Memorandum

To: *Judith Hansen, Plant Superintendent, Kingston Water Department*

From: *Jennifer Lind & Howard Matteson, CDM Smith*

Date: *November12, 2014*

Subject: *Technical Memorandum – Niagara Water Bottling Plant Demand Analysis Results*

Executive Summary

Niagara Water has proposed to build a bottling plant that would require water service from the Kingston Water Department (KWD). The bottling plant would represent a new customer with a high water demand relative to existing system customers. The KWD requested an analysis of their distribution system to determine the potential impacts of the Niagara Water Bottling Plant (Bottling Plant). The analysis included serving an average demand that could range from 0.5 million gallons per day (mgd) to 1.75 mgd. Additionally, the bottling plant would require a periodic demand of 2,500 gallons per minute (gpm) for a 30-minute duration for filter backwash purposes. The required minimum pressure at the Bottling Plant site would be 50 psi.

CDM Smith applied the City's existing hydraulic model to perform the analyses. Based on the model results presented herein, the existing distribution system can supply an average demand of up to 1 mgd to the site. It should be noted that this 1 mgd supply does not account for fire protection. It is the assumption through this analysis that if a fire were to occur on the Bottling Plant site, prior to any system upgrades, the bottling production would be suspended and all water would be devoted to extinguishing the fire. To supply the backwash demand, a dedicated backwash tank would be required onsite to reduce the impact of the large backwash demand on the distribution system. Additionally, to supply more than 1 mgd to the Bottling Plant site, the following projects are recommended:

- Install approximately 5,000 linear feet of new 12-inch main from the three supply transmission mains feeding the City to the Bottling Plant site. This alignment parallels an existing 12-inch main. The new 12-inch main should be cross-connected with each of the three supply transmission mains and should have tie-ins to the existing 12-inch main at regular intervals.

- Install approximately 1,200 linear feet of 24-inch main from the NYS Thruway valves to the Binnewater Reservoir. Ideally, this line should provide a second inlet to the Binnewater

Reservoir. However, if this is not possible due to issues with constructability, the new 24-inch should extend as close as possible to the Binnewater Reservoir.

Introduction

The purpose of this technical memorandum (TM) is to present an analysis of the Kingston Water Department (KWD) water distribution system performance under the future demands of the proposed Niagara Water Bottling Plant. CDM Smith used the KWD's water distribution system hydraulic model to evaluate the potential impacts of the bottling plant on KWD's system. The hydraulic model was originally developed by CDM Smith in 2005 as part of the *System Expansion Impact Analysis* study.

Overview

The hydraulic model is capable of simulating and comparing different water supply scenarios and resulting impacts. The model was configured with scenarios to represent average day and maximum day demand conditions based on 2013 actual demands and proposed demands of the Bottling Plant and backwash supply. Average day demands represent average conditions over the course of a typical year, or a condition that is frequently experienced in the field. Maximum day demands represent the maximum expected 24-hour demand for a given year, or a condition that is rarely experienced in the field.

Niagara requested a maximum demand of 1.75 mgd and a backwash supply of 2,500 gpm for a 30-minute duration when backwashing is required at the plant. These demands were initially simulated using only the existing water distribution system infrastructure (i.e., no improvements). The intent of this initial analysis is to present a summary of the issues that are anticipated to occur as a result of the addition of the Bottling Plant, and to identify potential capital improvements that may be required to alleviate those issues. The scope of the analysis focused on the Bottling Plant delivery point and the effect of the increased demand on the distribution system supply from the Binnewater Reservoir and the Filtration Plant.

The location of the proposed Bottling Plant and Binnewater Reservoir are shown on **Figure 1** while **Figure 2** shows the corresponding location of those elements in the hydraulic model.

Figure 1 – Niagara Water Bottling Plant Location

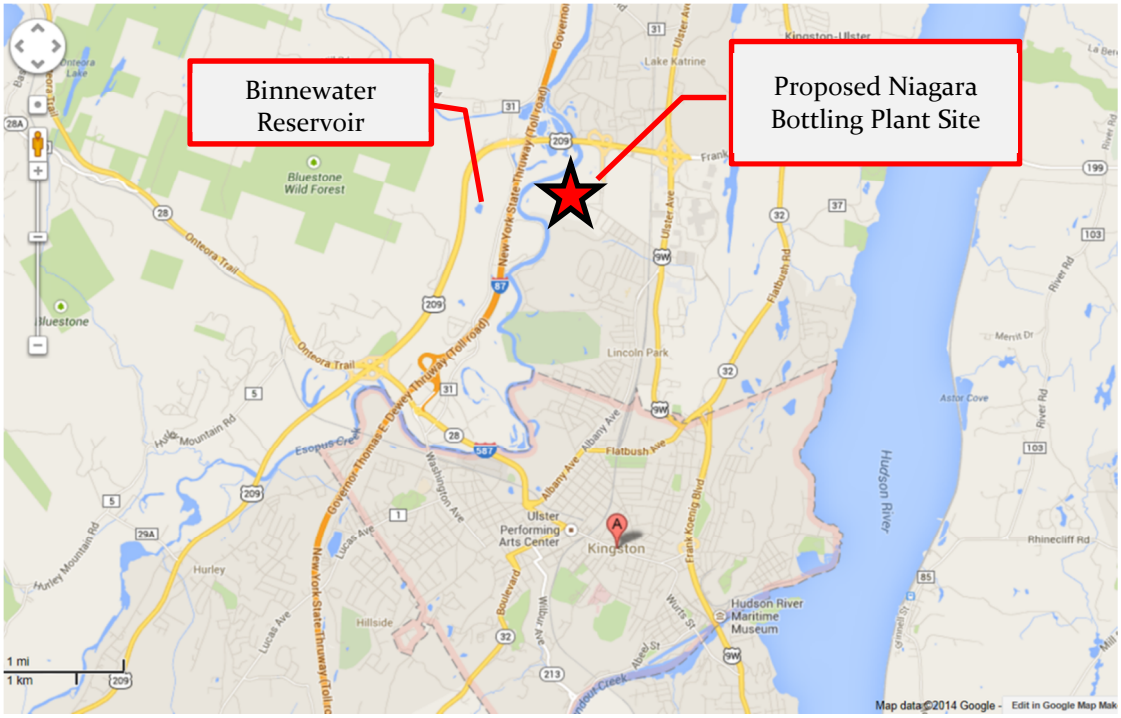
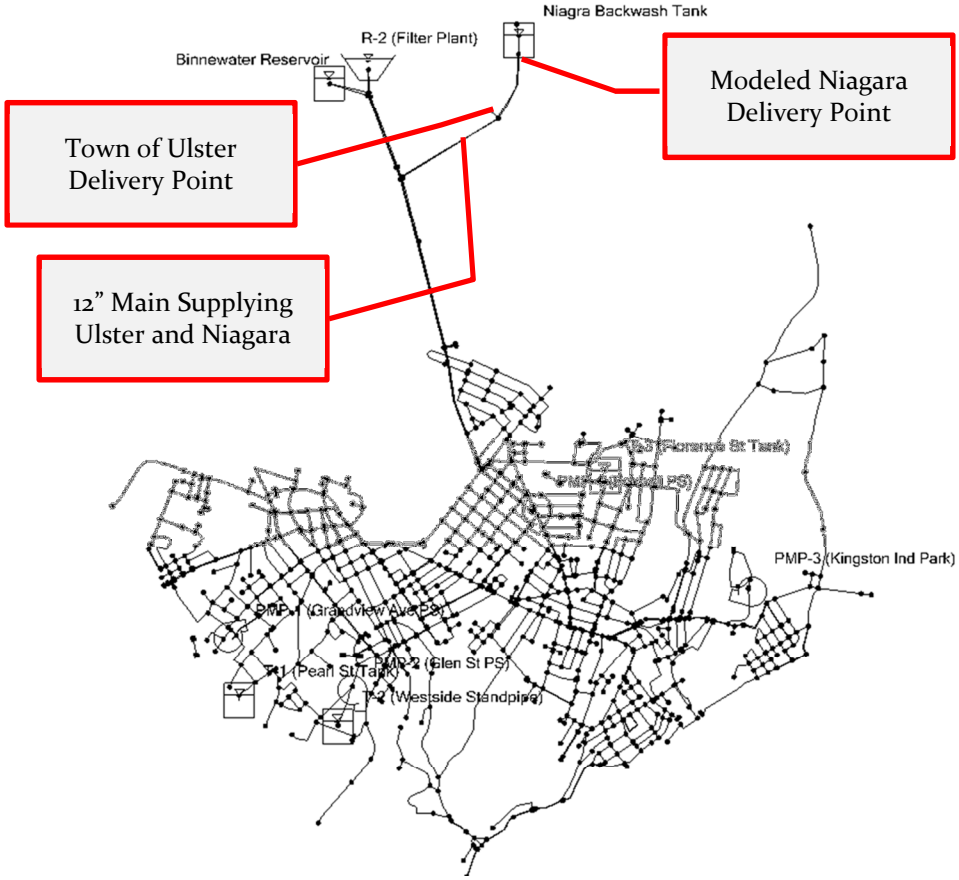


Figure 2 – Modeled Location of Niagara Bottling Plant



Assumptions

The following assumptions were made in the hydraulic model for the analysis:

- The starting hydraulic grade line (HGL) at Binnewater Reservoir was reduced to 337 feet from 342 feet to reflect a 2 pounds per square inch (psi) pressure drop due to the UV facility, per an email from Kingston Water Department on April 25, 2014. This change was necessary due to new construction since the model was first developed in 2005.

- The Filtration Plant was modeled as a fixed head reservoir set to maintain an HGL of 380 feet, assuming a discharge pressure to Binnewater Reservoir of 35 psi and a ground elevation at the Filtration Plant of 300 feet. Flow from the Filtration Plant to Binnewater Reservoir was limited to 8 mgd using a flow control valve.

- Hydraulic models use a roughness factor to reflect the material, age and condition of each pipe. This model used a roughness factor called the Hazen-Williams C-factor. All existing system pipes were assigned a C-factor of 100, unless otherwise noted in the analysis. Any mains modeled to represent potential infrastructure improvements were assigned a C-factor of 130, reflecting new materials. The total demand at the Town of Ulster supply point was set to 0.7 mgd, per an email from Kingston Water Department on May 6, 2014.

- The delivery point for the Bottling Plant is at the end of the existing 12-inch main serving Tech City and the Town of Ulster, and was set at elevation 175 feet.

- The Bottling Plant demand is assumed to be a constant rate at 24 hours per day.

- A 0.5 million gallon (mg) Backwash Tank with an overflow elevation of 285 feet was modeled just downstream of the Niagara delivery point node. A backwash demand of 2,500 gpm for a 30 minute duration was simulated to operate every 8.5 hours and was located downstream of the tank so that backwash water was forced to pull from the tank rather than the distribution system.

- To reduce the head loss in the pipe feeding the Niagara site, a flow control valve was placed on the influent tank line to limit the flow into the tank to no more than 150 gpm. This rate is sufficient to provide the required backwash supply every 8.5 hours to refill the tank prior to the next backwash event. Pumping is not required to fill the tank but could potentially be required to provide adequate pressure for filter backwashing, depending on the required pressure, length and diameter of the line to the filters, minor losses in the line etc. For the purposes of this analysis no pumps were modeled to serve the backwash demand.

Modeled Demands

The current (2013) average daily demand (ADD) in the distribution system is approximately 3.9 mgd and the estimated maximum day demand (MDD) is 4.6 mgd, as reported by the KWD. The demands include an ADD and MDD demand to the Town of Ulster, located north of Kingston along the Hudson River, of approximately 0.7 mgd and 0.83 mgd, respectively. The supply delivery point to the Town of Ulster is located off of the 12-inch main supplying Tech City. This line would also supply the proposed Bottling Plant.

In addition to the existing demands, a development called "The Landing" is planned, with construction commencing in the near-term. The location of this development is farther south in the KWD water distribution system and therefore has no effect on the head loss observed in the existing 12-inch main supplying the Bottling Plant site. The demands at this development will however, affect the overall system pressure and the head loss observed in the transmission mains supplying the Binnewater Reservoir. It is therefore necessary to evaluate the development's impact on the distribution system in conjunction with the demands at the proposed Bottling Plant site. At build-out, The Landing demand was originally planned to be approximately 0.5 mgd under ADD conditions. However, recent revisions to the development plan have lowered the demand projection to roughly 0.25 mgd. For purposes of this modeling analysis, an ADD of 0.25 mgd and a MDD of 0.55 mgd at The Landing was used to reflect the most recent demand projections.

The simulated demands to the Bottling Plant were increased incrementally under the base ADD and MDD scenarios to determine the point at which the additional Bottling Plant demands create hydraulic issues in the distribution system. It was assumed that the demand to the bottling plant would be a continuous supply at a constant rate rather than replicating diurnal fluctuations that a typical residential or commercial user would exhibit. **Table 1** lists the total system demand under each scenario.

Table 1 – Modeled System Demand

Demand Scenario	Base Demand (mgd)
ADD + Landing + 0.5 mgd Niagara	4.7
ADD + Landing + 1.0 mgd Niagara	5.2
ADD + Landing + 1.5 mgd Niagara	5.7
ADD + Landing + 1.75 mgd Niagara	6.0
MDD + Landing + 0.5 mgd Niagara	5.75
MDD + Landing + 1.0 mgd Niagara	6.25
MDD + Landing + 1.5 mgd Niagara	6.75
MDD + Landing + 1.75 mgd Niagara	7.05

A fire flow demand of 3,500 gpm operating for a 4-hour duration was also simulated in the distribution system under the MDD scenario with the maximum demand of 1.75 mgd at Niagara. This analysis was performed to verify that the distribution system would be capable of delivering fire flow under anticipated peak demand conditions.

Hydraulic Analysis

The hydraulic analysis of the impact of the Bottling Plant demand on the KWD distribution system primarily focused on two areas of the distribution system: the delivery point to the proposed Niagara site and the Binnewater Reservoir. To assess the impact of the Niagara demand on these two areas of the distribution system, flow to the Niagara site was increased incrementally under ADD and MDD conditions.

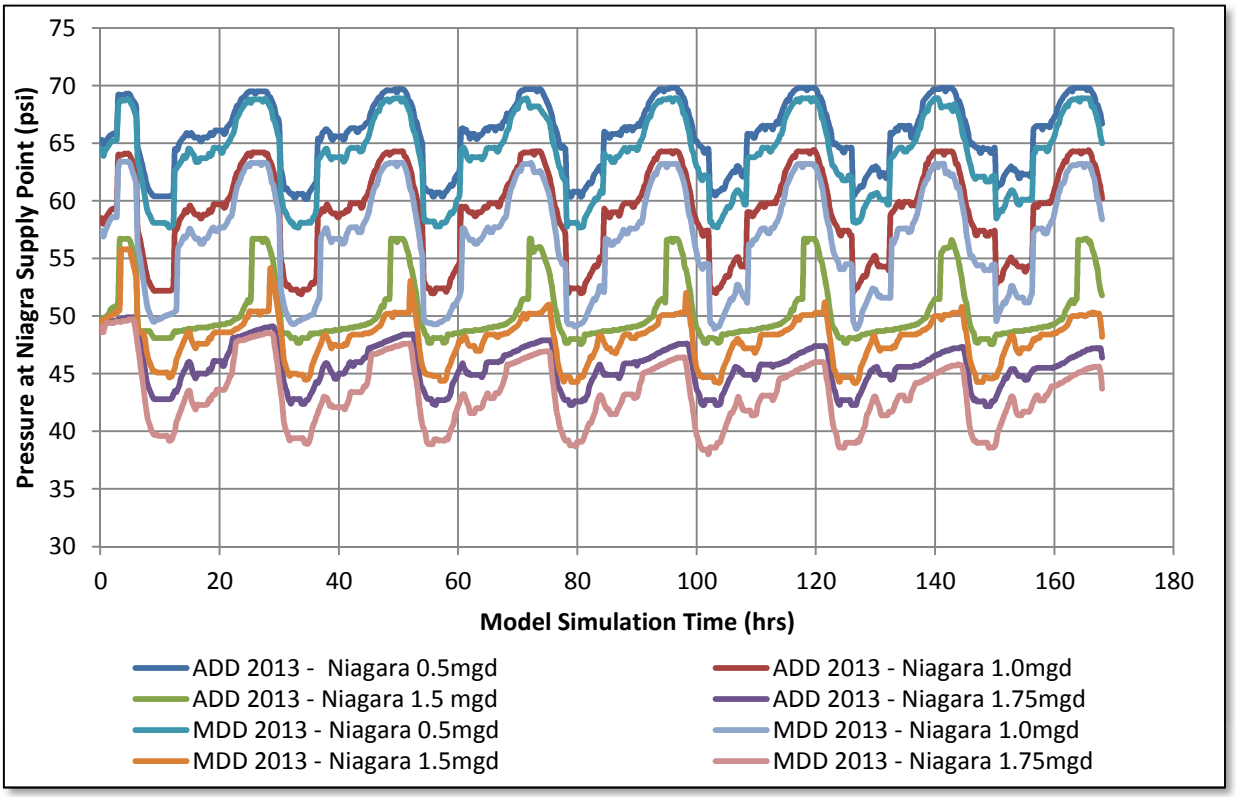
Niagara Delivery Point

Niagara Water requested a maximum demand of 1.75 mgd plus the necessary backwash at a minimum delivery pressure of 50 psi. Therefore, maintaining a minimum of 50 psi at the proposed Bottling Plant site was the modeling criteria used to determine whether the existing distribution system could meet the conditions, or what improvements would be required. As previously stated, a backwash tank was assumed to be present at the plant site to reduce the high, periodic backwash demand to a manageable constant demand of no more than 150 gpm.

The model-predicted pressure at the Niagara delivery point varies with the flow rate in the 12-inch main as well as the assumed Hazen Williams C-factor modeled to represent pipe roughness. Initial modeling scenarios assumed a C-factor of 100 and a demand at the Town of Ulster of 0.7 mgd as reported by the Kingston Water Department. The model-predicted pressures in the existing system under various demands at the Bottling Plant delivery point is shown on **Figure 3**.

Figure 3 illustrates the results of a set of different scenarios representing a combination of average day or maximum day demands, and different constant delivery rates to the Bottling Plant. The figure shows predicted pressures at the Bottling Plant delivery point over the course of a week (168 hours). Although the water supply to the Bottling Plant is constant, the pressure varies over time due to changing demands in the rest of the City water system.

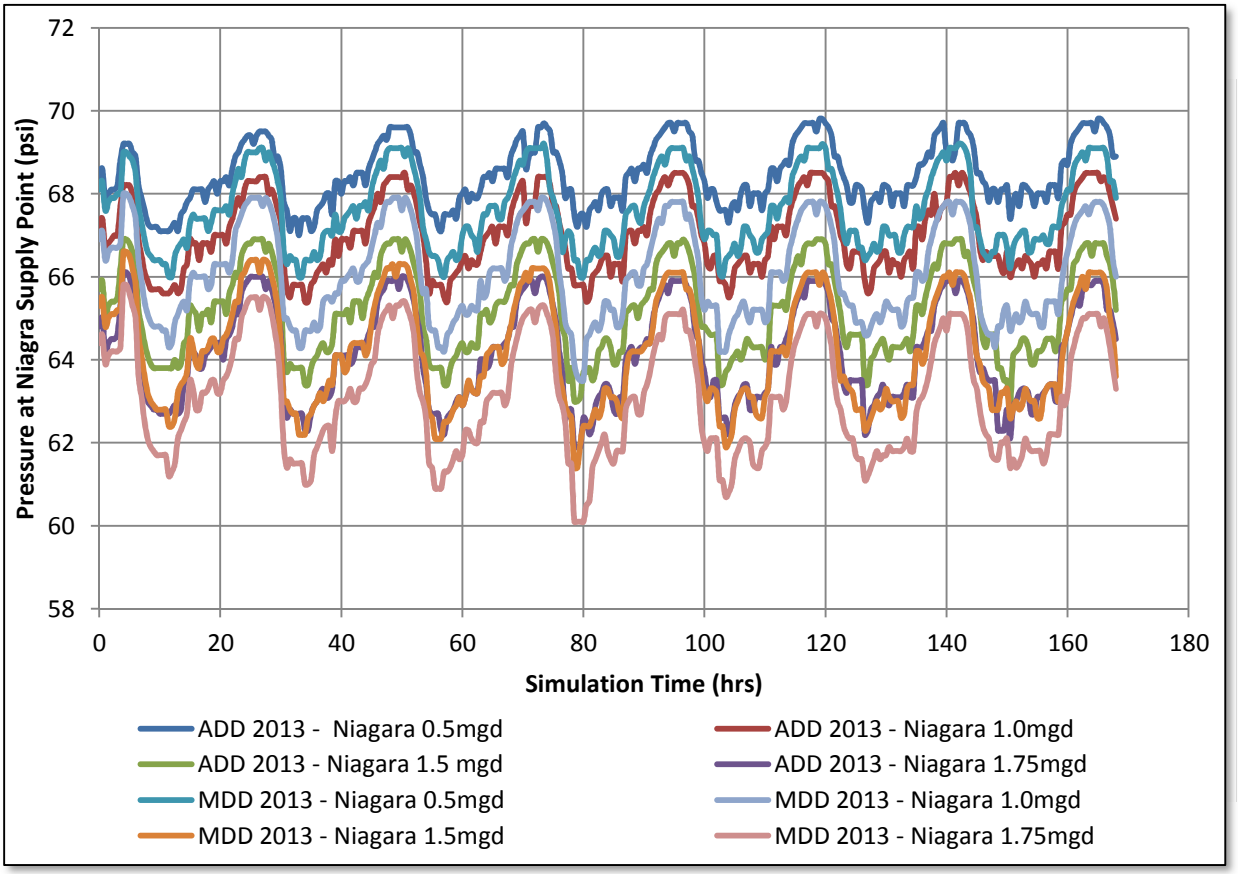
Figure 3 – Predicted Pressure at the Bottling Plant Site – Existing 12-inch Main



As shown in **Figure 3**, the predicted pressure at the proposed Bottling Plant ranges from 40 psi to 70 psi, depending on the demand at the plant site. The primary driver for the decrease in pressure is the constant demand at the site. As evidenced in **Figure 3**, there is not a significant difference between the ADD and MDD pressure predictions for any continuous flow rate. However, there is a relatively large difference as the continuous supply rate increases. The increased base delivery to the site dictates the flow rate, velocity, and resulting head loss through the existing 12-inch main feeding the plant site.

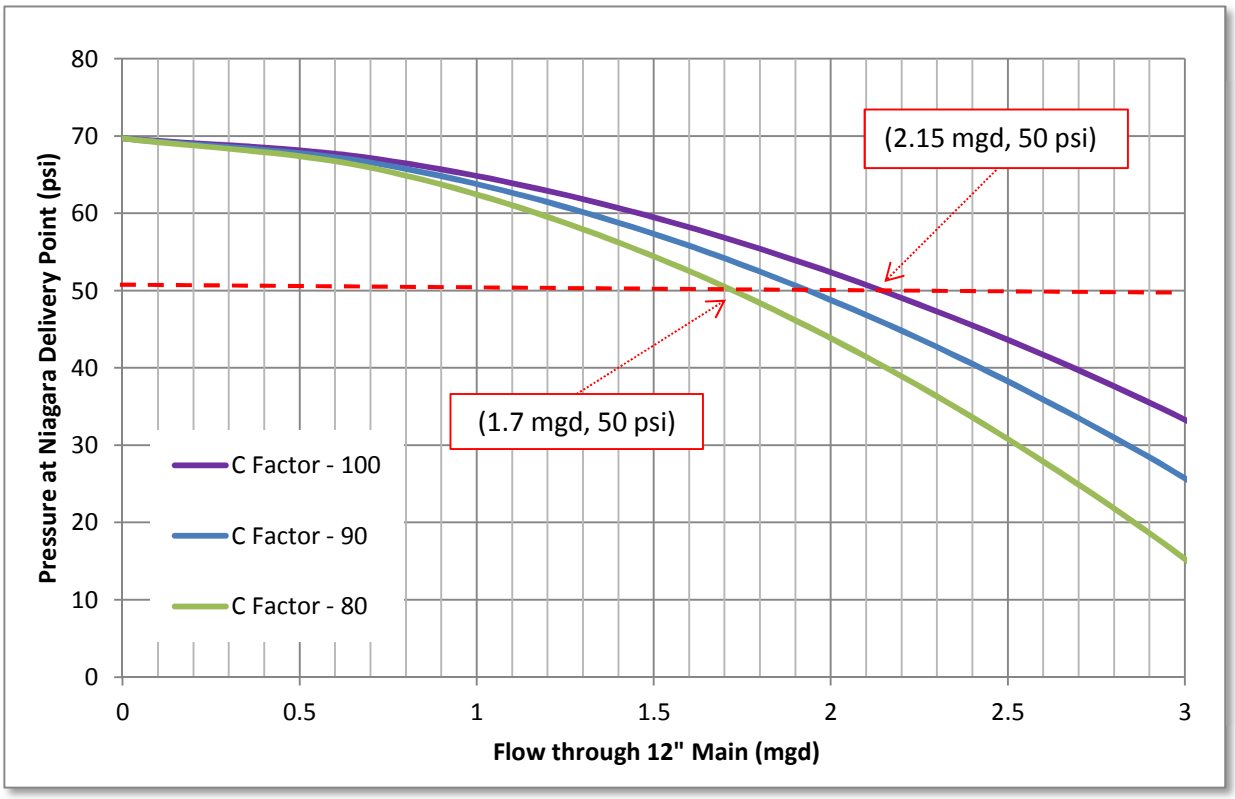
The scenarios in which the pressure at the Bottling Plant site drops below 50 psi are the 1.5 mgd and 1.75 mgd Bottling Plant demand delivery scenarios under both ADD and MDD conditions. To increase pressure to the Bottling Plant site, an additional scenario was run in which the existing 12-inch main was paralleled with a new 12-inch main. The results of that scenario are shown in **Figure 4** and demonstrate that the predicted pressures at the plant site would increase from a minimum of 40 psi with a single 12-inch main to a minimum of 60 psi with the parallel 12-inch mains. An additional benefit of adding a secondary 12-inch main to feed the Bottling Plant site and the Town of Ulster is that it provides redundancy to the existing 12-inch main, which is over 60-years old.

Figure 4 – Predicted Pressure at the Bottling Plant – Parallel 12-inch Mains



After these initial model results were presented, subsequent conversations were held with the Kingston Water Department in which it became clear that the amount of flow to the Town of Ulster and the Bottling Plant could vary significantly from the original demand assumptions. Further, the assumption of a C-factor of 100 could also vary, since the existing 12-inch pipeline has not specifically been field tested to measure the roughness. Therefore, **Figure 5** is presented to illustrate the head loss through the existing 12-inch main in terms of total instantaneous flow rate through the pipe and with a varying C-factor, rather than in terms of the specific Bottling Plant demand scenarios.

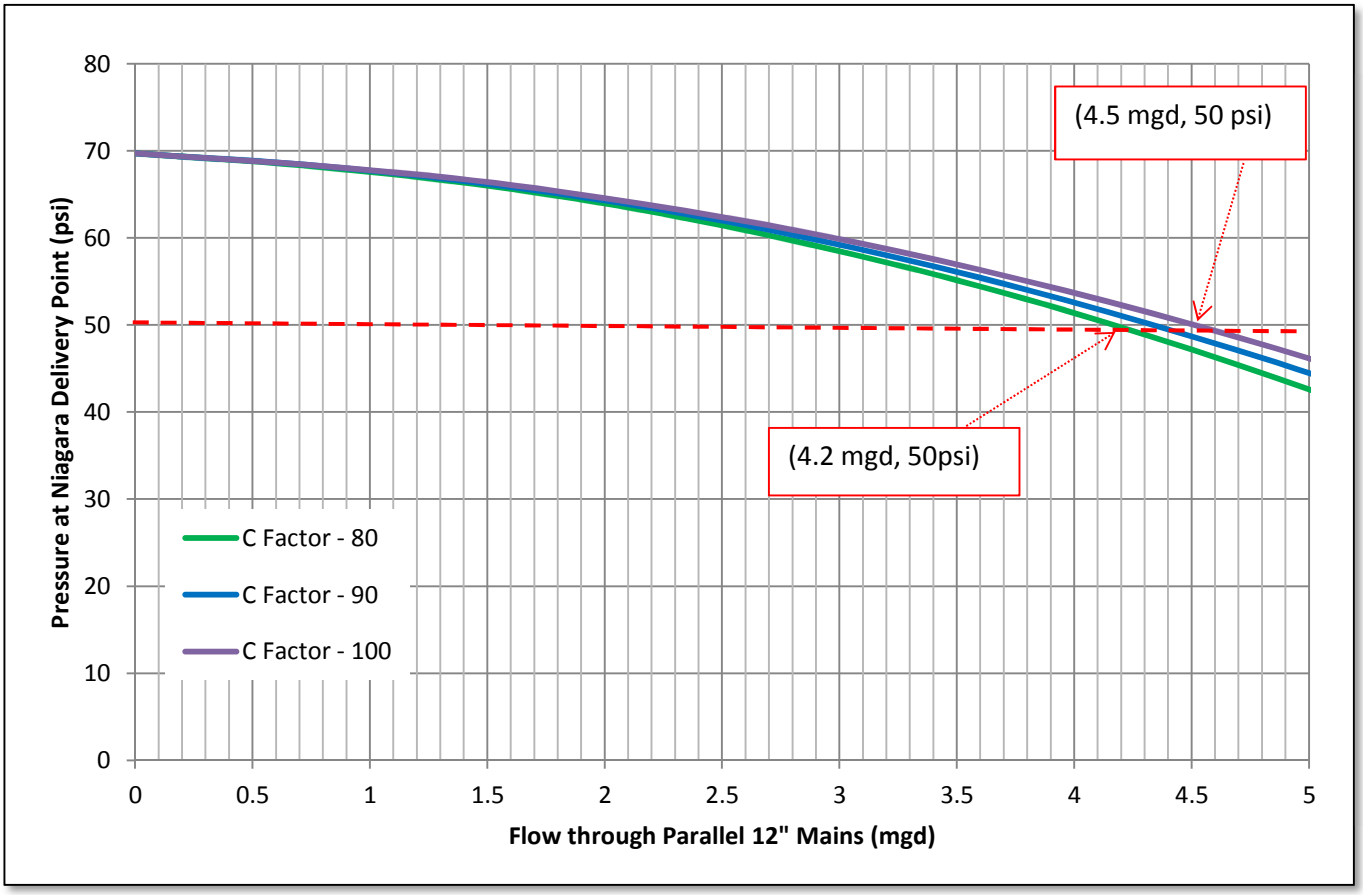
Figure 5 – Pressure Variation at the Bottling Plant Delivery Point Based on Flow Rate through the Existing 12-Inch Main



As shown in **Figure 5**, as the flow rate through the existing 12-inch main reaches between 1.7 mgd and 2.1 mgd, the pressure at the Bottling Plant site will approach 50 psi, depending on the actual roughness of the existing 12-inch main. It should be stressed that this accounts for instantaneous flow rate through the pipe, rather than average daily flow through it so fire flow has not been accounted for in the summation of flow through this pipe. In other words, if the predicted peak-hour demands at the Town of Ulster and the Bottling Plant total only 1.5 mgd but the Bottling Plant requires a fire flow of 1,500 gpm (2.16 mgd) at 50 psi, the peak flow through the existing 12-inch main equals 3.66 mgd and the main will be unable to deliver at the required pressure or even to provide any fire flow in this specific example. Therefore, it is the assumption of this analysis that if a fire were to occur on the Bottling Plant site, all bottling water demands would be suspended and resources would be solely devoted to extinguishing the fire.

The same head loss analysis above was performed with the existing 12-inch main and a new parallel 12-inch main from the three transmission mains to the Bottling Plant site. **Figure 6** illustrates the model-predicted pressure at the Bottling Plant site with parallel 12-inch mains feeding the location. The modeled C-factor was only adjusted in the existing 12-inch main while the new 12-inch modeled main was assumed to have a C-factor of 130, representing new piping.

Figure 6 – Pressure Variation at the Niagara Delivery Point Based on Flow Rate through Parallel 12-Inch Mains



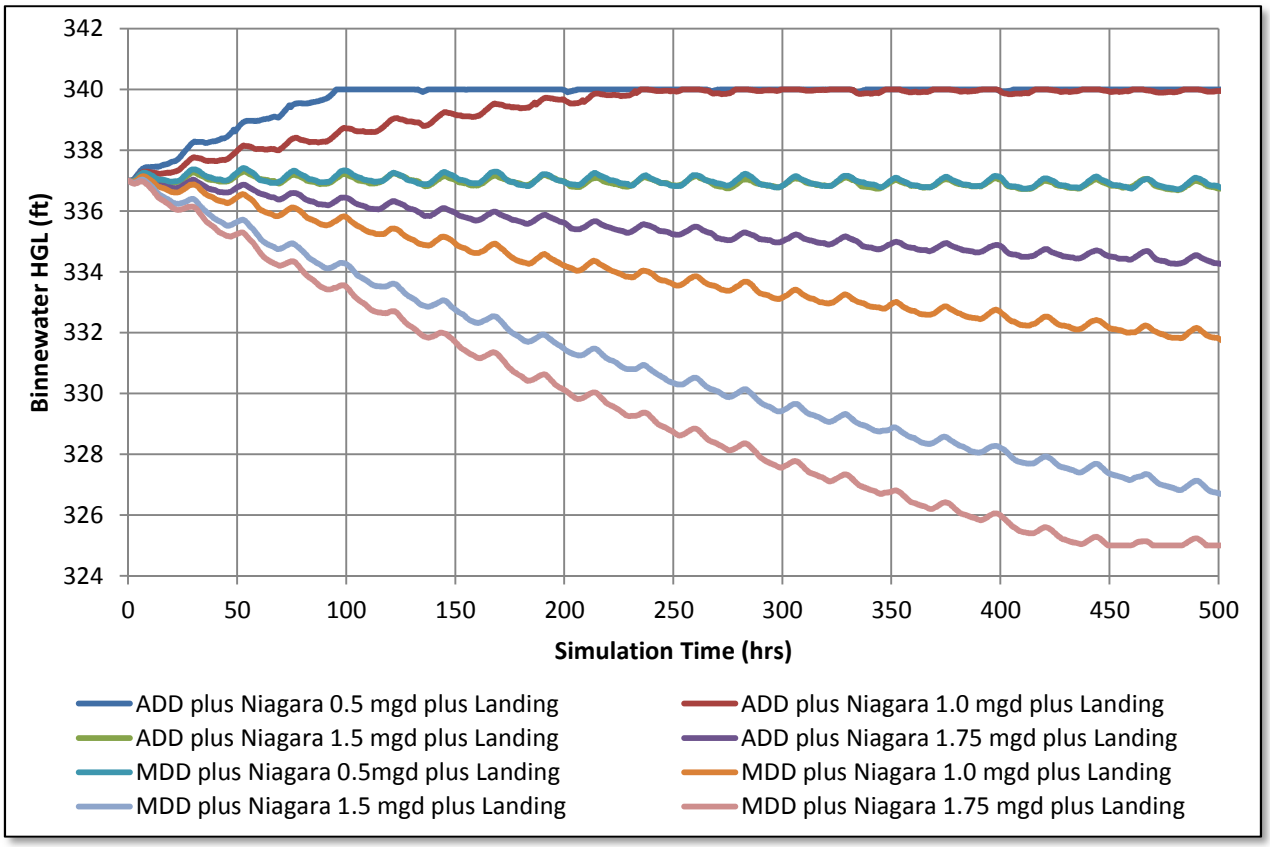
As shown in **Figure 6**, the flow rate through the parallel 12-inch mains can exceed 4 mgd before the pressure at the Bottling Plant site is predicted to drop below 50 psi. The figure also illustrates that the parallel mains are much less sensitive to changes in the C-factor observed in a single 12-inch as shown previously in **Figure 5**.

Binnewater Reservoir Levels

While the pressure at the Niagara delivery point varies based on the demand at the Bottling Plant and the instantaneous flow through the existing 12-inch main, the levels at the Binnewater Reservoir depend on the system-wide demand and the capability of the Filtration Plant to refill the reservoir and can only be viewed as trends over time, rather than an instantaneous result.

Figure 7 illustrates the predicted reservoir levels at the Binnewater Reservoir under various demand scenarios at the Bottling Plant site and an average demand of 0.25 mgd at The Landing development. Demands were simulated for a period of 500 hours to determine which demand scenarios could be sustained for a long period.

Figure 7 – Model Predicted Binnewater Reservoir Levels Under Niagara Demand Scenarios

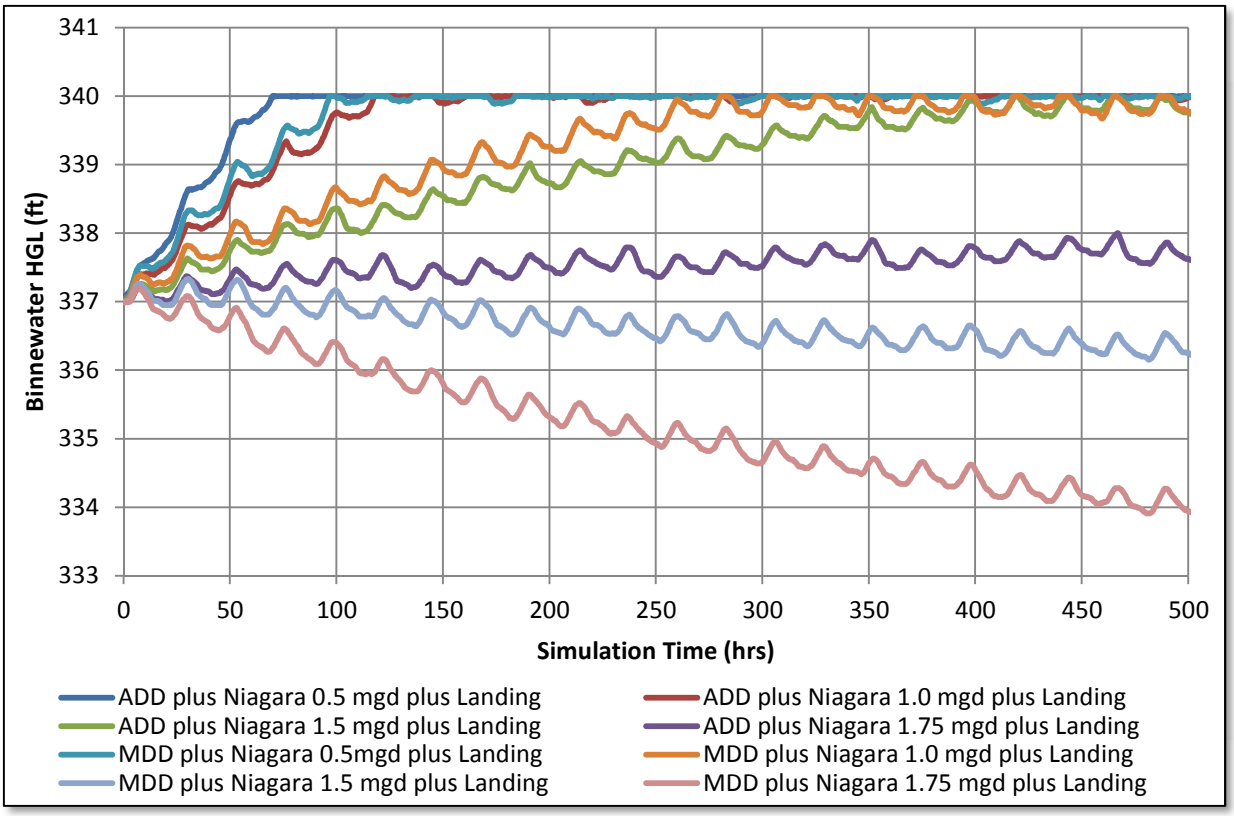


As shown in **Figure 7**, the Binnewater Reservoir levels trend downward from their starting point under most scenarios. A downward trend in reservoir level indicates that the reservoir is slowly dropping. For the ADD scenarios simulated, this possibility is only a concern for the 1.5 mgd and 1.75 mgd scenarios. Under maximum day demand conditions, only the 0.5 mgd scenario results in a constant or upward trend in the reservoir level. However, maximum day scenarios are less severe in that it would be highly unlikely for multiple days to result in maximum day demand in succession. This analysis suggests that a demand of 1.0 mgd to the Bottling Plant site could be safely delivered without lowering the reservoir level significantly. The primary cause of the drop in the reservoir levels is the head loss in the conveyance piping between the Filtration Plant and the Binnewater Reservoir, with much of the head loss occurring in the 20-inch main that serves as the influent pipe to the reservoir as well as the parallel 18-inch and 20-inch mains that stretch over 3 miles to convey water from the Filtration Plant and tie into the 20-inch influent main to the reservoir.

In an effort to reduce head loss to the reservoir and maintain the reservoir levels under larger system demands to the Bottling Plant, a 24-inch main was simulated to parallel the existing 20-inch main that serves as the influent main to the Binnewater Reservoir. This simulated 24-inch main extended from the Binnewater valves adjacent to the NYS Thruway to the Binnewater

Reservoir (~1,200 feet). All other model parameters were kept the same as the previous analysis. **Figure 8** illustrates the predicted Binnewater Reservoir levels with 2 parallel influent pipes to the reservoir.

Figure 8 – Model-Predicted Binnewater Reservoir Levels with Parallel 20-inch (existing) and 24-inch Influent Mains



As shown in **Figure 8**, a parallel main to the existing 20-inch influent pipe to Binnewater can reduce the head loss between the Filtration Plant and Binnewater and the reservoir is capable of maintaining an HGL at or above 337 feet under all modeled scenarios except the MDD plus 1.5 mgd and 1.75 mgd demand at Niagara. Based on the information shown in **Figure 8**, it is safe to assume that a flow of 1.5 mgd could be supplied if the parallel 24-inch main were constructed. However, a flow of 1.75 mgd to the Bottling Plant could result in a long-term loss of water in the reservoir if an extended period of higher than average demand were to occur.

Again, because the projected demands at various developments and wholesale customers in the KWD distribution system can vary significantly, an analysis was performed to relay the results of increased system demand on the Binnewater Reservoir in terms of total system demand rather than incremental demand increases at the Bottling Plant site. As with the 12-inch feeding the Niagara plant site, these results will depend on the actual roughness of the pipes conveying water to and from the Binnewater Reservoir. However, it can be assumed these pipes may have a

slightly higher C-factor (less rough) than the 12-inch main to Niagara as these pipes have likely been flowing at a higher velocity for the majority of their lifespan, which can reduce the corrosion and tuberculation in a pipe. A comparison was then performed to illustrate the difference in the maximum demands at which the existing system can maintain a 337-foot reservoir level compared to the system with a modeled parallel 24-inch pipe from the NYS Thruway valves to Binnewater.

Table 2 lists the predicted maximum overall system demand at which the Binnewater Reservoir can be completely refilled from the supply mains, (i.e. the reservoir HGL does not trend downward) under the existing system conditions and with a parallel influent 24-inch main to the Binnewater Reservoir.

Table 2 – Predicted Maximum System Demand at which the Binnewater Reservoir Maintains 337 Feet – Existing Mains

Assumed C-Factor	Max system demand - Existing System	Max system demand - Parallel 24" Influent Pipe
110	5.7 mgd	6.6 mgd
100	5.2 mgd	6.0 mgd
90	4.7 mgd	5.5 mgd
80	4.2 mgd	4.9 mgd

As shown in **Table 2** and **Figure 8**, a parallel 24-inch main from the NYS Thruway valves to the Binnewater Reservoir would decrease the head loss between the Filtration Plant and the Binnewater Reservoir and increase the overall capacity of the distribution system by maintaining adequate reservoir levels under the majority of modeled Niagara demand scenarios.

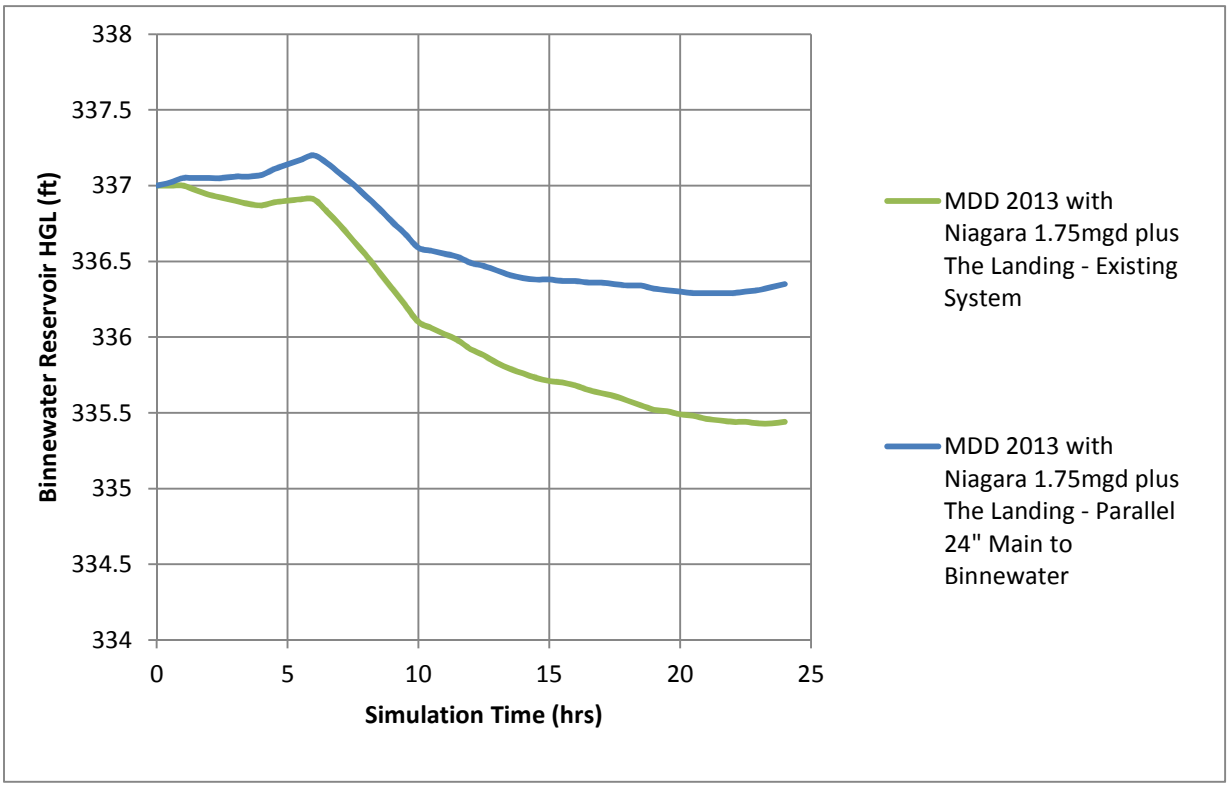
Under the MDD 1.5 mgd and 1.75 mgd to Niagara scenarios, it is recommended that Niagara or other bulk users decrease their demands as they would still create a drop in the HGL at the Binnewater Reservoir levels even with the parallel 24-inch main to Binnewater. Because these are maximum day scenarios, they are not expected to occur frequently, and therefore may not warrant a large capital expense, provided large users in the distribution system (Niagara, Town of Ulster, etc.) understand the limitations.

Distribution System Fire Flow

Fire flow to any point in a distribution system is contingent on the pressure supplied from the water source feeding the hydrant and the cumulative head loss in the pipes between the supply source and the hydrant.

A detailed fire flow analysis was not performed for this project. However, the Binnewater Reservoir is the main supply to the distribution system so if levels can be maintained at the reservoir, similar to where they are currently operating, the distribution system will not see a significant drop in pressure as a result of the Niagara Water demands coming online. Cumulative head loss in the piping will not affect the remainder of the distribution system in this case due to the isolated location of the plant site from the remainder of the distribution system, provided the Binnewater Reservoir levels can be maintained adequately. Therefore, the 24-inch parallel main to the Binnewater Reservoir, discussed in the previous section, will also help provide adequate fire flow to the distribution system as it will maintain the necessary levels at the Binnewater Reservoir. **Figure 9** illustrates the effect of a large fire flow demand on the Binnewater Reservoir levels under the maximum demand scenario with and without a parallel 24-inch main feeding Binnewater. A fire flow demand of 3,500 gpm was simulated at a random point in the KWD distribution system from 6:00 AM to 10:00 AM in the time shown on the graph.

Figure 9 – Effect of Fire Flow on the Binnewater Reservoir under the Maximum Demand Scenario



As shown in **Figure 9**, the scenario in which a parallel 24-inch main is modeled to the Binnewater Reservoir mitigates the drop in simulated HGL and the reservoir recovers much more quickly (i.e., the level begins to return to its starting point) than the existing system.

It should be noted that as developments continue to be planned in the distribution system, such as the Landing, a fire flow analysis should be performed to verify the development can receive the required fire flow. This analysis is will be dependent on the local pipes feeding the hydrants in question as well as the Binnewater Reservoir.

Summary and Recommendations

Head loss in the local water mains is the major cause of the pressure drop shown at the Niagara Water Bottling Plant site and the drop in reservoir levels at the Binnewater Reservoir. Based on the modeled scenarios, the existing 12-inch main will not be able to maintain the required 50 psi at the Niagara Water Bottling Plant site under the higher Niagara demand scenarios or when the flow rate through the pipe reaches somewhere between 1.7 mgd and 2.1 mgd. Additionally, because of the cumulative head loss in the piping between the Filtration Plant and the Binnewater Reservoir, the reservoir level will drop below 337 feet under the majority of the modeled scenarios or at a system demand between 4.2 mgd and 5.7 mgd.

Based on the model results presented in this technical memorandum, the recommended projects necessary to supply the Bottling Plant the required backwash demand and more than 1 mgd of water, while maintaining or improving service to the remainder of the distribution system, are described below and illustrated in **Figure 10**:

- The Bottling Plant site will require a backwash tank capable of supplying backwash demands to the facility. The tank should be sized appropriately and the influent flow to the tank should be limited to reduce head loss in the pipe during the tank fill cycles.

- Install approximately 5,000 linear feet of 12-inch main from the three transmission mains feeding the City to the Bottling Plant site. This new 12-inch main should be cross connected with the three transmission mains and should have tie-ins to the existing, parallel12-inch main at regular intervals.

Install approximately 1,200 linear feet of 24-inch main from the NYS Thruway valves to the Binnewater Reservoir. Ideally, this should provide another inlet to the Binnewater Reservoir. However, if this is not possible due to issues with constructability, the new 24-inch should extend as close as possible to the Binnewater Reservoir.

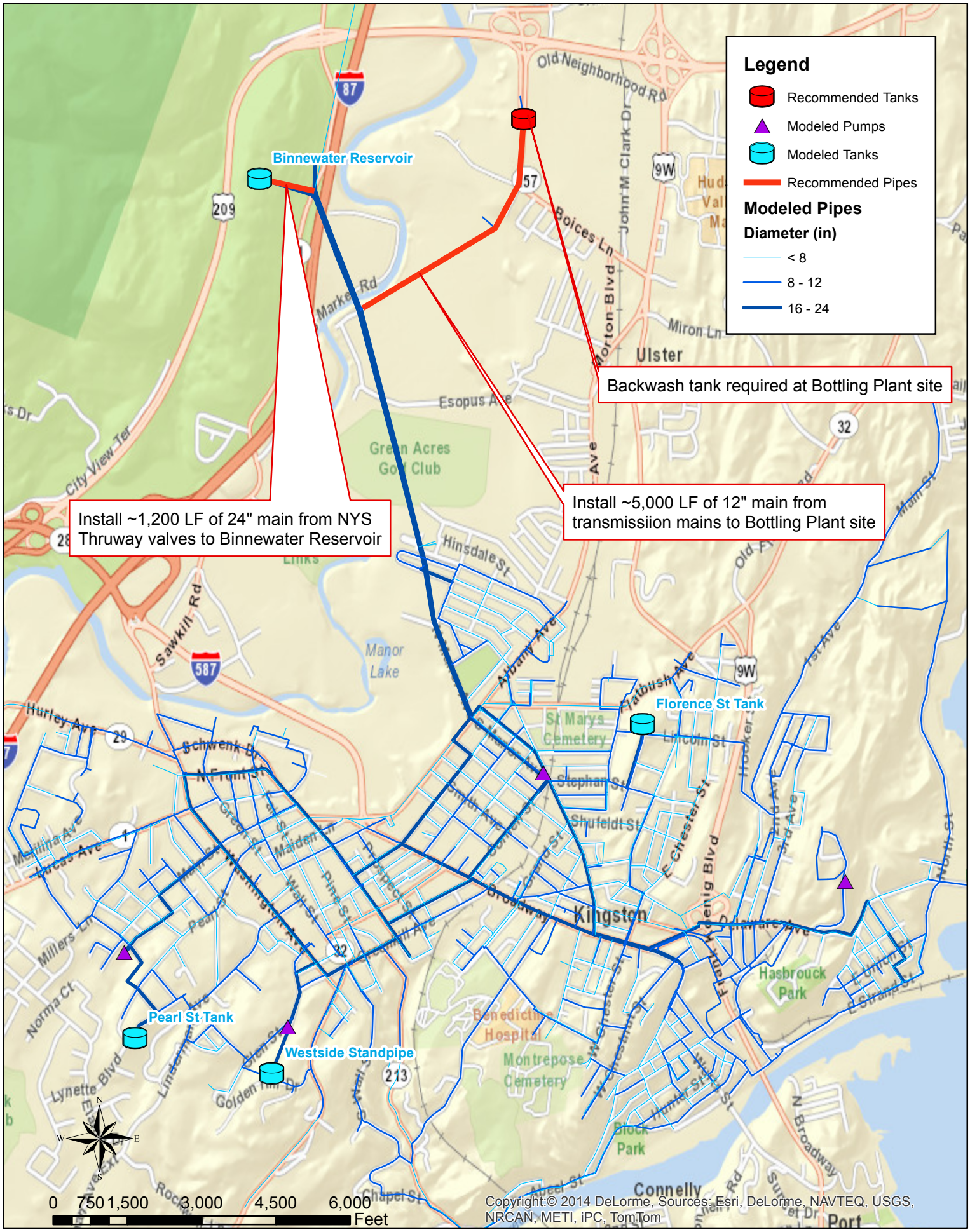



Figure 10 - Recommended Improvements