According to EGLE's generally accepted "Recommended Standards for Water Works" (more commonly known as "Ten States Standards for Water Systems"), the normal working pressure in the distribution system should be approximately 60 to 80 psi and not less than 35 psi. However, the document suggests that individual water systems should be evaluated on their own unique basis and circumstances.

For the purposes of this Water Distribution System Reliability Study, we adopted EGLE's recommended minimum pressure constraint of 35 psi. The normal working pressures in the distribution system can range between 45 psi and 50 psi, which are above the minimum pressure criteria, but below the normal working pressures indicated by EGLE. However, the existing pressures in the system are suitable for the physical characteristics of Marine City's Water Distribution System.

In conjunction with criteria set by EGLE, the fire flow simulations for this study were completed using maximum day demands. This is a conservative approach for determining recommended system improvements; however, future trends and usage, individual pipe conditions, and unidentifiable isolated ground elevation discrepancies justify being conservative.

Fire flow simulations completed for the entire system were generalized for residential, commercial, and industrial flows. The criteria were set at values of 1,000 gpm for residential areas and 2,500 gpm for commercial/industrial areas. The flow values exceed the minimum value of 500 gpm recommended by EGLE and meet the minimum NFF for residential areas set by ISO. Also adopted for the fire flow scenarios was the criterion set by EGLE stating that no point within the system shall have a residual pressure drop to less than 20 psi at any point during a fire scenario.

6.3 EXISTING CONDITIONS MODEL EVALUATION

The existing conditions model was created by inputting the average water use during 2019 into the calibrated system model. The model was used to develop four scenarios: average day, maximum day, peak hour, and maximum day plus fire flow. A discussion of each scenario is presented as follows:

Average Day Scenario

The water use in the distribution system under the average day scenario is approximately 222 gallons per minute (gpm). The model results show that system pressures in the City range from 48.6 psi to 54 psi. None of active nodes in the model indicated pressures below 40 psi. Overall, the City experiences consistent pressures with less than 10 psi variance across the City. Areas with the highest pressures are near to the Belle River and all pressures throughout the system meet the minimum pressure criterion. Figure 6 presents a color-coded water system map of the expected pressure ranges for the existing conditions scenario under average day demands.

Marine City

St. Clair County, Michigan

FIGURE 5

EXISTING PRESSURES
AVERAGE DAY SCENARIO

0.2 Miles

Legend

WTP

Tanks

Pressure

<35

35 - 40

40 - 45

45 - 50

50 - 55

Water Main

Roads

Railroad

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July 2020

Maximum Day Scenario

A peaking factor of 1.83 was applied to the average day water usage to generate the demands for the maximum day scenario. The peaking factor was determined based on historical analysis of similar water distribution systems in the area. The water use for this scenario is approximately 395 gpm. The model results show that the system pressures range from 48.6 psi to 54.0 psi with little change from the average day scenario results. All nodes remain above 40 psi. Similar to the average day results, the City experiences consistent pressures with less than 10 psi variance across the City. All pressures throughout the system meet the criterion established for minimum pressures. Figure 6 presents a color-coded water system map of the expected pressure ranges for the existing conditions scenario under maximum day conditions.

Peak Hour Scenario

A peaking factor of 4.0 was applied to the average day water usage to generate the demands for the peak hour scenario. A peaking factor of 4.0 was utilized to be conservative. Due to the ageing water distribution system, a conservative peaking factor was selected to be better prepared for large water main failures. The water use for this scenario is approximately 657 gpm. The model results show that the system pressures range from 48.4 psi to 53.7 psi. Similar to the average day results, the City experiences fairly consistent pressures with less than 10 psi variance across the City. All pressures throughout the system are indicated to meet the criterion established for minimum pressures. Figure 7 presents a color-coded water system map of the expected pressure ranges for the existing conditions scenario under peak hour conditions.

Marine City

St. Clair County, Michigan

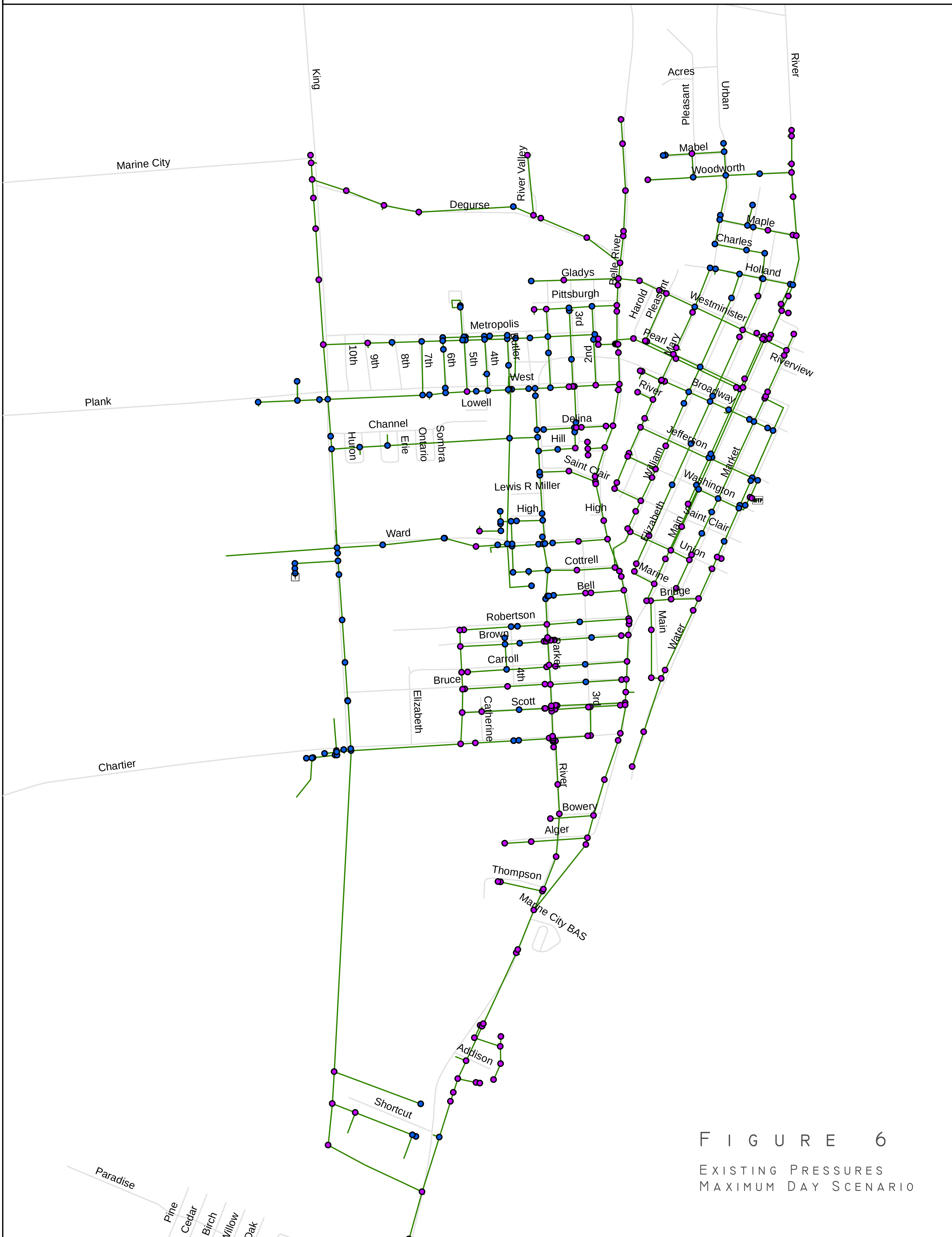

FIGURE 6

EXISTING PRESSURES
MAXIMUM DAY SCENARIO

Legend

- WTP
- Tanks

Pressure

- <35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55

- Water Main
- Roads
- Railroad

0.2 Miles

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Marine City

St. Clair County, Michigan

FIGURE 7

EXISTING PRESSURE
PEAK HOUR SCENARIO

0.2 Miles

Legend

WTP

Tanks

Pressure

<35

35 - 40

40 - 45

45 - 50

50 - 55

Water Main

Roads

Railroad

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Maximum Day plus Fire Flow Scenario

The maximum day scenario was used as the basis for the evaluation of fire flow availability. The model results indicate that approximately 91% of the distribution system is capable of providing over 1,000 gpm of water and 61% of the distribution system is capable of providing over 2,000 gpm of water. The areas that do not have sufficient fire flow are scattered throughout the water system.

The dead-end mains (particularly those that are excessively long) and undersized pipe are the primary reasons low flows are generated in the system. The water main located at higher elevations and at longer distances from water supply points also affect the amount of flow that can be delivered; this is prominent in the northwest corner of the system. The areas with the lowest available fire flows exist on dead-end four-inch mains. Figure 8 presents a color-coded water system map of the available fire flows for the existing conditions scenario under maximum day conditions. Figure 9 indicates the areas that do not meet the minimum fire flow requirements.

St. Clair River Sewer and Water Authority

St. Clair County, Michigan

FIGURE 8

EXISTING FIRE FLOWS
MAXIMUM DAY SCENARIO

0.2 Miles

Legend

- WTP Water Treatment Plant
- T Tanks
- Water Main
- Road
- Railroad

Fire Flow (gpm)

- 0 - 500
- 500 - 1000
- 1000 - 1500
- 1500 - 2000
- 2000 - 2500
- 2500 - 3000
- 3000 - 3500

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6.4 FUTURE TEN-YEAR CONDITIONS MODEL EVALUATION

Future scenarios typically incorporate projected water main projects, water usage, supply, and any other system variables (e.g., pipe degradation, controlled pressures, etc.) that may change over time. The majority of the water distribution system framework is presently in place, and rather than simulating ultimate build-out of the system, future growth through the next ten years was our focus for generating future conditions scenarios.

Water system hydraulic analyses typically extrapolate historical population growth as a method of estimating future water demands. The SEMCOG population forecasts for Marine City (which are further detailed in Section 4.2, Future Water Use) results in a total population decrease of 268 people and an average day demand decrease of 19 gpm. The specific locations of the decrease are unknown. Since removing large additional demands in areas that might never change could generate unfavorable model results, the future 2040 scenarios assume that the total water demands of the residents and businesses will uniformly decrease (across all applicable model nodes) throughout the system.

The interior conditions of the existing water main pipe are not expected to change much in the future. Asbestos cement, ductile iron, HDPE, and PVC pipe typically experience minimal degradation in their pipe interior over their life span, which does not significantly inhibit their ability to transport flow. Therefore, the Hazen-Williams C-factors for the pipes in the water distribution system are not expected to change much over the next ten years.

The pressure provided from the WTP are not expected to change much over the next decade; therefore, the HGL at the treatment plant and the pumps' operation are expected to remain relatively unaffected. The WTP (with a maximum treatment capacity of 2.1 mgd and a firm capacity of 1.4 mgd) will be able to supply the future water demands. There are also no gate valves assumed to be closed in the 2040 scenarios. The average day, maximum day, peak hour, and maximum day plus fire flow results are described and shown on the following pages.

Average Day Scenario

The water use projected in the distribution system under the 2040 average day scenario is approximately 203 gallons per minute (gpm). The model results show that system pressures in the City range from 45 psi to 55 psi. None of active nodes in the model indicated pressures below 40 psi. Overall, the City experiences consistent pressures with less than 10 psi variance across the City. All pressures throughout the system meet the minimum pressure criterion of 35 psi. Figure 11 presents a color-coded water system map of the expected pressure ranges for the 2040 scenario under average day demands.

Maximum Day Scenario

A peaking factor of 1.83 was applied to the average day water usage to generate the demands for the 2040 maximum day scenario. The water use for this scenario is approximately 361 gpm. The model results show that the system pressures range from 48 psi to 54 psi with little change from the average day scenario results. All nodes remain above 40 psi. Similar to the average day results, the City experiences consistent pressures with less than 10 psi variance across the City. All pressures throughout the system meet the minimum pressure criterion. Figure 12 presents a color-coded water system map of the expected pressure ranges for the 2040 scenario under maximum day conditions.

Peak Hour Scenario

A peaking factor of 4.0 was applied to the average day water usage to generate the demands for the peak hour scenario. The water use for this scenario is approximately 581 gpm. The model results show that the system pressures range from 48 psi to 54 psi. Similar to the average day results, the City experiences fairly consistent pressures with less than 10 psi variance across the City. All pressures throughout the system meet the minimum pressure criterion. Figure 13 presents a color-coded water system map of the expected pressure ranges for the 2040 scenario under peak hour conditions.

Maximum Day plus Fire Flow Scenario

The maximum day scenario was used as the basis for the evaluation of fire flow availability ten years into the future. The model results indicate that approximately 91% of the distribution system is capable of providing over 1,000 gpm of water and 61% of the distribution system is capable of providing over 2,000 gpm of water. However, approximately 21.6% of the distribution system is projected to be unable to provide the recommended fire flow rates for residential areas (1,000 gpm) and commercial areas (2,500 gpm) while maintaining a residual pressure of 20 psi throughout the system. The areas that do not have sufficient fire flow are scattered throughout the entire water system.

The dead-end mains (particularly those that are excessively long) and undersized pipe are the primary reasons low flows are generated throughout the system. Older cast iron pipes that have deteriorated are another concern for areas with low fire flows. The water main located at higher elevations and at longer distances from water supply points also affect the amount of flow that can be delivered; this is prominent in the northwest corner of the system. The areas with the lowest available fire flows exist on dead-end four-inch mains. Figure 14 presents a color-coded water system map of the available fire flows for the 2040 scenario under maximum day conditions. Figure 15 indicates the areas that do not meet the minimum fire flow requirements.

Marine City

St. Clair County, Michigan

F I G U R E 9

Future Pressures
Average Day Scenario

0.2 Miles

Legend

WTP	WTP
T	Tanks

Pressure

- <35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55

- Water Main
- Roads
- Railroad

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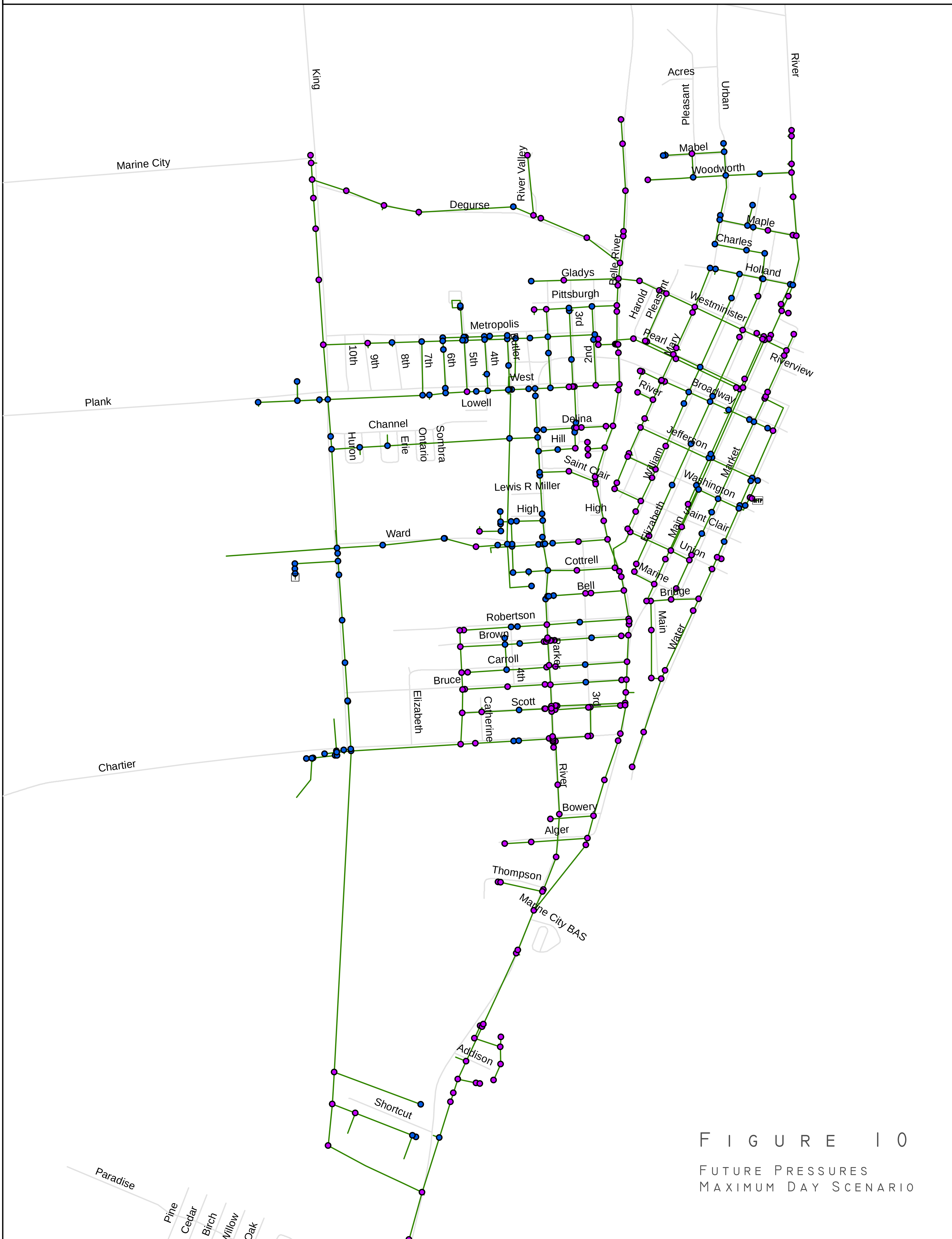

FIGURE 10

FUTURE PRESSURES
MAXIMUM DAY SCENARIO

Legend

WTP
Tanks

Pressure

●	<35
●	35 - 40
●	40 - 45
●	45 - 50
●	50 - 55

Water Main
Roads
Railroad

0.2 Miles

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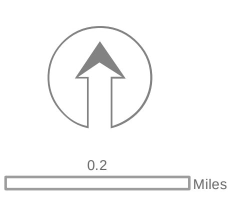
Marine City

St. Clair County, Michigan

FIGURE 11

FUTURE PRESSURE
PEAK HOUR SCENARIO



Legend

WTP

Tanks

Pressure

<35

35 - 40

40 - 45

45 - 50

50 - 55

Water Main

Roads

Railroad

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7.0 RECOMMENDATIONS

7.1 WATER SYSTEM MANAGEMENT

The model of the existing water system identifies several areas in the City where existing deficiencies need to be addressed. The pressures throughout the system were maintained above the minimum requirement of 35 psi during each scenario simulated; however, many areas throughout the system cannot currently deliver water flow that achieves the minimum fire flow requirements during the maximum day scenario. Several residential and commercial/industrial areas cannot supply 1,000 gpm and 2,500 gpm of water, respectively, while maintaining residual pressures of 20 psi.

The primary concerns in the system are the longer dead-end water mains and undersized pipe. The locations providing the lowest fire flows in the system are serviced by dead-end four-inch main. All other areas that are not capable of providing required fire flows are located on undersized lines or in areas of higher elevation.

The highest elevations within the water network are in the northwest of the system. These areas require water to be pumped upward to receive service and result in lower pressures. However, all pressures throughout the system meet the criterion established for minimum pressures.

It is also known that the City has insufficient valving, while not extensively reviewed in this study, a report compiled by the DPW Superintendent dated December 10, 2015 indicates that approximately 1,000 valves are currently in the system and approximately three times that are required. In that same report, it is recognized that much of the Marine City system is past its recommended lifespan. Fifty-one percent of the mains in the system have been installed prior to 1950. This report is included in the Appendix.

Several dead-end mains occur throughout the water system. These dead-end mains can reduce pressures, water quality, available fire flow, system reliability, and system redundancy. There are many dead-end mains off key distribution lines that do not generate the minimum required fire flow. The most prominent areas of deficient dead-end water mains are those exceeding 200 feet in length. Many of these dead-end mains would better service the system if they utilized larger diameter pipe, or if they were looped to nearby mains.

Since the water system is typically well-looped and sufficiently sized along the main lines, many of our recommended water system improvements are for replacing undersized pipes in residential areas. However, there are also a couple of areas where looping dead-end pipes to other existing mains would greatly improve the water system. The recommended water system improvements are summarized in the following table and are further described in Section 7.3.

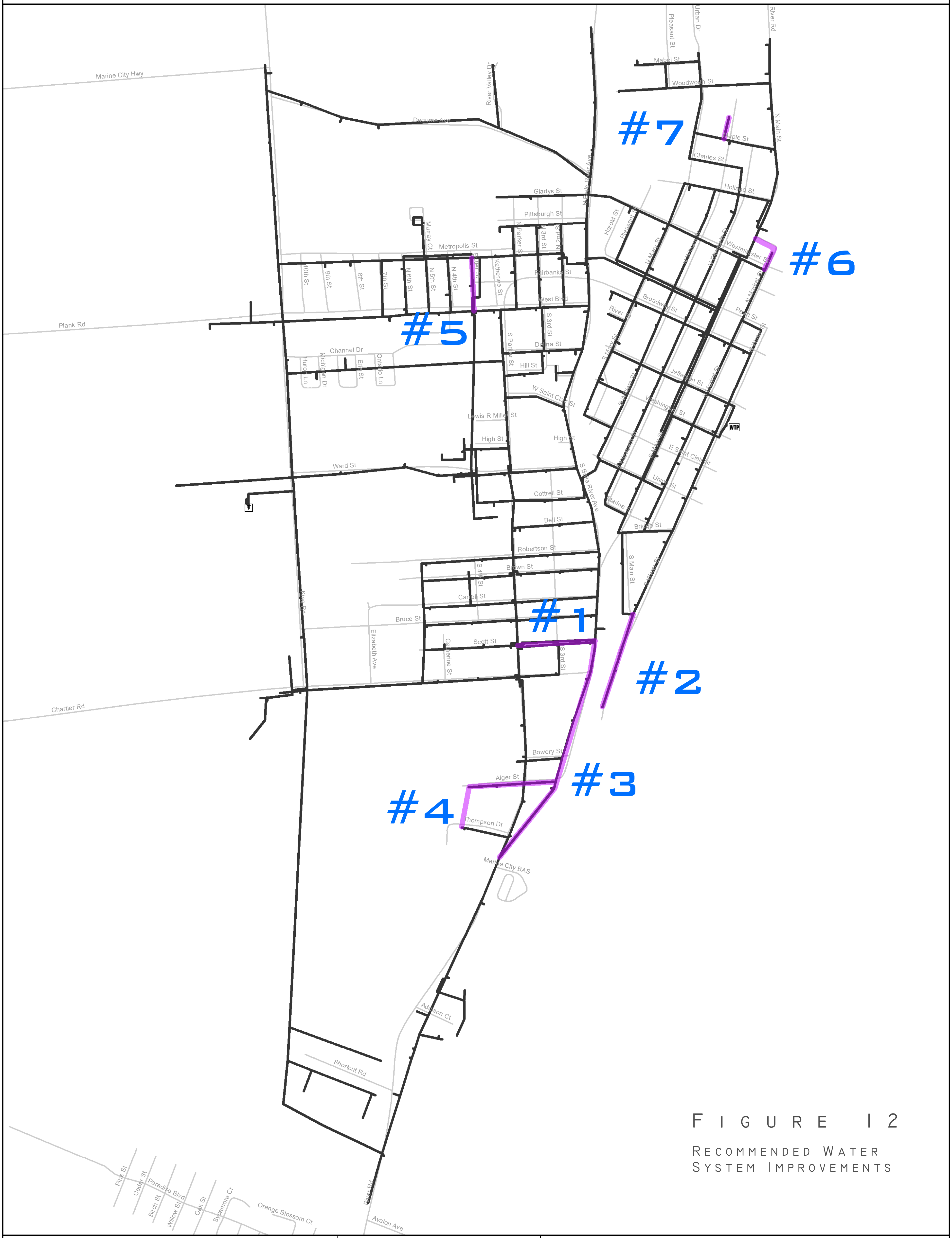
The recommended water system improvements are based on maintaining minimum pressure while complying with fire flow requirements throughout the distribution system. The improvements are categorized into high and low priorities based on several factors such as the immediate benefit to the overall system, the increase in pressure and available fire flow, potential water quality issues, and overall reliability and redundancy of the system. Individual projects in the same vicinity that require similar work have been grouped together to be more cost effective and minimize the effect that construction will have on nearby residents. The map identification numbers listed in the tables identify the project locations in Figure 12.

Table 6. Recommended Improvements

Map Identification Number	Water System Improvement
	HIGH PRIORITY
1	Abandon 4” cast iron main on Scott Street from Parker to Belle River Avenue and transfer services to parallel 8” ductile iron main
2	Upsize main on South Water Street, south of South Main Street to 6”
	LOW PRIORITY
3	Replace 4” on S. Belle River Ave from Scott Street to River Road with 6” main
4	Replace 4” on Alger Street from Belle River Ave to dead end to the west with 6” main or loop with main on Thompson Drive
5	Replace 2” water main on Butler Street from Metropolis Street to West Blvd with 6” main
6	Replace 2” water main on N William Street from Maple Street north to dead end with 6”
7	Replace 2” water main on N Market Street from Westminster north to dead end with 6” main and loop with N Main Street.

Marine City

St. Clair County, Michigan



F I G U R E 12

RECOMMENDED WATER SYSTEM IMPROVEMENTS

0.15 Miles

Legend

- Tanks
- WTP
- Recommended Improvements
- Water Main
- Roads

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November 2020

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7.2 COST ESTIMATES

Conceptual cost estimates were developed for each recommended improvement. General per foot estimates were obtained based on the size of the water main to be installed and applied to the total length of each improvement project. The project costs account for surveying, construction costs, engineering, administrative costs, legal costs, and project contingencies. Pipe replacement costs are included in the cost estimates; however, costs for significant pipe removal and/or major/minor site conflicts have not been incorporated. The cost estimates are based on the cost of construction during 2020.

The cost estimates assume that the majority of water main is not installed under pavement; if the existing main is located under pavement, then additional costs for removing and replacing the pavement will be required. Alternative methods of installing water main such as pipe bursting or pipe lining should be considered to minimize above ground impacts; however, these options are not considered in the cost estimates. The cost estimates for the recommended improvements are shown in Table 7. As indicated in the table, the approximate costs to complete all of the high and low priority recommended improvements are $305,000 and $1,090,000, respectively.

This listing of project improvements should not be considered as the only improvements that can be conducted in the water distribution system. Other isolated or dead-end mains can be looped, 4-inch and 6-inch lines can be replaced with larger 8-inch diameter pipe, and older mains can be scheduled for future replacement.

Table 7. Improvement Projects Cost Analysis

Year	Map ID Number	Project Description	Quantity*	Project Cost*
		HIGH PRIORITY		
2021	1	Abandon 4" cast iron main on Scott Street from Parker to Belle River Avenue and transfer services to parallel 8" ductile iron main	850 L.F.	$85,000
2021	2	Upsize main on South Water Street, south of South Main Street to 6"	1,100 L.F.	$220,000
		Total for High Priority	**1,950 L.F.**	**$305,000**
		LOW PRIORITY		
2021	3	Replace 4" on S. Belle River Ave from Scott Street to River Road with 6" main	2,650 L.F.	$530,000
2021	4	Replace 4" on Alger Street from Belle River Ave to dead end to the west with 6" main or loop with main on Thompson Drive	1,400 L.F.	$280,000
2021	5	Replace 2" water main on Butler Street from Metropolis Street to West Blvd with 6" main	600 L.F.	$120,000
2021	6	Replace 2" water main on N William Street from Maple Street north to dead end with 6"	250 L.F.	$50,000
2021	7	Replace 2" water main on N Market Street from Westminster north to dead end with 6" main and loop with N Main Street	550 L.F.	$110,000
		33-36	**5,450 L.F.**	**$1,090,000**
2021		**Total for High and Low Priorities**	**7,400 L.F.**	**$1,395,000**

*Figures have been rounded

7.3 RECOMMENDATIONS

Our recommendations for improving the Marine City Water Distribution System have been categorized into two high priority and five low priority improvement projects. Projects are primarily classified as high priority if the project areas consist of available fire flows below 500 gpm. Other considerations include potential water quality issues and overall reliability and redundancy of the system. Projects are generally classified as low priority if the residential areas consist of fire flows between 500 gpm and 1,000 gpm and the commercial/industrial areas have fire flows between 500 gpm and 2,500 gpm.

Several other projects that would improve various areas of the system to meet fire flow requirements or simply function more efficiently include replacing cast iron pipes throughout the system with either ductile iron, PVC, or HDPE mains. Cast iron has a low C-factor which greatly reduces pressure and flow in their immediate area. The majority of the Marine City distribution system consists of mains under eight inches in diameter. It is generally recommended to use a minimum of eight-inch main to improve pressure and flow throughout the system.

The minimum pressure requirement of 35 psi continues to be achieved throughout the distribution system for each scenario (i.e., average day, maximum day, and peak hour) incorporating the recommended improvements. Also, nearly 98% of the hydrants in the model were able to achieve the minimum fire flow requirements for residential and commercial/industrial areas (1,000 gpm and 2,500 gpm, respectively).

The list of recommendations in this report should not be considered as the only improvements needed in the water distribution system. Other mains or structures (such as hydrants and valves) throughout the system may experience deterioration, numerous breaks, obstructions, or are simply approaching the end of their life expectancy. We also recommend that the City continue to utilize pipe at least eight inches in diameter for any future water main improvement projects.

We recommend that the City continue to keep a record of all water main breaks that occur in the system. A log of the dates, locations, and the methods of repair can help identify pipes that need replacement or identify areas where preventative maintenance or other system corrections can reduce future impairments in the system.

We also recommend that the City continue to track hourly data be tracked for water flow going to/from each of the storage tanks and treatment plant. This information can accurately indicate how the system components are functioning over time, particularly during peak periods of water use and during times when the system users are relying entirely on the storage tanks for water supply to the system.

Any additional major improvements not consistent with this analysis should be modeled with the computer program to determine the impact on the system. The hydraulic model should be used on a continual basis for managing the water distribution system. All major changes in the existing distribution system should be integrated into the water model. Future updates to the hydraulic network analysis are recommended every five years and more frequently if major changes in estimated system demands and/or improvements are made to the system.

A copy of this report should be submitted to EGLE for compliance with the “Safe Water Drinking Act,” Public Act 399 of the State of Michigan.