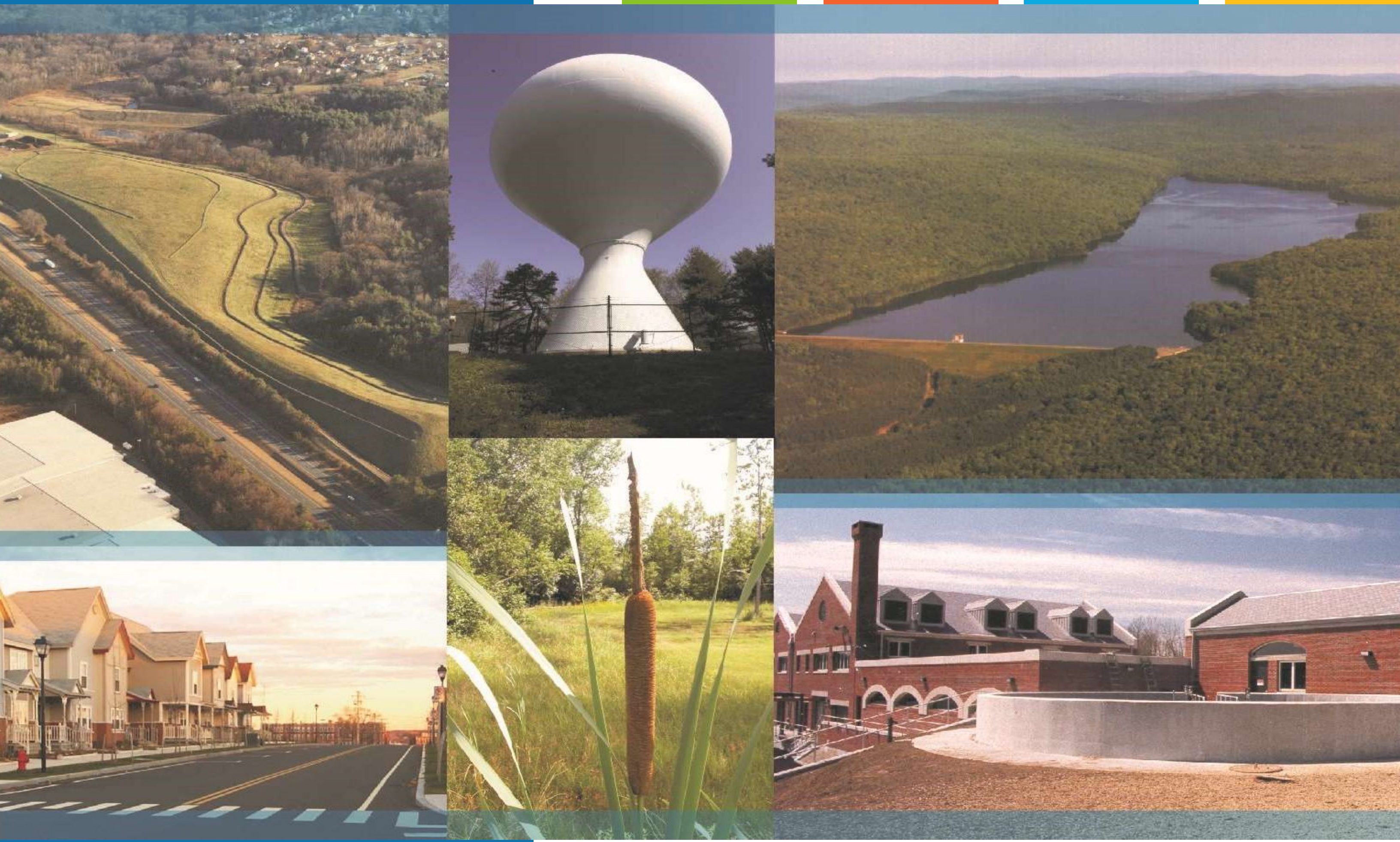

Uxbridge, Massachusetts

Uxbridge Water Distribution System Evaluation

Town of Uxbridge, MA

October 2, 2020

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Section 5 Hydraulic Evaluation

Section 6 Criticality Analysis

Section 7 Water Main Asset Management

Section 8 Recommendations

APPENDIX

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Executive Summary

This report presents Tighe & Bond's 2020 Evaluation of the Uxbridge Water Distribution System in the Town of Uxbridge, Massachusetts. The Uxbridge Water System is composed of three pressure zones, three wellfields, two booster pump stations, 65 miles of water main, and serves approximately 3,500 customers. The scope of this evaluation included an in-depth analysis of the existing water distribution system infrastructure including wellfields, pump stations, storage tanks, and water mains using both the Uxbridge hydraulic model, and existing facility permits and records. A facility conditions assessment was not included in the scope of this evaluation and the capital improvements recommended in this report do not consider the condition of these facilities.

Supply capacity and distribution system hydraulics were evaluated based on the ability to meet current and projected system demand over 5-, 10-, and 20-year planning periods. Population projections were developed using historical population growth and future population projections available from the Central Massachusetts Regional Planning Commission, as well as information provided by the Town's planning department regarding potential developments. Demand projections were determined based on the projected population growth, as well as planning documents for projects currently in progress or under review and information regarding potential areas of water system expansion.

The existing Uxbridge hydraulic model was updated as part of this evaluation. The 2020 model update included hydrant flow testing and model recalibration, demand reallocation using customer billing records, incorporation of recent water main improvements, and development of projected demand scenarios. The updated hydraulic model was used to calculate system hydraulics (pressure, headloss, and flow velocity), available flow, and identify critical water mains. In this analysis, critical water mains are defined as water mains that, if removed from service (such as from a water main break), would isolate either a critical customer or a significant portion of system demand from a tank or wellfield.

The results of the hydraulic, available fire flow, and criticality analyses were used to develop an asset management database prioritizing critical pipe assets. Water main improvements were recommended using asset management ranking criteria for criticality of failure, risk of failure, hydraulic performance, and available fire flow improvement with replacement.

The key findings of this evaluation included:

- Projected demands are close to or exceed current authorized withdrawals.
- Well production capacity is unknown. If current production rates decrease or additional wells need to be taken offline, such as for elevated iron and manganese, current and projected max day demands will not be met.
- The main water quality issues for the Town's wells are elevated levels of iron and
- manganese.
- High elevation customers located near the High Street and Richardson Street Tanks were identified as having low pressure (<35 psi).
- The East Street Pump Station is unable to provide fire protection or estimated peak hour demands with the largest pump out of service. The East Street Service Area lacks water storage, which could alleviate these needs.
- Four sections of pre-1940 universal cast iron water main, totaling 9,285 linear feet, were identified as high priority assets serving critical customers and/or a significant percentage of total system demand.

The findings presented in this report, and summarized above, were used to develop a distribution system improvement plan to satisfy the projected system expansion and development over the 20-year planning period. The 2020 Water Distribution System Evaluation recommends $21.8 million dollars of prioritized distribution system improvements to address supply, pumping, and water main capacity to meet the current and projected future needs of the Uxbridge Water System.

Section 1 Introduction

1.1 Introduction

The Town of Uxbridge Department of Public Works (DPW) provides drinking water to residential and non-residential customers in the Town of Uxbridge and portions of the Towns of Millville and Northbridge. The Uxbridge DPW water supply system consists of seven groundwater wells. The wells are located within the Blackstone River Basin and include Blackstone Wells #1, #2, and #3, Bernat Wells #4, #5 and #6, and Rosenfeld Well #7.

The water distribution system consists of approximately 62 miles of water main ranging in size from two to 20 inches in diameter. The existing water system consists of three service areas: the Low Service Area, the High Service Area and the East Street Service Area. There are two storage facilities and two booster pump stations in the distribution system.

1.2 Objectives

The purpose of this Water System Evaluation and Model Update is to accurately reflect system demands and improvements and modify long-term planning based on the evolving needs of the water supply. This plan updates the existing hydraulic model to reflect current conditions and incorporate scenarios for future conditions including potential development and system expansion, projected demands, and future system supply and capacity. Evaluation of existing and future scenarios is used to update the water main asset management databases, aid in capital planning, and predict the impact of potential system improvements. The plan is meant to allow the Town to continue to provide a sustainable, high-quality drinking water source for residents, businesses, and industry, as well as to operate and maintain the town's drinking water system.

1.3 Water System Overview

The Uxbridge water system serves approximately 3,492 residential, commercial, industrial, and municipal customers. Approximately 96% of customers are residential. In 2019, the system had an average daily demand of 0.676 mgd. Figure 1-1 presents a static hydraulic profile of the water system.

1.3.1 Water Management Act

1.3.1.1 Maximum Authorized Withdrawals

The maximum authorized annual withdrawal volumes of raw water that may be withdrawn by the town in terms of both total annual volume (MGY) and daily average volume (MGD) is defined in the town's Water Management Act (WMA) permit for each five-year period of the permit term. Maximum authorized daily withdrawal volumes (MGD) for the Bernat and Rosenfeld Wells are also defined in the WMA. Maximum average annual withdrawal volumes for the Blackstone Wells are defined in the original registration statement (2-12-304.01).

The permit authorizes the town to withdraw water from the Blackstone River Basin at the rates described in Table 1-1. The maximum authorized annual average withdrawals are provided for each five-year period of the permit term.

TABLE 1-1
Maximum Authorized Annual Withdrawal Volumes

5-Year Periods		Total Raw Water Withdrawal Volumes			
		Permit		**Permit + Registration**	
		Daily Average (MGD)	Total Annual (MGY)	Daily Average (MGD)	Total Annual (MGY)
Period One Years 2-5	3/1/2010 to 2/28/2014	0.21	76.65	0.87	317.55
Period Two(1) Years 6-10	3/1/2014 to 2/29/2019	0.23	83.95	0.89	324.85
Period Three(1) Years 11-15	3/1/2019 to 2/28/2024	0.27	98.55	0.93	339.45
Period Four(1) Years 16-20	3/1/2024 to 2/28/2029	0.32 (0.36(2))	116.80 (131.40(2))	0.98 (1.02(2))	357.70 (372.30(2))

(1) This permit is being issued under the Interim Safe Yield methodology adopted by MassDEP on December 14, 2009. (Refer to WMA for additional information).

(2) Period Four volumes may be increased by an additional 5% buffer to accommodate uncertainty in the growth projections used by the Department of Conservation and Recreation in the 20-year water needs forecasts, and/or to accommodate the water demand of a community that has not met the 65 rgpcd and 10% UAW performance standards, but has met the functional equivalence requirements included in this permit.

1.3.1.2 Maximum Authorized Daily Withdrawals by Source

Maximum withdrawals from groundwater withdrawal points are as summarized in Table 1-2 and are not to be exceeded without advance approval from the Massachusetts Department of Environmental Protection (MADEP).

The Town's permit was issued under the Interim Safe Yield Methodology adopted by MADEP on December 14, 2009. The maximum authorized daily withdrawal rates reflect the MADEP approved Zone II rates, described below:

Wellfields: Maximum permitted withdrawals for the wells reflect the MADEP approved Zone II maximum daily pumping rate for each well.

TABLE 1-2
Maximum Authorized Daily Withdrawal Volumes (2)

Source Name	PWS Source ID Code	MGD
Bernat Well #4	2304000-04G	
Bernat Well #5	2304000-05G	1.33
Bernat Well #6	2304000-06G	
Rosenfeld Well #7	2304000-0AG(1)	0.73

(1) The final PWS source ID code was assigned with the DEP final approval letter.

(2) MADEP approved pumping rates for Blackstone Wells from Registration 2-12-304.01: Well #1 – 0.43 mgd; Well #2 – 0.44 mgd; and, Well #3 – 0.32 mgd.

1.3.1.3 Performance Standard for Residential Per Capita Use and Unaccounted for Water

The WMA permit also includes a requirement for residential gallons per capita day water use (rgpcd) of 65 gallons or less and an unaccounted-for water (UAW) target of 10% of total production. The rgcpd and UAW requirements are applicable to all public water system permittees. Permittees that cannot comply with the targets within the time frame in their permit must meet Functional Equivalence requirements, which are outlined in the WMA permit attachments. UAW is calculated by subtracting total metered use and confidently estimated municipal use (CEMU) volumes from the total volume of finished water entering the distribution system.

As evaluated further in later sections of this plan, the Town is generally meeting the performance standard of residential use of 65 gpcd. However, unaccounted for water has been above the performance standard of 10% in previous years. The town is undertaking annual leak detection surveys to identify and repair leaks. Additionally, a project is currently underway to replace customer side meters, which should improve data accuracy and minimize customer side leaks.

1.3.2 Supply Sources

The water system is supplied by seven wells located across three wellfields - Blackstone Wells #1, #2, and #3, Bernat Wells #4, #5 and #6, and Rosenfeld Well #7. Table 1-3 presents operating characteristics of each source.

The wells are called on to operate based on water level in the storage tanks. The current control scheme allows for remote automatic operation of a combination of wells from two wellfields. The system cannot automatically call on a well from a third wellfield to operate remotely. The town would have to run a well or wells from a third wellfield manually. Therefore, Table 1-3 summarizes the total available assuming Blackstone and Rosenfeld wellfield are active and the largest wellfield (Bernat Wellfield) is offline.

Water from Wells #1, #2, and #3 (Blackstone) is combined prior to treatment, and water from Wells #4, #5, and #6 (Bernat) is similarly combined prior to treatment. Each well discharge line is equipped with a flow meter.

TABLE 1-3
Sources of Supply

Source	**Pump Rating**	**Max Authorized Daily Withdrawal** (1)	**Current Production Capacity** (2)
		(mgd / gpm)	
Blackstone Well #1 (3)			
Blackstone Well #2	1.19 / 825	1.19 / 826	0.55 / 385
Blackstone Well #3			
Bernat Well #4			
Bernat Well #5	1.33 / 925	1.33 / 924	0.67 / 465
Bernat Well #6			
Rosenfeld Well #7	0.73 / 510	0.73 / 507	0.73 / 507
Total Operating (Bernat Offline)	1.92 / 1,335	1.92 / 1,333	1.28 / 892

(1) The max authorized withdrawal rates reflect the MADEP approved Zone II rates.
(2) Based on max production rate observed for combined wellfield in July 2019.
(3) Offline since 2014 (not included in current production capacity).

Figure 1-2 presents the gallons produced per source per month in 2019. Well #7 is the largest producer, and Well #1 was offline. Based on the production data, Well #1 was offline all of 2015 through 2019.

The current production capacities listed in Table 1-3 are based on the max production rates observed for the combined wellfield in July 2019 according to the daily wellfield logs. It is not possible to determine from the data if this rate represents the max production that is possible or the max rate that was required to meet demands. As discussed elsewhere in this master plan, the town should conduct flow tests to verify the actual capacity available from each well.

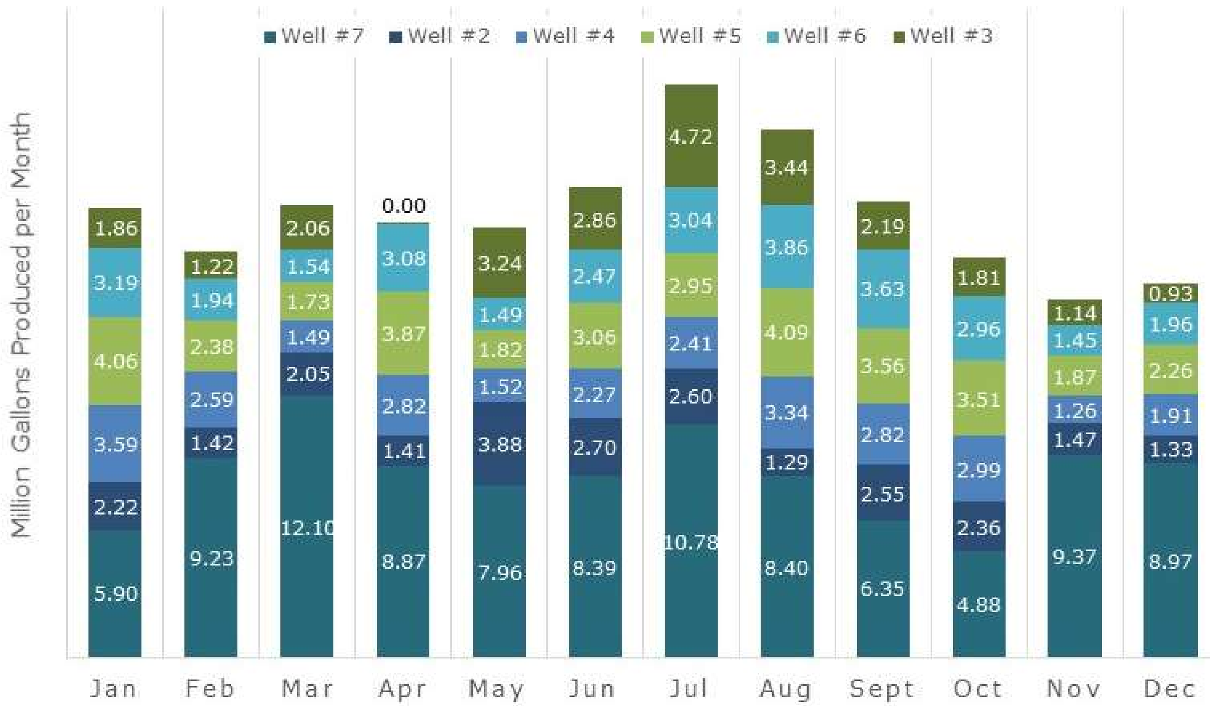


Figure 1-2: Production by Source in 2019

Figure 1-3 compares the historical production of the wellfield in 2018 and 2019 to the maximum authorized daily withdrawal rates (Well #1 offline). The Blackstone and Rosenfeld sources are generally able to withdraw up to their permitted rates, and on occasion have exceeded their permitted withdrawal.

The max day for the combined Bernat Wellfield production is shown, since the wellfield has a total authorized withdrawal rate. This max day is based on the daily sum of the production from the three wells, and not on the sum of the max production from each well (which occurs on different days for each well).

The Bernat Wells appear to be underutilized based on the total daily production data for the combined wellfield. Max day production from each well is shown on Figure 1-4 (max production occurs on different days for each well). The wells have required repairs over the years, including re-sleeving due to metal degradation of the casings. The repairs have impacted the production capacity by decreasing the well diameter. Operationally, the town staff have noticed the wells are worn down and producing less over the years. As discussed further in this report, the town should conduct flow tests at the wellfields (including the Blackstone and Rosenfled wellfields in addition to Bernat wellfield) to determine actual production capacity available from the wells, compare the pump actual operating point to the design curve, and evaluate if well capacity or pumping capacity is declining. These tests should be conducted periodically to monitor for changing conditions. Additionally, we recommend constructing a replacement well near one of the Bernat wells and removing an existing well from service. As conditions change, the town may need to consider additional replacement wells.

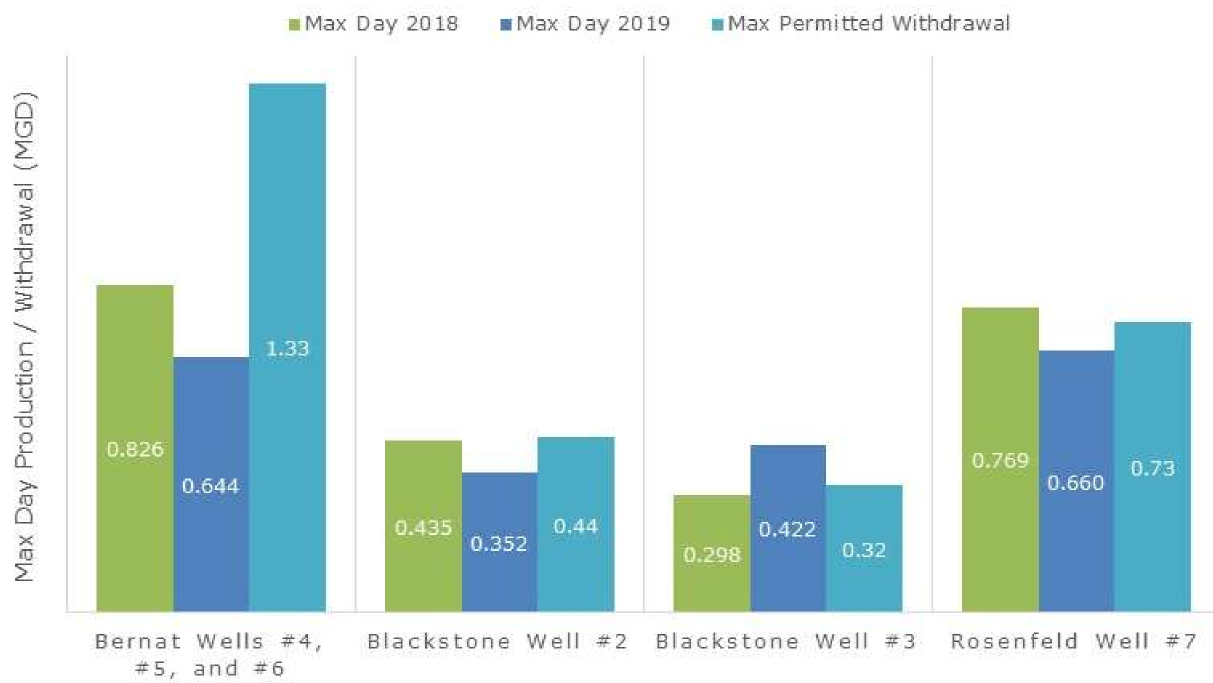


Figure 1-3: Max Day Source Production Compared to Permitted Withdrawal

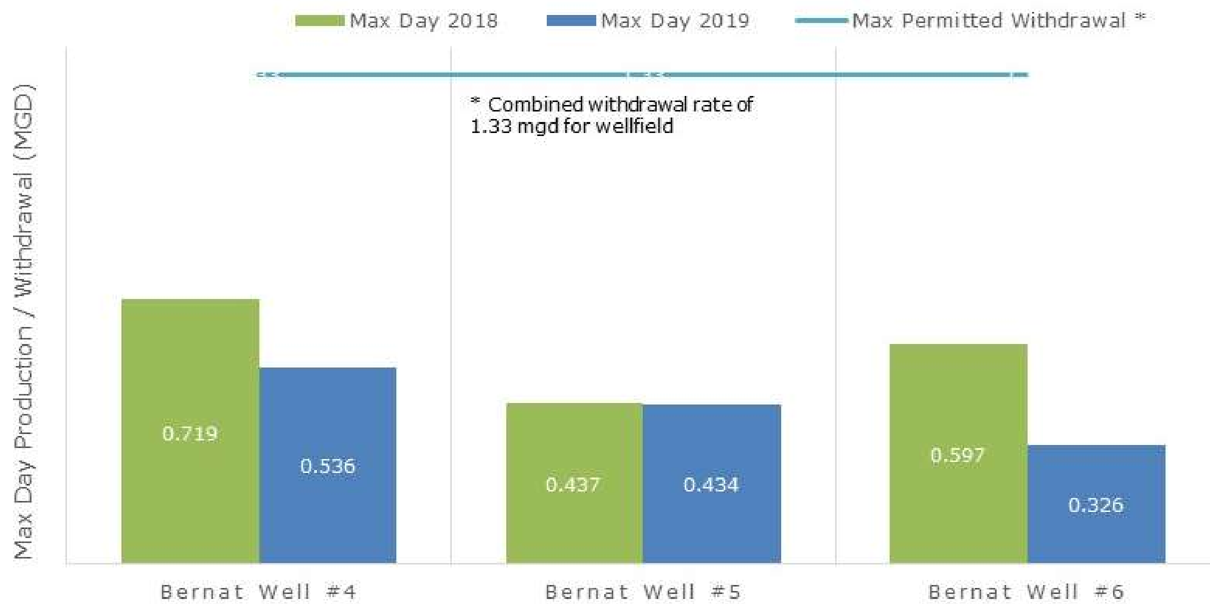


Figure 1-4: Bernat Wellfield Max Day Production per Well

1.3.3 Water Levels

As shown in the hydraulic profile in Figure 1-1, the water system consists of the Main Service (or Low Service) pressure zone and two high service pressure zones. The Main Service pressure zone is supplied by the groundwater wells and the High Street Tank. The High Service Area is supplied by the Fafard Booster Pump Station and the Richardson Tank. The East Street Service Area is supplied by the East Street Booster Pump Station and does not have atmospheric storage.

1.3.4 Treatment

All the system's sources of supply are treated with sodium hypochlorite for disinfection, potassium hydroxide for corrosion control, and polyphosphate for metals sequestering.

1.3.5 Pumping Facilities

All wells have vertical turbine pumps, and all pump wells have back-up power generators.

There are two booster pumping stations in the distribution system that boost pressure to two separate zones (Table 1-4). The Fafard Booster Pump Station supplies the western part of the system, and the East Street Booster Pump Station supplies an area off East Street along the eastern part of the system. Both stations are equipped with standby power equipment.

TABLE 1-4

List of Booster Pumping Facilities

Pump	Motive Power	Purpose	Capacity (gpm)
	Fafard Booster Pump Station		
Pump #1	Electric	Boost Pressure	175
Pump #2	Electric	Boost Pressure	175
Pump #3	Electric	Boost Pressure	175
	East Street Booster Pump Station		
Pump #1	Electric	Boost Pressure	50
Pump #2	Electric	Boost Pressure / Increase Flow	150

1.3.6 Storage Facilities

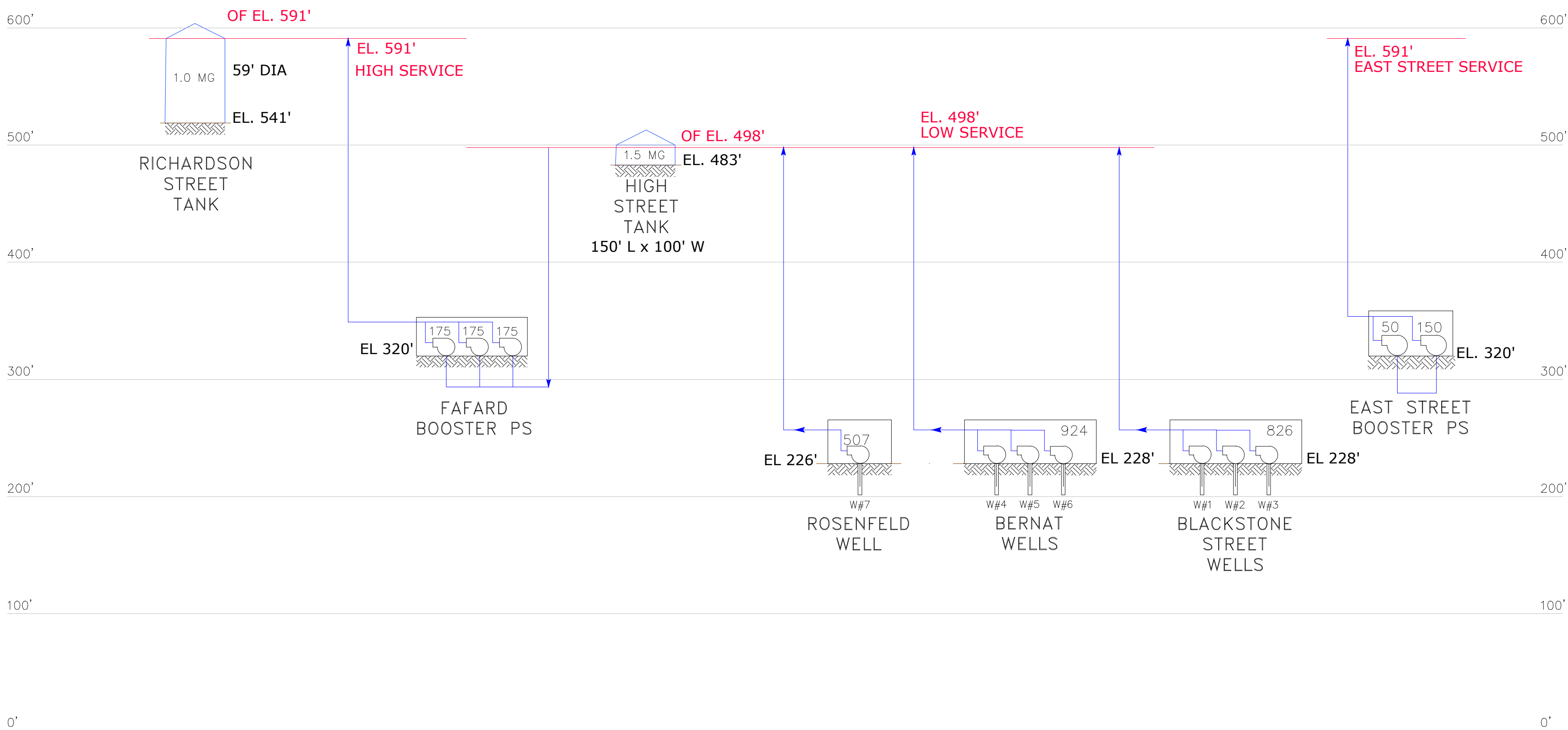
Two storage tanks provide atmospheric storage to the system, as summarized in Table 1-5: High Street Tank and Richardson Street Tank. The High Street Tank is a cast-in-place concrete tank that is partially buried. The Richardson Tank is an aboveground pre-stressed concrete tank.

TABLE 1-5

List of Storage Facilities

Storage Tank	Type	Volume (MG) (1)	Dimensions (ft)	Base Elevation (ft)	Overflow Elevation (ft)	Hydraulic Grade Elevation (ft) (2)
High Street	Concrete, partially buried	1.5	LxW 150x100	483	500	499
Richardson Street	Concrete, above ground	1.0	DIA 59	541	591	590

(1) Nominal capacity.
(2) Assumes 1-ft freeboard below overflow.



NOTES:

1. VERTICAL DATUM NGVD88.
2. PUMP CAPACITIES ARE IN GALLONS PER MINUTE (GPM)
3. WELLFIELD CAPACITIES EQUAL TO MAX DAILY AUTHORIZED WITHDRAWAL RATES.
4. HGL BASED ON FACILITY ELEVATIONS AND REPORTED DISCHARGE PRESSURES. VERIFY PRIOR TO USE.

2020 WATER SYSTEM EVALUATION

FIGURE 1-1
STATIC HYDRAULIC PROFILE

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1.4 Water Quality

Water quality data for the Town's wells were obtained from the Massachusetts Energy and Environmental Affairs (EEA) portal. Source water quality data were reviewed to identify trends in water quality over time which may indicate source degradation, as discussed below.

Additionally, a review of the Environmental Protection Agency's (EPA's) Safe Drinking Water Information System (SDWIS) database was conducted to identify any water quality violations in the water supply system for the previous ten years (2010 – 2019).

- The system reported a health-based violation of "Maximum Contaminant Level Violation, Monthly (TCR)" under the Total Coliform Rule for the compliance period July 1, 2004 to July 31, 2004.

- The system reported a health-based violation of "Maximum Contaminant Level Violation, E. coli (RTCR)" under the Revised Total Coliform Rule for the compliance period June 1, 2016 to June 30, 2016 and indicates that the Violation First Reported Date was March 28, 2019.

- Ultimately, the Town took steps necessary to return to compliance in both instances. The system also received violations related to Regular Monitoring for volatile organic chemicals in 1998. No other health based, monitoring and reporting, or other violations were reported.

Available Consumer Confidence Reports (CCRs) from 2014 through 2018 were also reviewed. The Uxbridge Water System did not have any water quality parameters out of compliance, except for iron and manganese issues discussed further below. A summary of the CCR data is provided in Table 1-7 at the end of this section.

1.4.1 Iron and Manganese

The main water quality issues for the Town's wells are elevated levels of iron and manganese. The US EPA established secondary maximum contaminant levels (SMCLs) for iron and manganese, which are non-mandatory, non-enforceable water quality standards that are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at their SMCLs of 0.3 mg/L for iron and 0.05 mg/L for manganese.

However, the State of Massachusetts established a Regulatory Limit in 2013 pertaining to manganese. The Massachusetts Department of Environmental Protection (MADEP) set a drinking water OSRG (Office of Research and Standards Guideline) for manganese of 0.3 mg/L to protect against potential manganese toxicity. There is no similar OSRG for iron. Potential health effects from manganese are a concern at concentrations approximately six times higher than the SMCL. The OSRG for manganese is based on the EPA's lifetime health advisory level for manganese in drinking water.

Table 1-6 summarizes the range and average concentrations of manganese and iron measured from 2015 through 2019 for each well. The following observations are made:

- In early 2014, Well #1 was removed from service when manganese levels exceeded 1.2 mg/L.

- On average, Wells #2, #3, and #7 have manganese concentrations above the SMCL, and Well #6 occasionally has individual samples above the SMCL.

- Well #6 had a single sample above the SMCL for iron, and other samples have had zero iron.

- On average, Well #3 has iron concentrations below the SMCL, but has had several samples at or above the SMCL, including samples above the MADEP OSRG of 0.3 mg/L.

- Well #2 generally has zero iron or iron levels below the SMCL but has had two samples above the SMCL in the previous 5.5 years.

- Wells #4 and #5 have historically had iron and manganese concentrations below the SMCLs.

TABLE 1-6
Observed Iron and Manganese Concentrations per Source – 2015-2019 (mg/L) [(1)]

	Manganese		Iron	
Source	**Range**	**Average**	**Range**	**Average**
Well #2	0 – **0.494**[(2)]	**0.055**	0 - **0.443**	0.087
Well #3	0 – **0.485**	**0.162**	0 – **0.447**	0.223
Well #4	0	0	0	0
Well #5	0 – 0.028	0.013	0	0
Well #6	0 – **0.072**	0.022	0 – **0.617**	**0.617**
Well #7	0.037 – **0.085**	**0.065**	0	0

(1) Well #1 removed from service in early 2014 when manganese levels exceeded 1.2 mg/L.
(2) SMCLs: 0.3 mg/L for Iron, 0.05 mg/L for Manganese. Numbers in bold exceed the SMCL.

The water quality data discussed above suggests that the current treatment approach, including raw water blending and phosphate addition for iron and manganese sequestration has not always been effective at reducing iron and manganese concentrations or mitigating the aesthetic impacts. Sequestration does not reduce iron and manganese concentrations, rather it prevents precipitation of the metals. Without additional treatment for iron and manganese removal, the raw water quality may limit production from wells with the highest concentrations or require taking a source offline, as experienced with Well #1.

TABLE 1-7
Water Quality Data Summary, as Reported in Annual Consumer Confidence Reports (2014-2018)

	Substance	Unit of Measure	Year Sampled	Applicable Regulation (MCL/MRDL/SMCL/AL)	Applicable Regulation Value	MCLG [MRDLG]	Amount Detected	Range (Low)	Range (High)	Exceedance
Regulated Substances	Chlorine	ppm	2018	MRDL	4	[4]	1	0.63	1.24	No
	Haloacetic Acids (HAAs)	ppb	2018	MCL	60	NA	10	ND	9.8	No
	Total Trihalomethanes (TTHMs)	ppb	2018	MCL	80	NA	27	5.6	27	No
	Barium	ppm	2017	MCL	2	2	0	0.021	0.036	No
	Combined Radium	pCi/L	2013	MCL	5	0	1	0.55	1.4	No
	Fluoride	ppm	2011	MCL	4	4	0	0.10	0.13	No
	E. coli	# of positive samples	2016	see note 1	see note 1	0	2	NA	N/A	Yes
	Alpha Emitters	pCi/L	2016	MCL	15	0	2	ND	3.4	No
	Beta/Photon Emitters	pCi/L	2016	MCL	50	0	33	28.7	39.2	No
	Nitrate	ppm	2018	MCL	10	10	1	0.60	1.1	No
	Perchlorate	ppb	2017	MCL	2	NA	0	ND	0.13	No
	Copper	ppm	2018	AL	1.3	1.3	0.199	NA	NA	No
	Lead	ppb	2018	AL	15	0	2.5	NA	NA	No
	Total Coliform Bacteria	# of positive samples	2018	MCL	TT	NA	1	NA	NA	No
Secondary Substances	Manganese	ppb	2014	SMCL	50	NA	1220 (2)(3)	ND	1220	Yes
			2015	SMCL	50	NA	42	ND	109	No
			2016	SMCL	50	NA	180	ND	493	No
			2017	SMCL	50	NA	131	ND	131	No
			2018	SMCL	50	NA	70	ND	335	No
	Total Dissolved Solids (TDS)	ppm	2018	SMCL	500	NA	202	95	280	No
	Iron	ppb	2017	SMCL	300	NA	396 (2)	368	396	Yes
Unregulated Substances	Chloroform	ppb	2018	NA	NA	NA	13	2.1	13	NA
	Sulfate	ppm	2018	NA	NA	NA	14	6.5	14	NA
	Sodium	ppm	2017	NA	NA	NA	61	27	61	NA
Unregulated Contaminant Monitoring Rule – Part 3 (UCMR3)	1,1-Dichloroethane	ppb	2014	NA	NA	NA	0.05	ND	0.05	NA
	Chromium, Hexavalent	ppb	2014	NA	NA	NA	0.09	0.05	0.09	NA
	Strontium	ppb	2014	NA	NA	NA	110	84	110	NA
	Chromium	ppb	2014	NA	NA	NA	0.09	0.05	0.09	NA

(1) Routine and repeat samples are total coliform-positive, and either is E. coli-positive, or system fails to take repeat samples following E. coli-positive routine sample, or system fails to analyze total coliform-positive repeat sample for E. coli.
(2) The high values shown were detected in a sample taken at Well #1, which was removed from service in early 2014.
(3) Well #1 was removed from service by the Department to reduce the level of manganese in the water.

Section 2
Model Update and Calibration

2.1 Introduction

The Town of Uxbridge Department of Public Works provided the most current version of the water distribution system hydraulic model, GIS data, and ISO hydrant flow test data. The Uxbridge hydraulic model was last updated in 2014. This section details the updates performed as part of this evaluation to bring the previous hydraulic model into conformance with existing system condition and operations and incorporate updated demand projections and system expansion plans.

2.2 Hydraulic Model

2.2.1 Updates to Existing Model

2.2.1.1 Pipe Attributes

Model pipe attributes were updated in the hydraulic model to incorporate improvements performed since the previous model update. Updates were made using a combination of record drawings and town feedback. Distribution system maps showing water main diameter, material, and installation year are included in Appendix A.

2.2.1.2 Elevation Data

Elevations were assigned to all model nodes using the ArcGIS Interpolate Shape and Add Z Information tools. Data was taken from a digital elevation model (DEM) and 2-foot elevation contours extrapolated from 2016 LiDAR data published by the MassGIS Bureau of Geographic Information Systems (MassGIS). Elevations of the nodes (point features) carried in the model data are approximate surface elevations. All model elevations are reported in North American Vertical Datum (NAVD) 1988 (2011).

2.2.1.3 Base System Demands

Customer billing data from 2019 were used to spatially allocate system demand across model nodes. The consumption data were provided by Uxbridge in spreadsheet format and included customer usage per quarter in cubic feet. Usage was converted from cubic feet per quarter to average gpm in 2019 to determine the baseline metered demand for each customer.

Customers were assigned geographic coordinates based on street address (in a process called "geocoding") to create a GIS shapefile. In the geocoding process, some customer addresses did not find a match, or had a low-accuracy match when geocoded. These addresses were manually located and placed using parcel information publicly available from MassGIS.

Billing records categorize customers as either residential or non-residential, and meters are classified as either water or irrigation. Customer-type categories for residential, non-residential, and irrigation were preserved in the geocoded customer database. Customers that did not have an indicated category in the billing data were included as either residential, or non-residential based on property use.

Once geocoded, customer consumption was assigned to the nearest model node using the spatial join tool in the ArcGIS software package. Often, a single model node represents multiple customers and total metered demand at these nodes reflects the demand of all spatially joined customers.

Non-revenue water was calculated as the difference between metered consumption and average day production. Non-revenue water was uniformly allocated across all system nodes for a total average day demand of 0.656 mgd.

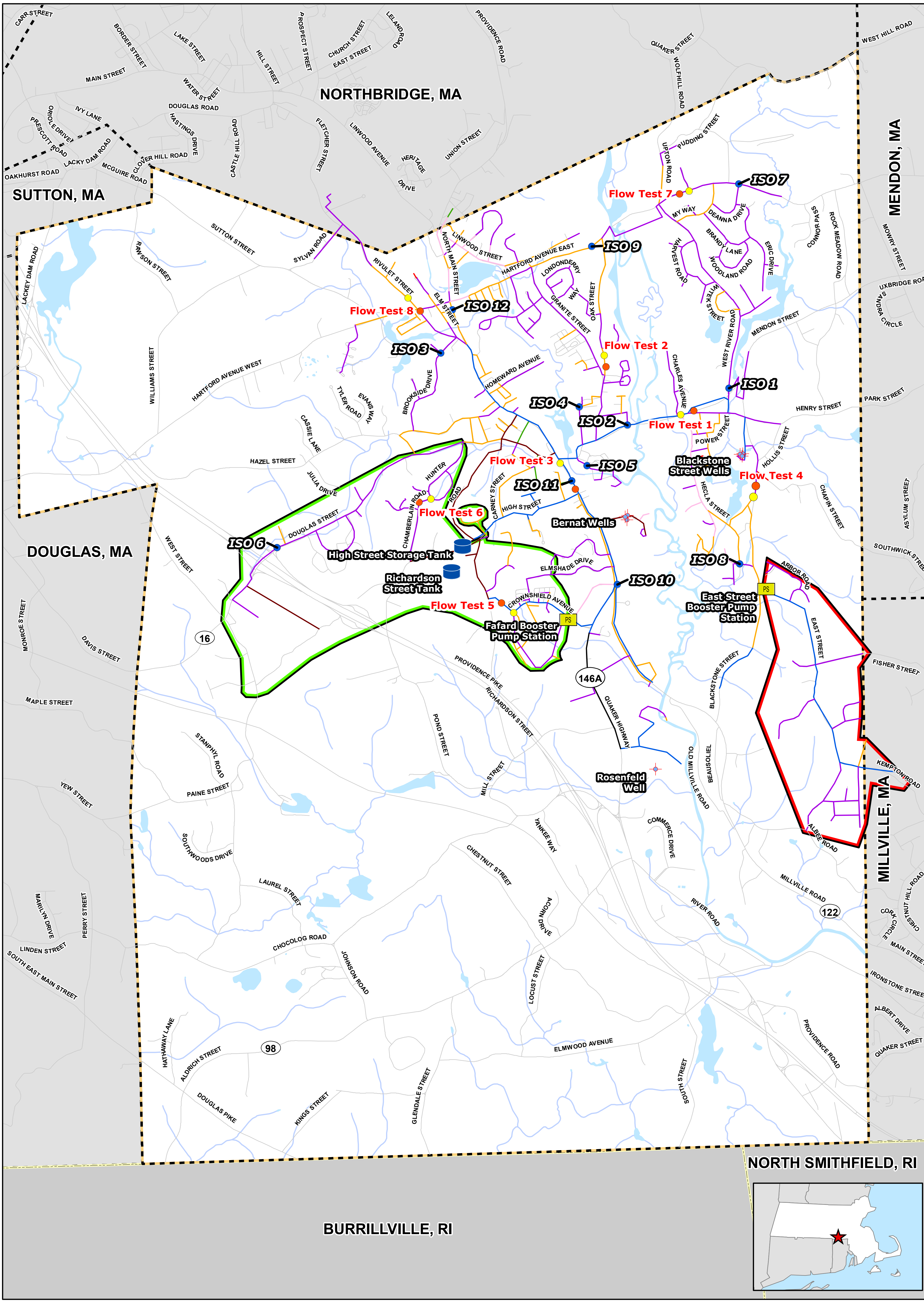
The 2019 maximum demand day (MDD) occurred on July 16, 2019, based on wellfield production records. MDD peaking factors for the model were calculated for the Main and East Street Service Areas by subtracting the Fafard PS flow from total wellfield production on July 16, 2019, resulting in a 1.83 peaking factor (0.865 mgd). Since flow records were not available for the East Street PS, this service area was combined with the Main Service Area for determining MDD. The Fafard PS does not operate daily, so in the absence of hourly storage levels in the Richard St Tank, the max demand week was used to prevent MDD inflation during tank filling cycles. The maximum 7-day average for 2019 (July 10, 2019 – July 16, 2019) results in a MDD peaking factor of 2.77 (0.181 mgd) in the High Service Area. The total modeled MDD is 1.046 mgd.

2.2.2 ISO Verification and Model Calibration

The model calibration was updated using a combination of fire flow testing data collected as part of this evaluation and data included in the 2013 Insurance Services Office (ISO). Calibration groups were created for pipes with similar attributes for age, material, and size. Pipe friction coefficients (C-factors) for each calibration group were adjusted to match measured headloss during the flow tests. Flow test locations are shown in Figure 2-1.

Flow testing is used to calibrate C-factors because the increased flow from opening hydrants generates a measurable drop in pressure as a result of increased headloss. Flow tests were simulated in the model by the measured flow as a “demand” at the node representing the test location.

C-factors were calibrated by measuring the difference between static (non-flowing pressure) and residual (flowing) pressure when the hydrant flow is added as a demand in the model. In this report, Delta P is defined as the difference between static and residual pressure during a fire flow test (Delta P = [Static Pressure] — [Residual Pressure]). The Delta Difference is defined as the difference between field-observed and modeled Delta P (Delta Difference = $[\text{Delta P}]_{field}$ — $[\text{Delta P}]_{model}$). Calculating the Delta Difference prevents compounding static pressure differences during calibration. C-factors were adjusted to minimize the Delta Difference for each flow test with a target calibration criterion of ±5 Static Difference and ±5 psi Delta Difference. Table 2-1 summarizes the flow test and calibration results.



Flowing Hydrant	Storage Tank	Uxbridge Town Boundary	**Water Main Size**
Residual Hydrant	Well	Other MA Town Boundary	2" / 10"
ISO Flow Test Location	Water Bodies	RI Town Boundary	4" / 12"
Pump Station (PS)	East Street Service Area		6" / 16"
	High Service Area		8" / 20"

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet

1:36,000

FIGURE 2-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Flow Test Locations
Uxbridge, Massachusetts

July 2020

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U-5004

TABLE 2-1

Summary of Model Calibration Results

Test Number [1]	Location	Flow (gpm)	Field Static Pressure (psi)	Field Residual Pressure (psi)	Model Static Pressure (psi)	Model Residual Pressure (psi)	Delta Static (psi) [2]	Delta Difference (psi) [2]
Flow Testing Performed by Tighe & Bond on 7/16/20								
Flow Test 1	Mendon St & Charles Ave	500	105	103	112	108	-7	-3
Flow Test 2	Oak St & Warsaw St	530	100	84	100	87	0	4
Flow Test 3	S Main St & Park St	750	100	96	100	99	0	3
Flow Test 4	Blackstone St & Brown Terr	530	110	110	110	102	0	-8
Flow Test 5	Crownshield Ave & Cotton Mill Way	700	40	40	47	46	-7	-1
Flow Test 6	Chamberlain Rd & Hunter Rd	650	75	65	68	57	7	-1
Flow Test 7	Hartford Ave E & Serenity Dr	530	103	79	99	78	4	3
Flow Test 8	Hartford Ave W & Robert St	520	100	90	95	86	5	1
Flow Testing Data from 2013 ISO Survey								
ISO-1	Mendon St & Patrick Henry St	1,360	120	80	114	72	6	-2
ISO-2	Mendon St & Cross St	1,500	119	90	117	90	2	2
ISO-3	Rivulet St and Brookside Dr	1,030	81	40	93	55	-12	3
ISO-4	Capron St at High School	1,240	101	60	105	61	-4	-3
ISO-5	Depot St, 400 ft S of Mendon St	1,300	111	70	115	74	-4	1
ISO-6	Douglas St & Rte 146	730	70	18	70	14	0	-4
ISO-7	East Hartford Ave 5,000 ft E of Deanna Dr	1,060	108	40	107	35	1	-4
ISO-8	End of Bacon St Off Elmdale	1,160	100	50	106	52	-6	-4
ISO-9	E Hartford Ave & Oak St	580	81	50	85	54	-4	1
ISO-10	S Main St & Quaker Hwy	1,580	110	90	108	85	2	-3
ISO-12	N Main St & Sayles St	1,030	98	71	95	66	3	-2

[1] Flow Test locations are shown on Figure 2-1.
[2] Highlighted cells indicate results unable to be calibrated within 5 psi.

As shown in Table 2-1, at several locations static pressures were unable to be calibrated to within 5 psi. Static pressure differences may be related to inaccuracies in elevation data, or differences in operating conditions. During the 7/16/20 flow testing, system operating conditions before and after flow testing were accounted for and multiple pressure gages were used to confirm static pressure readings. Error in static pressure in these tests is likely related to changing system conditions during flow testing or errors in elevation data.

A single flow test (Flow Test 4 on 7/16/20) was unable to be calibrated within 5 psi. Water mains in this part of the system, between Blackstone Wellfield and East St PS, are listed as 6-inch, 8-inch, and 10-inch universal water main installed in 1929. This type of water main calibrated to C-factors ranging from 45-65 in other parts of the system, but show little to no headloss during flow testing, a result unable to be replicated in the model even with C-factors increased to 130.

Another anomaly identified during calibration was unusually low C-factors on Brookside Drive (ISO Site 3). Water main in this part of the System is 8-inch ductile iron installed in 1986. C-factors were locally reduced to 50 in Brookside Drive near the intersection with Rivulet St to replicate observed headloss. The unusually high headloss in this part of the model paired with the observed static pressure 12 psi lower than modeled results suggests there may be a hydraulic constriction in the vicinity of this test, potentially a closed or partially closed valve.

Flow Tests data for ISO Site 11 was discarded during model calibration. Significant differences were observed between model results and recorded pressure changes. Additionally, the water main in North Main St was replaced in 2015 so current conditions are expected to vary from those reported during 2013 flow testing.

A summary of C-factors assigned to the model pipes is provided below in Table 2-2.

TABLE 2-2

Summary of C-Factors by Pipe Material and Installation Year - Uxbridge, MA

Material	Diameter Range (in)	Assigned C-Factor (1)	Adjusted C-Factor Range	Year Installed Range
PVC	6-8	130	130-140	1980-1995
Universal	2-12	70	30-130(2)	1929-1949
Cement Lined Cast Iron	6-8	90	90-130	1965-1967
Ductile Iron (Pre-2000)	6-16	110	50-130(2)	1940-1999
Ductile Iron (Post-2000)	4-20	120	120-140	2000-2016
Unlined Cast Iron	4-16	70	50-75	1890-1946

(1) Original pre-calibration C-factors

(2) In several locations pipes calibrated with C-factors outside typical ranges. These locations are considered outliers and are described further in the text.

Section 3
Demand Projections and System Expansion

This section examines the water system's existing service area and develops population and demand projections based on potential growth and system expansion for the planning periods ending 2025, 2030, and 2040. Historical demand data is evaluated to determine usage for the existing customer base, which forms the basis for the demand projections.

Figure 3-1 at the end of this section illustrates the current area served by the water system and is based upon the location of existing water mains and service connections, as well as tax assessors' parcels and existing building locations. The distribution system map also illustrates the wellfields, storage tanks, pump stations, and the boundaries of the two high pressure service zones. Other small public water systems within the Town are also presented on the map and listed in Table 3-1. These systems are presented for reference; interconnections to these systems are not anticipated.

Figure 3-2 at the end of this section illustrates areas of potential service expansion, which are based on areas identified for potential growth as described below. These areas consist of potential new developments and potential system expansion to serve other areas in town, including residential areas listed in Table 3-5 and commercial/business developments listed in Table 3-10 further below. The geographic system expansion shown is used to project water demands in Section 3.2.

TABLE 3-1
Other Public Water Systems in Uxbridge

PWS Name	PWS ID	Location
Bangmas Farm Store and Dairy Barn	2304014	504 W Hartford Ave
BJs Wholesale Distribution Center	2304013	869 Quaker Highway
Blissful Meadow Golf Club	2304010	801 Chocolog Road
Faith Fellowship	2304015	647 Douglas Street
Gia Restaurant	2304007	785 Quaker Highway
Green Room Billiard Club	2304017	535 Quaker Highway
McDonalds	2304002	200 Quaker Highway
Quaker Motor Lodge	2304006	442 Quaker Highway
Quaker Tavern	2304005	466 Quaker Highway
True Data Products	2304012	775 Quaker Highway
West Hill Dam	2304008	518 Hartford Ave E

3.1 Population Trends and Projections

Projections of the number of people to be served by the Town's water system provide the basis for projecting future water demand needs and assessing the adequacy of the existing supply sources. This Section presents population trends over the past five years and projections for 2025, 2030, and 2040.

3.1.1 Historical and Projected Population for the Town of Uxbridge

Historical population data, annual estimates, and population projections were obtained for the Town of Uxbridge. Table 3-2 and Figure 3-3 show the historical and projected populations for the town.

The population increased between 1990 and 2010, including a 20% increase from 2000 to 2010 (about 2% per year), according to the U.S. Census. The American Community Survey's (ACS) annual estimates indicate slight increases of less than 1% per year through 2018. Uxbridge's population was 13,457 at the time of the 2010 Census.

Population projections were obtained from the Central Massachusetts Regional Planning Commission (CMRPC) and are based on 2018 Regional Transportation Plan population projections developed by MassDOT and the University of Massachusetts Donahue Institute (UMDI). Projections are provided in 5-year intervals from 2020 to 2040.

The CMRPC projections predict a much higher 2020 population than the ACS annual estimates through 2018. Therefore, the projections used in this plan are based on adjusting the CMRPC projections by reducing the totals to better align with the ACS estimates, as shown in Figure 3-3 (2060 projections are extrapolated). The projections indicate a sustained increase in the town's population.

TABLE 3-2
Town of Uxbridge Population Projections

		Population	CMRPC (1)	Projections Used in this Plan
U.S. Census	1990	10,415		
	2000	11,141		
	2010	13,457		
Post-Census American Community Survey (ACS) Annual Estimates	2011	13,233		
	2012	13,382		
	2013	13,487		
	2014	13,609		
	2015	13,709		
	2016	13,765		
	2017	13,815		
	2018	13,903		
	2020		15,981	**14,781**
	2025		17,356	**16,156**
	2030		18,681	**17,481**
	2035		19,220	**18,020**
	2040		19,722	**18,522**
	2060 (2)		*24,339*	**23,139**

(1) Central Massachusetts Regional Planning Commission population projections based on 2018 Regional Transportation Plan population projections by MassDOT and the University of Massachusetts Donahue Institute (UMDI).
(2) Projections in italics were extrapolated; 2060 based on same percent change from 2020 to 2040 assumed for 2040 to 2060.

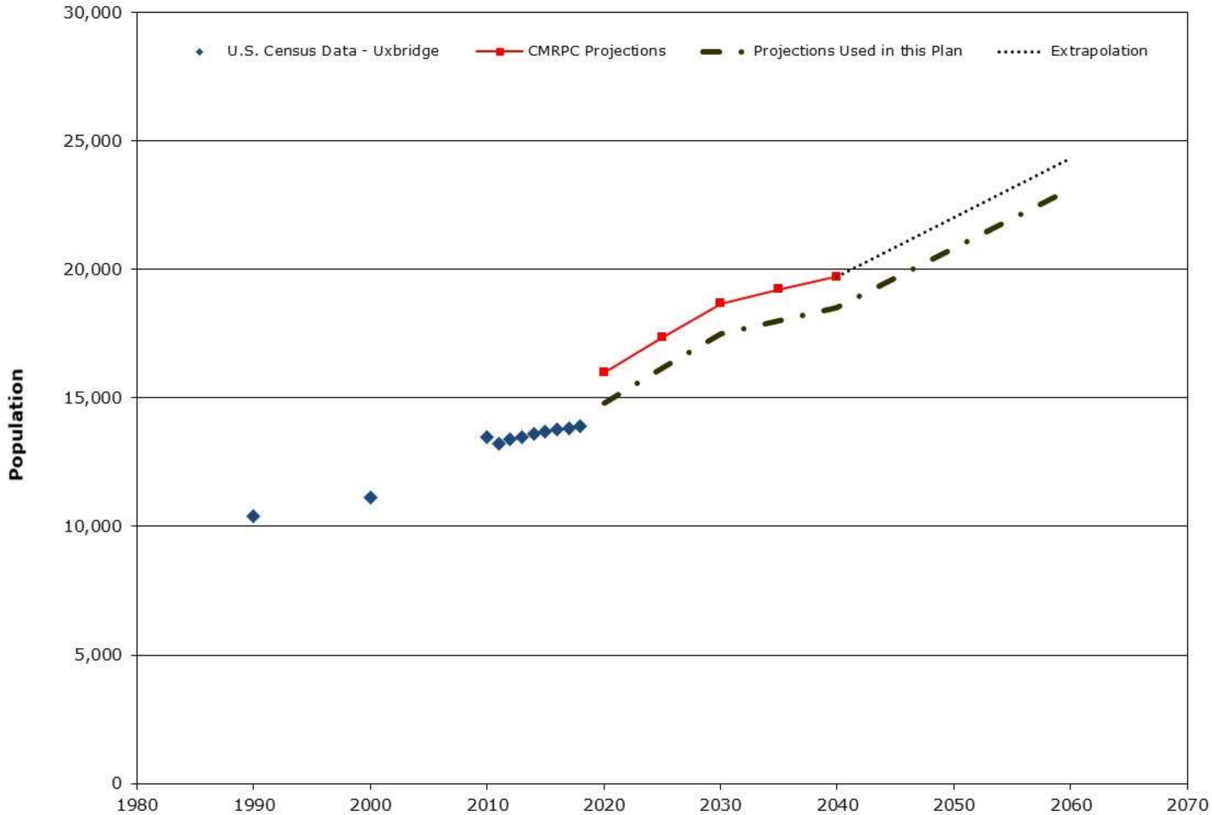


Figure 3-3: Uxbridge Population Projections

3.1.2 Historical Population Served by the Water System

The historical population served by the water system in Uxbridge is based on the town's records for number of residential connections and estimates of the average household size (people per household, or ppl/hh) by account type. Household sizes are based on the annual ACS estimates for single-family, two-family, and three-family units; an assumed 2 ppl/hh for condominiums and Code 111/112 units; and, an assumed 1 ppl/hh for elderly housing units.

Table 3-3 provides a summary of number of residential connections and of the population served estimate (detailed calculations based on the Town's records of number of connections are included in Appendix B). As shown, the water system is estimated to serve 80% to 83% of the Town's population, or 11,491 people as of 2019.

Table 3-4 summarizes the total number of connections by user category as reported in ASRs, including Residential, Residential Institutions, Commercial, Industrial, Municipal / Institutional / Non-Profit, and Other.

TABLE 3-3

Historical Population Served

	2014	2015	2016	2017	2018	2019
Residential Connections	3,198	3,220	3,237	3,281	3,330	3,356
Population Served Estimate (1)	10,827	11,038	11,263	11,210	11,368	11,491
Percent of Town-Wide Population (2)	80%	81%	82%	81%	82%	83%

(1) Population Served Estimates detailed in Appendix B, based on the sum of the following:
- Total Number of Single-Family, Two-Family, and Three-Family Residential Connections multiplied by the ACS Average Household Size for the respective year (ppl/unit);
- Total Multi-Family Residential Connections multiplied by 2 ppl/unit (includes service connections with 4-8 units and with greater than 8 units, Quaker Village Condos (48 units), Crown & Eagle Apartments (61 units), and Blanchard Apartments (25 units));
- Elderly Housing Authority Connections multiplied by 1 ppl/unit (includes Calumet Court (30 units) and Centennial Court (56 units)).

(2) Based on ACS Yearly Estimates of Town Population, Table 3-2 (2018 and 2019 percent served based on 2018 ACS Estimate).

TABLE 3-4

Number of Service Connections by User Category from ASRs

Year	*Residential*	*Residential Institutions*	*Commercial*	*Industrial*	*Municipal / Institutional / Non-profits*	*Other*	*Total*
2015	3,220	1	90	2	15	27	3,355
2016	3,237	1	86	2	17	25	3,368
2017	3,281	1	86	2	16	27	3,413
2018	3,330	1	88	2	15	25	3,461
2019	3,356	1	86	2	17	30	3,492

3.1.3 Projected Population Served by the Water System

The population served by a system can increase in two ways: to serve population growth in town due to new people and new residential developments, or to serve more of a town's existing population by expanding the infrastructure to serve residents currently served by private wells, which may be located within the existing service area or that could be served by expanding the existing service area.

3.1.3.1 General Population Growth and New Residential Developments

As discussed, the CMRPC Town-wide population projections indicate a sustained population increase in Uxbridge through 2060. The planning office for the town was contacted to discuss the reasonableness of the CMRPC population projections and current or future projects that may impact the population served by the water system. The planning office agreed the town's population is increasing, consistent with current patterns of residential growth. The planning office also provided information on projects approved since 2015 and others that are currently in progress or under review.

Descriptions of identified new developments that may be served by the water system are summarized in Table 3-5, including the planned number of housing units and estimated population served for each project. The estimated number of housing units listed for each development is based on information provided in the planning decision documents. The number of people for residential developments listed in Table 3-5 was calculated based on 2.90 ppl/hh (2018 ACS estimate). These potential new residential developments are shown on Figure 3-2 by planning period. The numbers in Table 3-5 are referenced on Figure 3-2.

Population served projections for the system are based on the larger of:

- The anticipated population from specific new developments that may be served by the water system (listed in Table 3-5), OR

- The portion of the Town-wide population growth anticipated to be served by the water system, based on the assumption that future population growth will be served in the same proportion as the existing population (i.e. change in population served = change in population * 2019 % of population served). The percentage of the population currently served in town is 83%.

Generally, the projected population from new developments listed in Table 3-5 is consistent with serving 83% of the Town-wide projected growth. Therefore, residential development of the specific parcels is assumed to be included in the general Town-wide projected growth. This does not include system expansion to serve existing residents, as described below.

The planning office also identified potential new business and commercial developments. Water demands for these non-residential projects are calculated and discussed in Section 3.2.

3.1.3.2 Water System Service Area Expansion

In addition to growth due to new construction and new residents, the population served by a water system can increase to serve more of a Town's existing population, including residents currently served by private wells.

The following potential areas of geographic system expansion are considered:

- **Expansion along Route 122 (Millville Road) and Albee Road, in the vicinity of the East Street High Service Area:** as shown on Figure 3-2 and summarized in Table 3-5, the existing service area could be expanded to serve up to 100 existing residences located along Millville and Albee Roads. This area includes 21 undeveloped parcels in Residential Zones that could be developed into new residences.

  Expanding the system in this area would require approximately 17,500 feet of new water main.

- **Expansion along Route 16 near Route 146 to the Douglas town border:** the planning office indicated that there are several parcels in the Route 16 corridor that are not currently on the Town water system and which would benefit economically from being on municipal water. Included is a parcel that abuts the Town of Douglas and has been the subject of preliminary conversations regarding a collaboration between Uxbridge and Douglas to create a new Industrial/Commercial development. Potential commercial projects are discussed further in Section 3.2.

  Expansion of the system in this area could also include connecting to 13 existing residences. This would require approximately 4,800 feet of new water main to the Douglas town border. None of the undeveloped parcels in this area are in Residential Zones; therefore, population projections from developing these parcels were not determined.

  Additional expansion in this area could include connecting to 23 existing residences, as a result of installing 9,400 feet of new water main to loop the Douglas Street / Rt 146 side of the distribution system.

- **In-fill expansion within the boundaries serviceable by the existing system:** this consists of connecting developed and undeveloped parcels that are located within 500 feet of an existing water main. As summarized in Table 3-5, there are 213 existing residences that are not yet connected to the system, as well as 236 undeveloped parcels in Residential Zones that could be developed as residences and connected to the system. Population projections for 34 undeveloped parcels in non-Residential Zones were not determined.

Additionally, the Town planning office indicated there is a Master Plan in progress for the North and South Main Streets to reinvent the corridor as a mixed-use area, thereby providing for a better blend of residential and commercial uses. The timeline for presenting the Master Plan to the Town boards and committees has not yet been determined. Most of this area is already served by the water system, but there are 6 undeveloped parcels in Residential Zones that could be developed as residences and connected to the system.

- **Quaker Highway:** the Town planning office indicated the Quaker Highway area is being considered for potential redevelopment, but plans are not yet well defined, as summarized below. The Town retained GHD in 2015 to perform an economic development and utilities extension analysis for Quaker Highway. The assessment focused on economic development opportunities that may develop if sewer service is extended in this area. As shown in the water distribution system service area map in Figure 3-1, water in this area is provided by small public water systems other than the town's water system, as well as presumably by private wells. System expansion to serve the southern portion of Quaker Highway to the Rhode Island border would require approximately 16,200 feet of new water main.

  The 2015 analysis found that near-term opportunities for economic development lay primarily in limited industrial uses such as warehouse and distribution facilities or light manufacturing, which tend to be low water users with a low need for sewer service. However, the analysis theorized that extending sewer service in this area could attract multi-family housing development in connection with the Boston-Worcester-Providence labor market area. Longer-term opportunities identified included retail, restaurant, commercial, and multi-family residential, which would all benefit from sewer service. In particular, the study indicates that rising demand for housing in the Blackstone Valley coupled with proximity to regional travel routes in Uxbridge could generate multi-family development proposals in this area of town if additional sewer capacity is provided. The study recommends the town anticipate this potential growth and plan accordingly, if multi-family housing in this area is desirable; if undesirable, the study recommends enacting proper protection before acting on a sewer extension plan.

  The study included a build-out analysis and developed water demand and wastewater flow projections for different development scenarios: for example, if all developable parcels are rezoned and redeveloped into single-family homes, or if all developable parcels are rezoned and redeveloped into commercial properties.

  As noted in the report, the build-out analysis provides a planning tool to help assess the development potential of the town, predicting future conditions in Town when all developable space has been developed to its highest water use potential. This area includes 4 undeveloped parcels and 27 developed parcels in Residential zones, as well as 28 undeveloped Non-Residential Zoned parcels and 48 developed Non-Residential Zoned parcels.

  However, given that this planning process is in the very early stages at this time and that the build-out analysis represents an ultimate water use scenario, population projections for this area were not determined nor were the build-out water demand projections included in this master plan. As the Town further evaluates and considers plans for this area regarding growth (i.e., consider attracting multi-family residential vs. maintaining light industrial), potential demand projections can be added to the projections developed in this master plan.

Finally, the Town planning office indicated they are proposing a bylaw revision that will create a Mixed Commerce Overlay District in the Route 146 corridor. The plan encompasses over 5000 acres and extends the full length of Uxbridge. Outside of the two areas discussed above (the Route 16 corridor near Route 146 to Douglas and the southern portion of Quaker Highway), expansion of the water system to serve more of Route 146 would require significant new infrastructure. Therefore, it is not considered feasible to serve new areas along Route 146.

TABLE 3-5

Potential New Residential Developments and System Expansion to Serve Existing Residents

Development	No. of Housing Units	Projected Population [1]	No. on Figure 3-2
2025 Planning Period			
ARIS Group, Old Elmdale Road - 19 new residential units[2]	19	see note 2	9
TDJ Materials, 300 Mendon Street - 25 new duplexes	50	see note 2	3
111 Rivulet Street - sub-division into 2 lots	2	see note 2	2
31 Sylvan Road - sub-division into 2 lots	2	see note 2	1
Tucker Hill Road - full build-out (14 existing, 25 total)	11	see note 2	8
68 Henry Street - 12 new single-family homes	12	see note 2	4
Cote Lane (Stage One Investors LLC) - 6 new single-family homes	6	see note 2	5
Kettle Hill Road - 3 new single-family homes	3	see note 2	11
Forest Glen Estates, off Taft Hill Lane - new age-restricted community	44	see note 2	7
Rt 16 Corridor near Rt 146 to Douglas town border and system loop - Expansion to serve existing residences (Agricultural, Business, and Industrial Zoned)	36	104	12
Route 122 (Millville Road) and Albee Road Expansion to serve existing residences	100	290	13
Route 122 (Millville Road) and Albee Road Expansion to serve potential new residences [3]	21	see note 2	13
Potential in-fill - connecting developed parcels not yet connected to the town system, that are located within 500 ft of an existing water main [5]	213	618	in-fill
Potential in-fill - connections to potential new residences in undeveloped Residential parcels, that are located within 500 ft of an existing water main [6]	236	see note 2	in-fill
2025 Total	732	945	

TABLE 3-5

Potential New Residential Developments and System Expansion to Serve Existing Residents

Development	No. of Housing Units	Projected Population (1)	No. on Figure 3-2
2030 Planning Period			
North and South Main Street - Master Plan in progress to encourage mixed-use, potential new developments (4)	6	see note 2	14
2030 Total	6	--	
2040 Planning Period			
Quaker Highway - Expansion to serve potential area of redevelopment / new developments (7)	--	--	15
2040 Total	--	--	

(1) Based on 2.90 people/household (2018 ACS Estimate)

(2) Residential development of this specific parcel is assumed to be included in the general Town-wide projected growth.

(3) Based on 21 undeveloped parcels in Residential Zones.

(4) Unserved parcels along North and South Main Street include 6 Residential Zoned parcels that are currently undeveloped.

(5) Includes developed parcels in Agricultural (20), Industrial (1), and Business (1) Zones that consist of Residences.

(6) Population projections or demands for undeveloped non-Residential parcels were not determined: fifteen (15) Agricultural, ten (10) Business, and nine (9) Industrial Zoned.

(7) Potential area of redevelopment is not yet well defined; therefore, demand projections were not determined. This area includes 4 undeveloped Residential Zoned parcels and 27 developed Residential Zoned parcels.

3.1.3.3 Population Projections by Planning Scenario

Table 3-6 summarizes the population projections by planning period. Three growth scenarios are presented, given the inherent uncertainty regarding requests for service from existing residences and further expansion of the water system and infrastructure. The growth scenarios presented include:

- **Scenario A:** Serving New Growth in Town
- **Scenario B:** Population estimates from Scenario A plus New Population from In-Fill
- **Scenario C:** Population estimates from Scenario B plus New Population from System Expansion

TABLE 3-6
Projected Population Served

Scenario A	Current and Projected Town Population (1)	New Growth in Town to be Served by the PWS (2)	Total Population Served
2019	13,903		11,491 (5)
2025	16,156	1,862	13,353
2030	17,481	1,095	14,448
2040	18,522	860	15,308
Scenario B	**Population Served from Scenario A**	**New Population Served from In-fill (3)**	**Total Population Served**
2019	11,491		11,491 (5)
2025	13,353	618	13,970
2030	14,448		14,448
2040	15,308		15,308
Scenario C	**Population Served from Scenario B**	**New Population Served from System Expansion (4)**	**Total Population Served**
2019	11,491		11,491 (5)
2025	13,970	290	14,260
2030	14,448		14,448
2040	15,308		15,308

(1) Projected Town Population based on adjusted CMRPC projections.
(2) Based on serving projected town growth within existing service areas in same proportion as existing percent served (83%).
(3) Includes new people served within existing service area due to in-fill (connecting existing parcels with private wells within 500-ft of existing mains).
(4) Includes new people served due to expanding service area: Rt 16 corridor near Rt 146 to Douglas town border, and Route 122 and Albee Road Expansion.
(5) Current population served estimate (2019).

3.2 Water Consumption Trends and Projections

Water demand trends and projections are presented below and compared to existing sources to determine the adequacy of supplies to meet current and future needs.

3.2.1 Historical Water Demands

Historical demands were evaluated separately by user category as presented in Table 3-7 and Figure 3-4. Residential demands and unaccounted for water (UAW) make up the largest portions of the total system production, at 74% and 15.9% in 2019, respectively. UAW is calculated by subtracting total metered use and confidently estimated municipal use (CEMU) volumes from the total volume of finished water entering the distribution system. CEMU can include uses such as fire protection and training, hydrant and water main flushing, main construction, flow testing, bleeders and blow-offs, tank overflow and drainage, sewer and stormwater system flushing, street cleaning, source meter calibration adjustments, and major water main breaks (excluding leak detection). These types of uses are not metered and do not generate revenue for the system (non-revenue water).

As shown on Figure 3-4, demands have remained relatively consistent in the previous five years, except Commercial demands have steadily increased in the previous three years. UAW averaged 18% of total production in 2015 to 2019. The performance standard in the town's WMA permit is 10% or less of unaccounted for water. Appendix B of the Town's Water Management Act permit details the requirements associated with meeting the UAW standard. As mentioned, some mitigation efforts conducted include annual leak detection surveys and replacement of customer meters.

Table 3-8 presents average day, maximum month, and maximum day system demands and a peaking factor summary of max month to average day and max day to average day demands. For the purposes of determining future max month and max day demand projections, peaking factors of 1.40 and 2.00 are used, respectively. It is assumed these peaking factors will remain constant through the 2040 planning period.

Table 3-9 presents the per capita consumption rates based on the population served estimates presented previously. Per capita consumption has remained stable, averaging 45 gallons per capita per day (gpcd), and reaching as high as 49 gpcd. For purposes of determining future residential demands, a per capita consumption rate of 50 gpcd is used. The performance standard in the town's WMA permit is 65 gpcd.

As with residential usage, it can be assumed that commercial water use is proportional to the population served by a system. Between 2015 and 2019, commercial demand ranged from 0.017 mgd to 0.023 mgd. Based on the population served estimates, this yields an average commercial demand of 1.69 gpcd, as shown in Table 3-9. For purposes of determining future additional commercial demands in Uxbridge proportional to changes in population, a per capita consumption rate of 1.80 gpcd is used.

TABLE 3-7

Historical Demands by User Category - Uxbridge System

Year	Residential (mgd)	Residential Institutions (mgd)	Commercial (mgd)	Industrial (mgd)	Municipal / Institutional / Non-profits (mgd)	Other [1] (mgd)	CEMU [2] (mgd)	Unaccounted for Water (UAW) [3] Demand (mgd)	Unaccounted for Water (UAW) [3] Percent of Total	Total Production (mgd)
2015	0.545	0.004	0.018	0.0007	0.035	0.0060	0.0120	0.125	17%	0.744
2016	0.527	0.005	0.018	0.0010	0.025	0.0038	0.0181	0.113	16%	0.711
2017	0.491	0.005	0.017	0.0008	0.023	0.0047	0.0126	0.103	16%	0.657
2018	0.499	0.005	0.019	0.0044	0.029	0.0033	0.0094	0.187	25%	0.756
2019	0.500	0.006	0.023	0.0005	0.019	0.0036	0.0163	0.108	16%	0.676
% of total in 2019	74.0%	0.8%	3.4%	0.1%	2.9%	0.5%	2.4%	15.9%		

(1) Metered use not included in other metered categories.
(2) Confidently Estimated Municipal Use (not metered, non-revenue).
(3) UAW = Total Production – (Total Metered Consumption + CEMU).

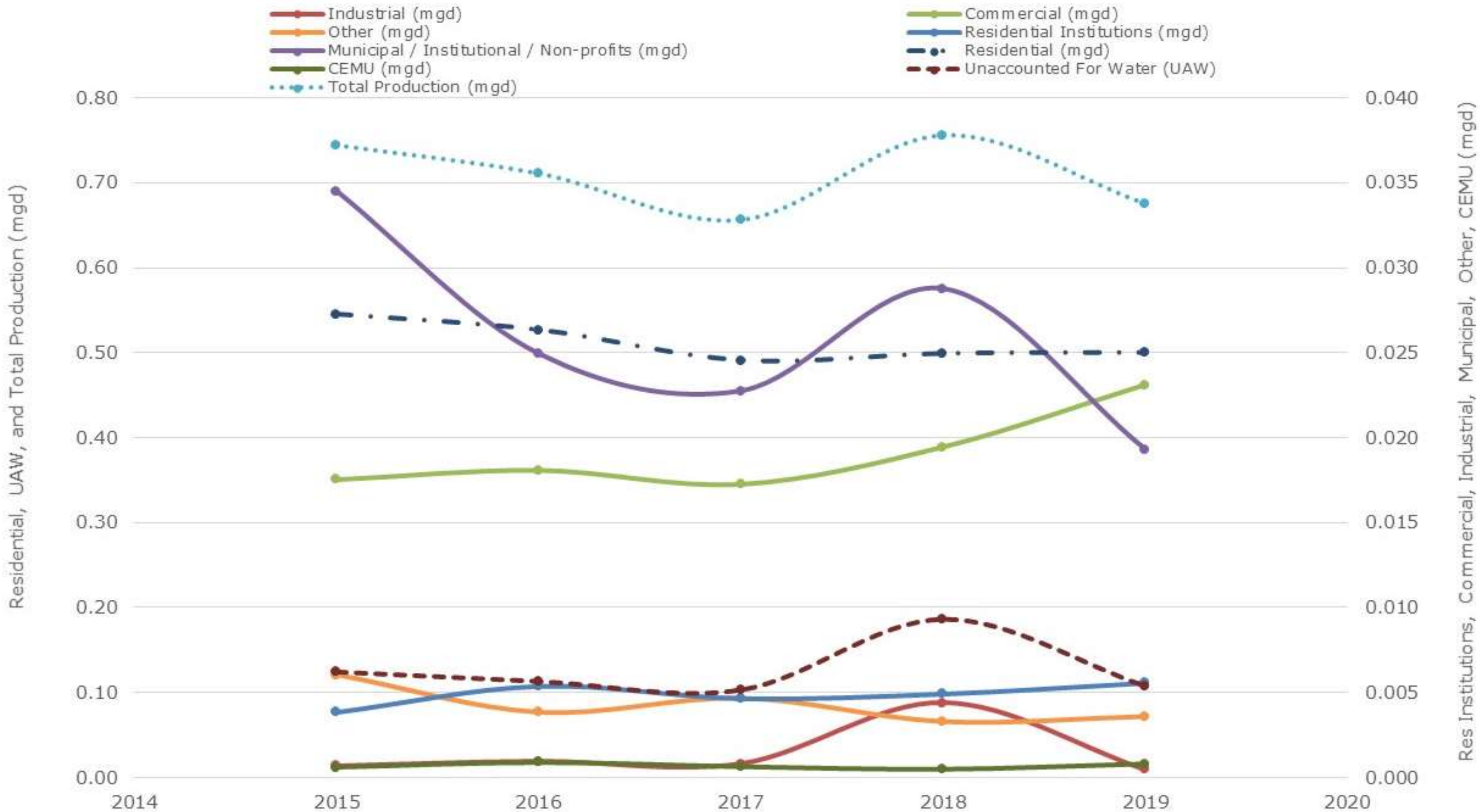


Figure 3-4: Historical Demands Trend Analysis

TABLE 3-8

Peaking Factor Summary - Uxbridge System

Year	Average Day Demand (mgd)	Maximum Month Demand (mgd)	Maximum Day Demand (mgd)	Max Month Peaking Factor	Max Day Peaking Factor
2015	0.744	0.973	1.375	1.31	1.85
2016	0.711	1.038	1.531	1.46	2.15
2017	0.657	0.872	1.159	1.33	1.76
2018	0.756	0.998	1.325	1.32	1.75
2019	0.676	0.855	1.332	1.26	1.97
			Average	1.34	1.90
			2020 Master Plan	**1.40**	**2.00**

Year	Population Served	Residential Consumption (mgd)	Residential Consumption per Person (gpcd)	Commercial Consumption (mgd)	Commercial Consumption per Person (gpcd)
2015	11,038	0.545	49	0.018	1.59
2016	11,263	0.527	47	0.018	1.61
2017	11,210	0.491	44	0.017	1.54
2018	11,368	0.499	44	0.019	1.71
2019	11,491	0.500	44	0.023	2.01
		Average	45		1.69
		2020 Master Plan	**50**		**1.80**

3.2.2 Demand Projections

Table 3-11 and Figure 3-6 present the water demand projections for 2025, 2030, and 2040, which were developed as described below. Demands are presented for three scenarios, based on the different residential growth patterns discussed above.

3.2.2.1 Residential

Residential demand projections were calculated based on the population served projections for each planning period (Table 3-6) and the per capita residential consumption rate (Table 3-9), at the three different growth scenarios.

3.2.2.2 Commercial

As with the population projections, commercial demand projections were determined for three different scenarios as follows (corresponding to the same population growth scenarios). These commercial demand scenarios are illustrated on Figure 3-5.

- **Scenario A:** Additional commercial demands from new developments and system expansion / in-fill expansion to serve existing businesses

- **Scenario B:** Commercial demands from Scenario A plus continued increase in commercial demands at the same rate as the previous three years

- **Scenario C:** Commercial demands from Scenario B plus new commercial demands proportional to changes in the population served, at the per capita commercial consumption rate (Table 3-9)

Commercial demands from potential new developments and system expansion to serve existing businesses are listed in Table 3-10 by planning period, consisting of:

- Developments listed for the 2025 planning period include projects currently in progress and under review, including the Zipp Industrial Park on Millville Road, the Campanelli Business Park cultivation facility, and the Serendipity Property sorting facility. As mentioned previously, the town planning office indicated interest in connecting unserved parcels along Route 16 near Route 146 to the Douglas town border. Expansion of the water system to serve this area could connect 4 existing developed parcels. Demands for 12 undeveloped parcels in Agricultural, Business, and Industrial Zones in this area and for two parcels in Douglas were not determined.

- Developments listed for the 2030 planning period include in-fill expansion to serve existing businesses along North and South Main Street that are not currently connected. Demands for 12 undeveloped parcels in Business Zones in this area were not determined.

- The development listed for the 2040 planning period is the potential redevelopment of the Quaker Highway area. Demands for this area were not determined because this is in the early planning stages (see Section 3.1.3.2).

For the projects listed in Table 3-10, average water demand was estimated from peak wastewater flows provided in 310 CMR 15.00: Septic System ("Title 5"). Water demand projections are half the peak wastewater flow and are increased by 15% to account for consumptive water uses. Detailed calculations of commercial demand projections are included in Appendix B. Actual demand projections will vary as proposed developments are better defined.

TABLE 3-10

Potential New Business / Commercial Developments

Development	**Average Water Use (gpd)** [1]	**No. on Figure 3-2**
2025 Planning Period		
Zipp Industrial Park, 290 Millville Road - Bare Naked Greens Cultivation Facility, 60 employees and cultivation (commercial factory)	20,529	10
Campanelli Business Park, 100 Campanelli Drive - Cultivate, cultivation facility 128,932 sq.ft.	25,072	6
TDJ Materials, 300 Mendon Street - 102,000 sq.ft. self-storage	44	3
Rt 16 Corridor near Rt 146 to Douglas town border - expansion to serve existing businesses including 2 offices and 2 warehouses (Agricultural, Business, and Industrial Zoned) (2)	1,238	12
515 Douglas Street - redevelopment of existing parcel into 500,000 sq.ft. sorting facility	3,529	16
2025 Total	50,413	
2030 Planning Period		
North and South Main Street - Master Plan in progress to encourage mixed-use, assumes expansion to existing businesses not currently served (3 offices Business Zoned) (3)	162	14
2030 Total	162	
2040 Planning Period		
Quaker Highway - Expansion to serve potential area of redevelopment / new developments (4)	--	15
2040 Total	--	

(1) Refer to Appendix B for calculations.

(2) Demands for undeveloped parcels were not determined: seven (7) Agricultural, two (2) Business, and three (3) Industrial Zoned, and two parcels in Douglas.

(3) Demands for undeveloped parcels were not determined: twelve (12) Business Zoned.

(4) Potential area of redevelopment is not yet well defined; therefore, demand projections were not determined. This area of town includes six (6) existing Public Water Systems located along Quaker Highway, 28 undeveloped Non-Residential Zoned parcels, and 48 developed Non-Residential Zoned parcels.

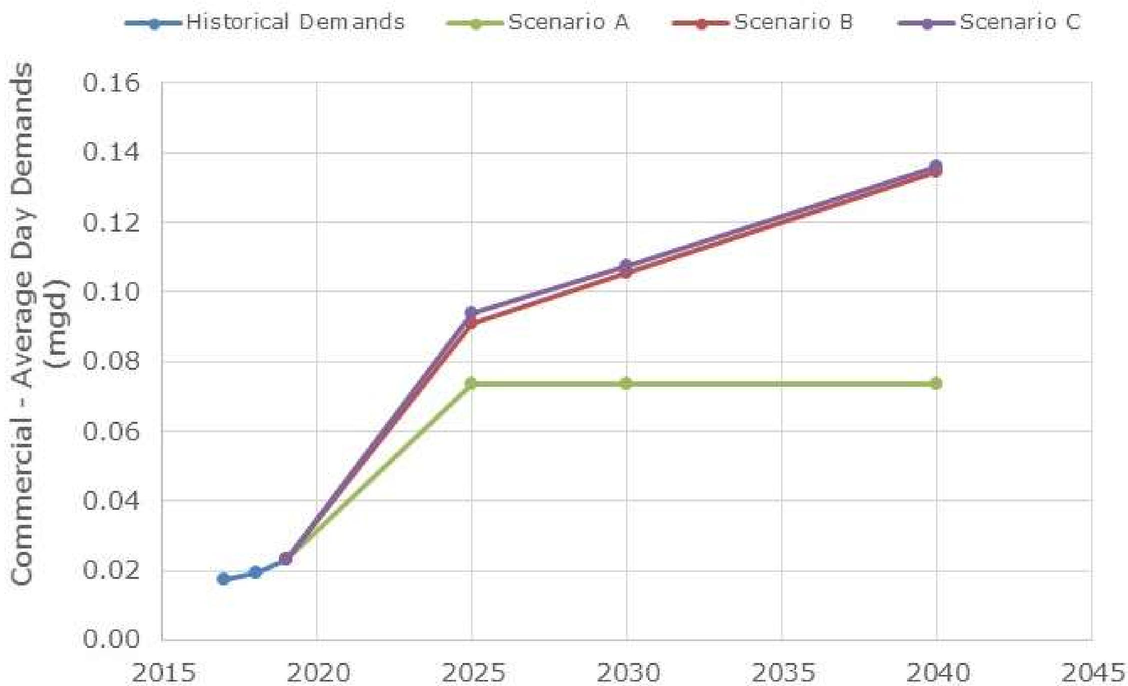


Figure 3-5: Commercial Demand Projections by Growth Scenario

3.2.2.3 Residential Institutions, Industrial, Municipal / Institutional / Non-Profits, Other, and CEMU

Demand projections in these categories were calculated based on the historical average of 2015-2019 water demands, as these are not anticipated to increase over the planning periods or otherwise significantly change.

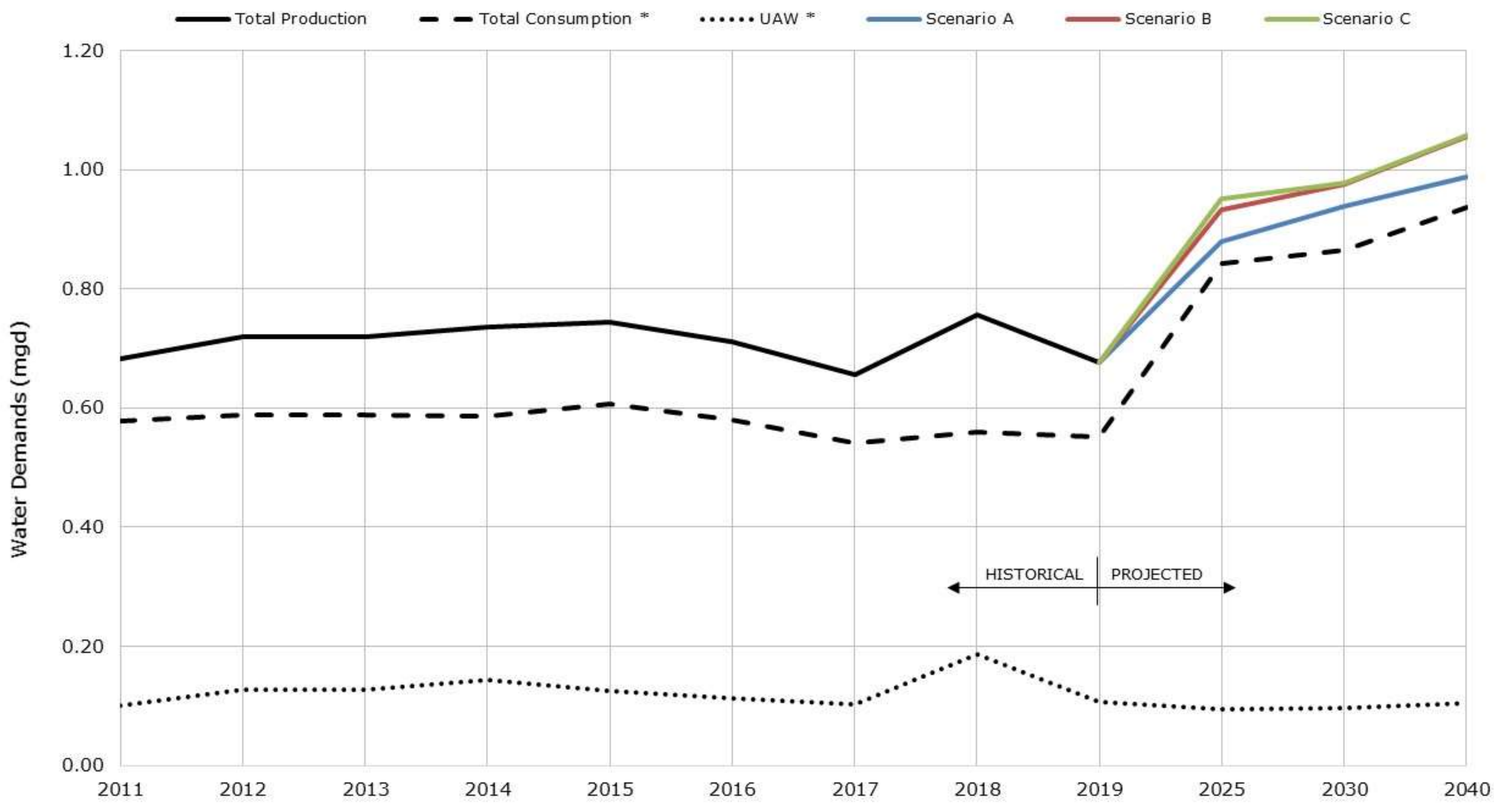
3.2.2.4 Unaccounted for Water

As presented in Table 3-7, UAW is generally approximately 18% of production. For planning purposes, UAW was projected to be 10% of production for all planning periods, in accordance with the WMA permit target goal.

TABLE 3-11
Projected Demands by User Category and Growth Scenario - Uxbridge System

Year	Residential (mgd)	Residential Institutions (mgd)	Commercial (mgd)	Industrial (mgd)	Municipal / Institutional / Non-profits (mgd)	Other (mgd)	CEMU (mgd)	Unaccounted for Water (UAW) Demand (mgd)	Unaccounted for Water (UAW) Percent of Total	Total Production (mgd)
Scenario A - Serving New Growth in Town and Potential New Business / Commercial Developments [1]										
2025	0.668	0.005	0.074	0.0007	0.026	0.004	0.014	0.088	10%	0.879
2030	0.722	0.005	0.074	0.0007	0.026	0.004	0.014	0.094	10%	0.940
2040	0.765	0.005	0.074	0.0007	0.026	0.004	0.014	0.099	10%	0.987
Scenario B - Demands from Scenario A plus New Population from In-Fill and Commercial Demands at Sustained Increased										
2025	0.699	0.005	0.091	0.001	0.026	0.004	0.014	0.093	10%	0.932
2030	0.722	0.005	0.106	0.001	0.026	0.004	0.014	0.098	10%	0.975
2040	0.765	0.005	0.135	0.001	0.026	0.004	0.014	0.106	10%	1.055
Scenario C - Demands from Scenario B plus New Population from System Expansion and New Commercial Growth Proportional to Town Population Growth										
2025	0.713	0.005	0.094	0.001	0.026	0.004	0.014	0.095	10%	0.952
2030	0.722	0.005	0.107	0.001	0.026	0.004	0.014	0.098	10%	0.977
2040	0.765	0.005	0.136	0.001	0.026	0.004	0.014	0.106	10%	1.057

[1] Commercial demands assumed to remain at 2019 level under Scenario A.



* Projected Consumption (Total Metered + CEMU) and Unaccounted for Water based on Scenario C.

Figure 3-6: Projected Average Day Demands by Growth Scenario

3.2.3 Demand Projections and Supply Capacity

As summarized in Table 3-8, peaking factors of 1.40 and 2.00 were used to determine future max month and max day demand projections, respectively, based on the average day demand projections by scenario presented in Table 3-11.

Table 3-12 below presents the WMA maximum authorized annual withdrawal volumes by period (see also Section 1.3). This includes the amounts in the current permit as well as the 0.66 mgd previously authorized under Water Management Act Registration 2-12-304.01. Table 3-13 presents the historical and projected demands compared to the maximum authorized withdrawal limits from the Town's WMA permit with Blackstone and Rosenfeld wellfields online and the largest wellfield, Bernat, offline. Figures 3-7 and 3-8 compare average day demands and maximum day demands to the authorized withdrawals, respectively. Maximum authorized daily withdrawals by source are listed in Tables 1-2 and 1-3 (additional discussion in Section 4).

Additionally, Figure 3-8 compares historical and projected demands to the current production capacity of the active wells from Table 1-3 with Blackstone and Rosenfeld wellfields online and the largest wellfield, Bernat, offline (Well #1 has been offline since 2014). Current production capacity is based on production rates observed at each wellfield in July 2019, which is representative of the wellfield's capacity during dry weather and high system demands.

TABLE 3-12

Maximum Authorized Annual Withdrawal Volumes

Period	Daily Average (MGD)	Total Annual (MGY)
3/1/2010 to 2/28/2014	0.87	317.55
3/1/2014 to 2/29/2019	0.89	324.85
3/1/2019 to 2/28/2024	0.93	339.45
3/1/2024 to 2/28/2029	0.98	357.70
3/1/2024 to 2/28/2029(1)	1.02	372.30

(1) Period four volumes may be increased by an additional 5% buffer to accommodate uncertainty in the growth projections used by the Department of Conservation and Recreation in the 20-year water needs forecasts, and/or to accommodate the water demand of a community that has not met the 65 RGPCD and 10% UAW performance standards, but has met the functional equivalence requirements included in the WMA permit.

TABLE 3-13
Uxbridge Water Demand Projections (UAW Reduced to 10%)

Year	Average Day Demand (mgd)	Maximum Month Demand (mgd)	Maximum Day Demand (mgd)	Maximum Authorized Withdrawal Daily Average (mgd)	Maximum Authorized Withdrawal Max Daily[1] (mgd)	Difference Daily Average Authorized to Average Day Demand	Difference Max Daily Authorized to Max Month Demand	Difference Max Daily Authorized to Max Day Demand
2015	0.744	0.973	1.375	0.890	1.920	0.15	0.95	0.55
2016	0.711	1.038	1.531	0.890	1.920	0.18	0.88	0.39
2017	0.657	0.872	1.159	0.890	1.920	0.23	1.05	0.76
2018	0.756	0.998	1.325	0.890	1.920	0.13	0.92	0.59
2019	0.676	0.855	1.332	0.930	1.920	0.25	1.07	0.59
Projections - Scenario A								
2025	0.879	1.230	1.757	0.980	1.920	0.10	0.69	0.16
2030	0.940	1.315	1.879	0.980	1.920	0.04	0.60	0.04
2040	0.987	1.382	1.975	0.980	1.920	-0.01	0.54	-0.05
Projections - Scenario B								
2025	0.932	1.305	1.864	0.980	1.920	0.05	0.62	0.06
2030	0.975	1.365	1.950	0.980	1.920	0.00	0.55	-0.03
2040	1.055	1.477	2.110	0.980	1.920	-0.08	0.44	-0.19
Projections - Scenario C								
2025	0.952	1.333	1.904	0.980	1.920	0.03	0.59	0.02
2030	0.977	1.368	1.954	0.980	1.920	0.00	0.55	-0.03
2040	1.057	1.480	2.114	0.980	1.920	-0.08	0.44	-0.19

[1] Total of maximum authorized daily withdrawal volumes by source (see Table 1-2) with Blackstone and Rosenfeld wellfields online and the largest wellfield, Bernat, offline: Bernat Wells #4, #5, and #6 – 1.33 mgd; Rosenfeld Well #7 – 0.73 mgd; Blackstone Well #1 – 0.43 mgd; Blackstone Well #2 – 0.44 mgd; and, Blackstone Well #3 – 0.32 mgd.

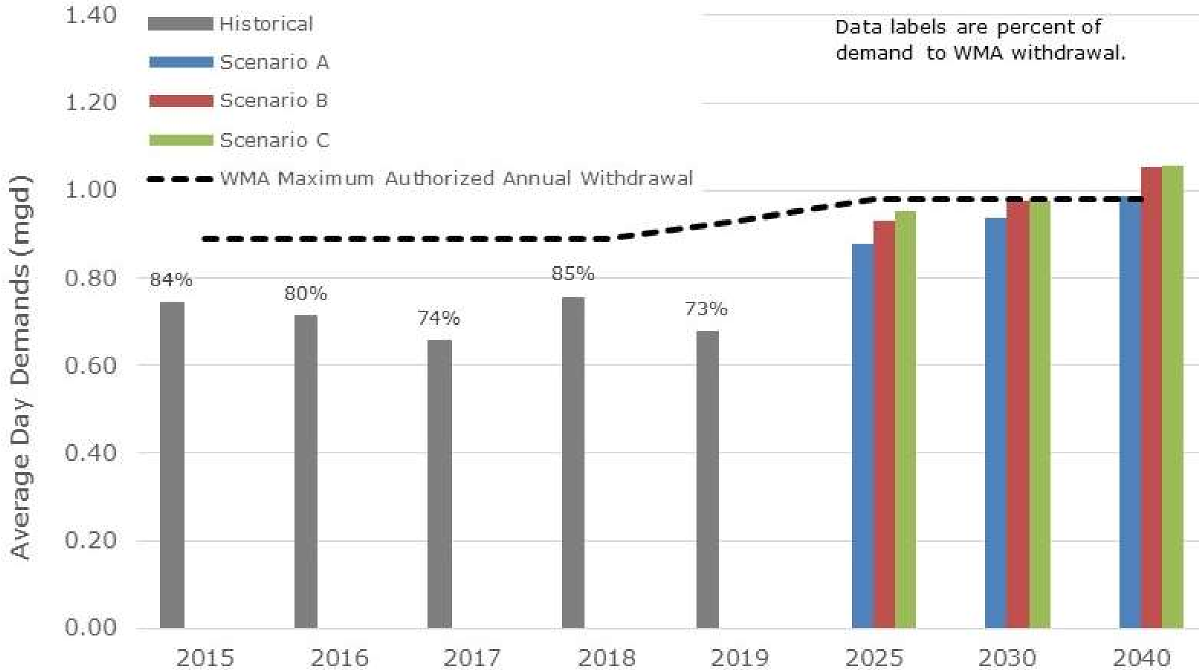


Figure 3-7: Average Day Demand Projections

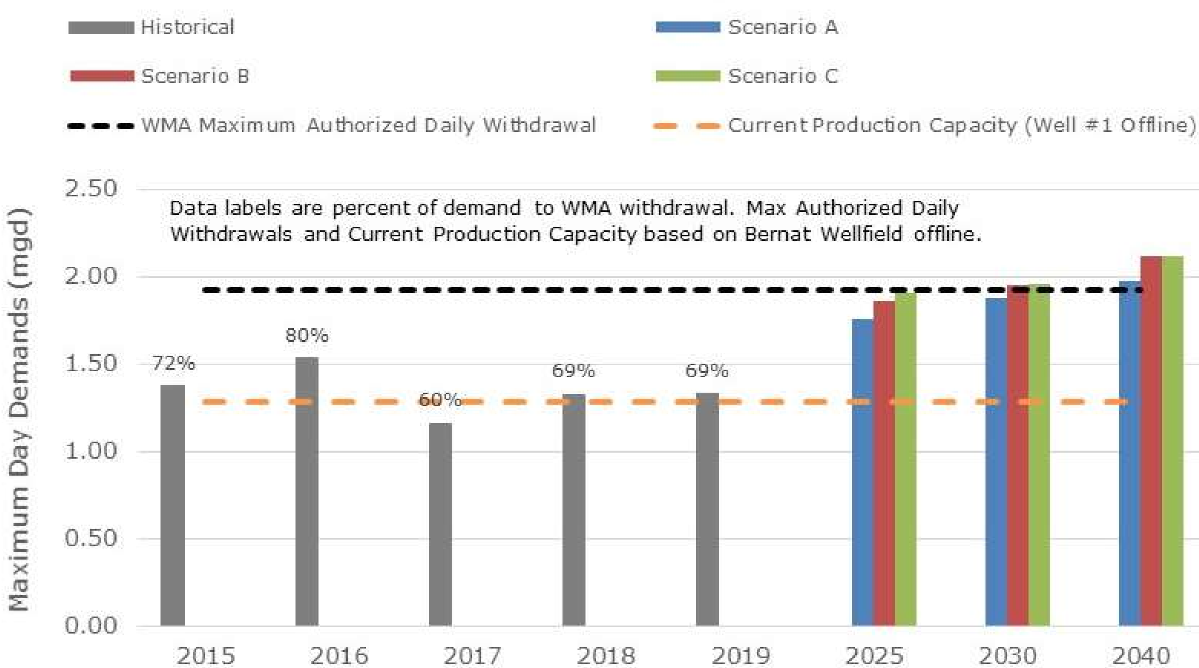


Figure 3-8: Maximum Day Demand Projections

Projected average day demands for 2025 and 2030 are close to but less than the authorized withdrawals for the different planning scenarios. However, projected demands for 2040 could be greater than the authorized withdrawals under all growth scenarios; average day demand projections for 2040 are also greater than the daily average withdrawal with 5% buffer of 1.02 mgd (Table 3-12) for scenarios B and C.

Max day demands are projected to be higher than the current production capacity available from the sources, based on Blackstone and Rosenfeld Wellfields online and Well #1 and Bernat Wellfield offline. As shown in Figure 3-8, if demands increase as projected, additional capacity will be required. The capacity of existing supplies to meet demands at current production capacities and with sources offline (for redundancy or due to water quality concerns) is evaluated further in Section 4.

The Town should monitor demands in the coming years. An increase to the authorized withdrawal volume following the 2/28/2029 period may be needed if demands increase as projected and if UAW is not reduced to 10% by 2025. Additionally, if the Town's population increases as projected by the CMRPC (as opposed to the population projections used in this plan which were reduced to be consistent with the ACS annual estimates) and UAW remains at approximately 18% of production as averaged in the previous five years, demands will be higher than the authorized withdrawals at all planning periods as shown in Table 3-14. This is a conservative scenario where demands would increase by 60% from 2019 to 2025.

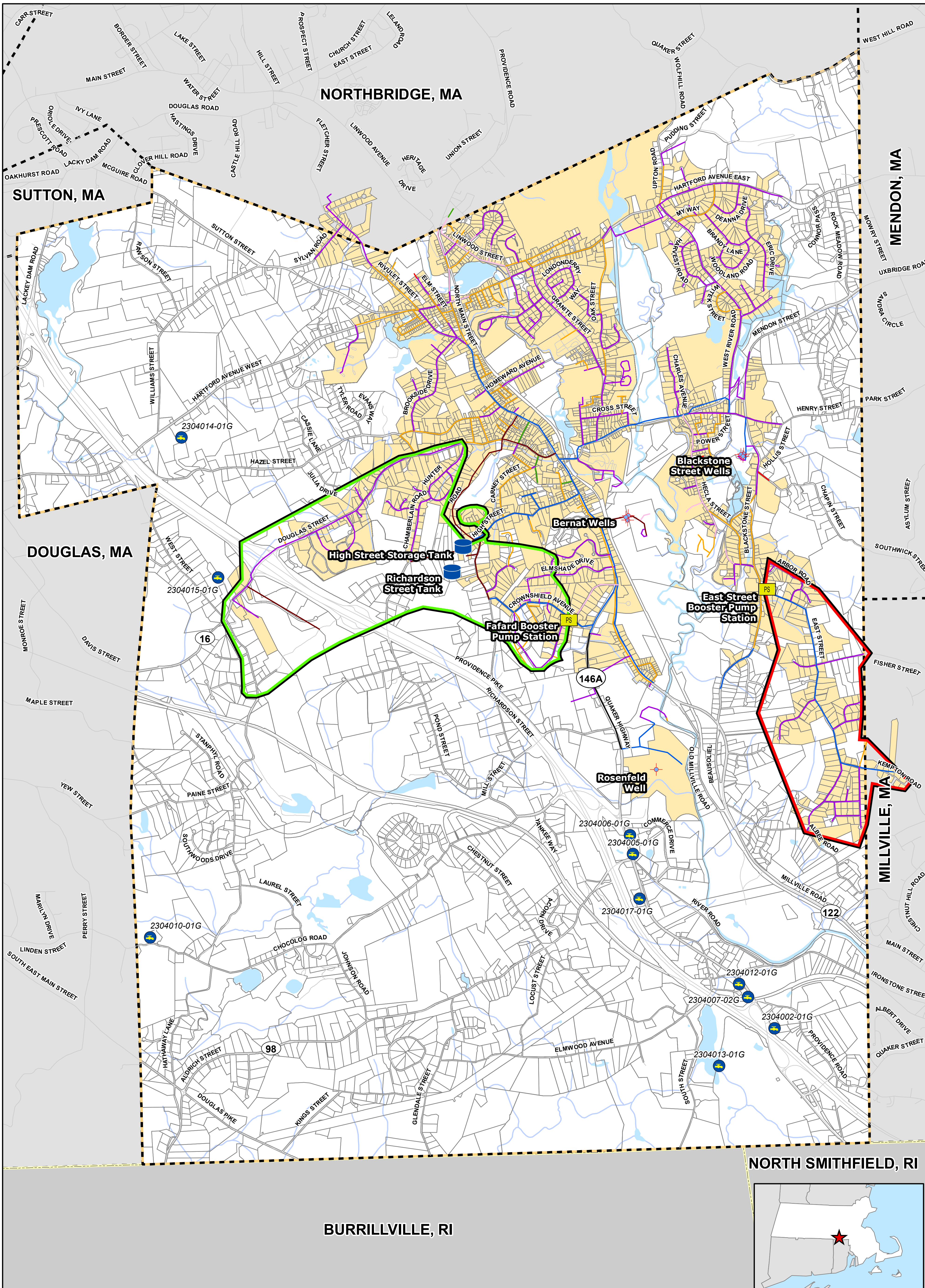
TABLE 3-14

Demand Projections Under Scenario C, Plus Population Growth at CMRPC Rates (1) and UAW Remaining at 18%

Year	Average Day Demand (mgd)	Maximum Month Demand (mgd)	Maximum Day Demand (mgd)
2025	1.105	1.547	2.211
2030	1.133	1.586	2.266
2040	1.221	1.709	2.441

(1) See Figure 3-3.

(2) At all planning periods, average demands are greater than the maximum authorized annual withdrawal volume of 0.98 mgd, and max day demands are greater than the maximum authorized daily withdrawal volume of 2.06 mgd.



Other Small Public Water Systems	East Street Service Area	Other MA Town Boundary	**Water Main Size**
Pump Station	High Service Area	RI Town Boundary	2" / 10"
Storage Tank	Service Area		4" / 12"
Well	Parcel Boundary		6" / 16"
Water Bodies	Uxbridge Town Boundary		8" / 20"

FIGURE 3-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Water System Service Areas
Uxbridge, Massachusetts

September 2020

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.
2. Parcels (FY2020) downloaded by MassGIS and are approximate.
3. Other Small Public Water Systems data provided by MassGIS.

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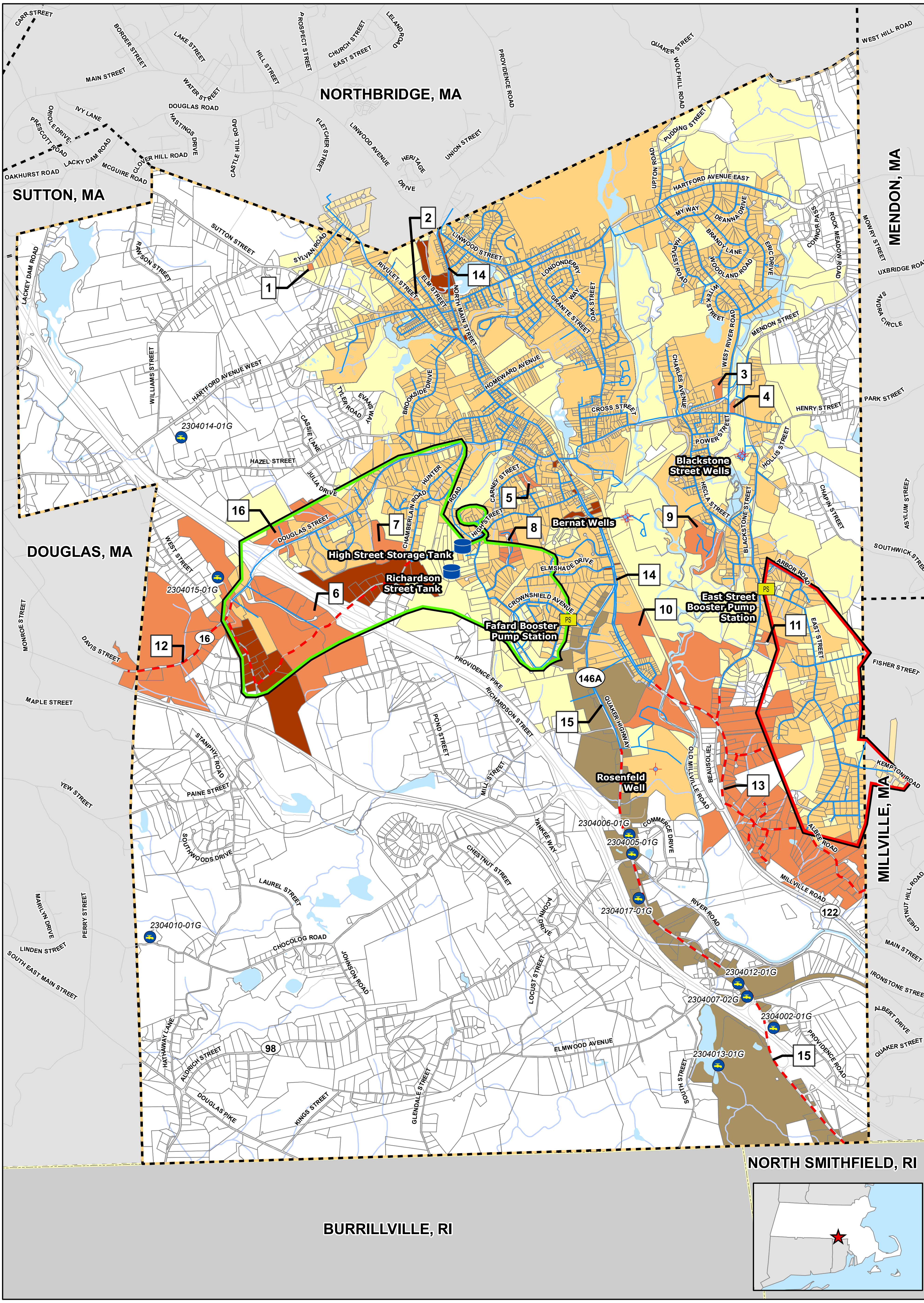

Other Small Public Water Systems

PS Pump Station

Storage Tank

Well

Water Main

Potential Water Main Expansion

Water Bodies

East Street Service Area

High Service Area

Parcel Boundary

Uxbridge Town Boundary

Other MA Town Boundary

RI Town Boundary

Service Areas (Existing and Future)

Infill

Existing Service Area

Potential 2025 Service Area

Potential 2030 Service Area

Potential 2040 Service Area

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.
2. Uxbridge (FY2020), Northbridge (FY2020), Douglas (FY2020) and Millville (FY2020) parcels downloaded by MassGIS and are approximate.
3. Other Small Public Water Systems data provided by MassGIS.

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FIGURE 3-2
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Water System Future Service Areas
Uxbridge, Massachusetts

September 2020

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Section 4
Storage Capacity and Supply Evaluation

This section evaluates the system's pumping and storage capacity compared to current and projected demands.

4.1 Quantity Assessment

4.1.1 System Supply Capacity

The capacity of the Town's sources to meet current and projected needs were evaluated under different source production scenarios and compared to demands. The need for potential future sources of supply is also considered.

Table 4-1 summarizes the Town's local sources and maximum authorized daily withdrawal rates from the WMA permit and registration, as well as different available water withdrawal scenarios. The quantities of water available from these scenarios are compared to maximum day demands (representative of peak demand conditions) on Figure 4-1. Projected demands are based on Scenario C from Section 3. Table 4-1 also summarizes the percentage of max day demands that each source could meet on its own (for example, at its permitted rate, Well #7 can meet 55% of current max day demands).

The following evaluation considers the pumping capacity available from the system's supply sources to meet the overall demands of the system, as well as the level of redundancy available if sources are offline. The Massachusetts Guidelines for Public Water Systems (April 2014) indicate that pumping facilities should be provided with at least two pumping units. The guidelines further state: "with any pump out of service, the remaining pump(s) shall be capable of providing the maximum daily pumping demand of the system," and "each booster pumping station contains not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service."

The production scenarios are consistent with the current operational capabilities that allow for remote automatic operation of two wellfields at a time, and are based on:

- Blackstone Wells #1, #2, and #3, and Bernat Wells #4, #5, and #6) operating at their permitted withdrawal rates, and Rosenfeld Well #7 offline per MADEP guidelines (Table 4-1 and Figure 4-1); this represents a best case scenario in which replacement wells or well rehabilitation at Bernat Wellfield restores the wellfield's capacity to its permitted value, Well #1 can be returned to service, and the online wells produce up to their permitted rates

- Blackstone Wells #2 and #3 and Bernat Wells #4, #5, and #6 operating at their permitted withdrawal rates, and Well #1 offline due to water quality concerns and Rosenfeld Well #7 offline per MADEP guidelines (Table 4-1 and Figure 4-1); this represents a scenario similar to the above but Well #1 is not returned to service

- All wells operating at current production capacities, with Well #1 offline and with the largest source (Well #7) offline (Table 4-2 and Figure 4-2); this represents current conditions in which Bernat Wellfield and Blackstone Wells #2 and #3 produce less than their permitted rates

Peak hour demands in Tables 4-1 and 4-2 are based on applying a peaking factor of 1.75 to the maximum day demands, like the peaking factor used in the hydraulic model.

TABLE 4-1
Uxbridge System - Pumping Capacity Evaluation Data at Permitted Withdrawal Rates

Facility Name		Demand / Capacity (gpm) (1)			
		2019	**Projected 2025**	**Projected 2030**	**Projected 2040**
Max Day Demand (MDD)		925	1,301	1,336	1,447
Peak Hour Demand (PHD=1.75X MDD)		1,619	2,277	2,338	2,532
Fire Flow		3,500	3,500	3,500	3,500
	Max Authorized Daily Rate *(2)*	*% of Current MDD*	*% of 2025 MDD*	*% of 2030 MDD*	*% of 2040 MDD*
Bernat Well #4 (3)	308	33%	24%	23%	21%
Bernat Well #5 (3)	308	33%	24%	23%	21%
Bernat Well #6 (3)	308	33%	24%	23%	21%
Blackstone Well #1	299	32%	23%	22%	21%
Blackstone Well #2	306	33%	23%	23%	21%
Blackstone Well #3	222	24%	17%	17%	15%
Rosenfeld Well #7	507	55%	39%	38%	35%
Total with Well #7 offline	1,750	189%	135%	131%	121%
Total with Wells #1 and #7 offline	1,451	157%	112%	109%	100%

Comparison to Criteria (Well #1 and Well #7 Offline)		
Pumping Capacity Minus Pump Offline > MDD	1,451	Criteria met under current and future demands
Pumping Capacity Minus Pump Offline > PHD	N/A	Peak hour demands on max day met from storage (4)
Ability to meet fire flow	N/A	Fire flow met from storage (4)

(1) Projections based on Scenario C and UAW reduced to 10%, Section 3.
(2) Maximum Authorized Daily Withdrawal from WMA Permit (Bernat Wells #4, #5, and #6 at 1.33 mgd and Rosenfeld Well #7 at 0.73 mgd) and Registration (Blackstone Well #1 at 0.43 mgd, Blackstone Well #2 at 0.44 mgd, and Blackstone Well #3 at 0.32 mgd). The sum of all sources is 2,257 gpm; however, current operational capabilities allow for remote automatic operation of only two wellfields at a time.
(3) Individual well capacity based on max authorized daily withdrawal for wellfield (1.33 mgd / 924 gpm) divided by number of wells.
(4) Fire flow and peak hour demands provided by High Street Tank.

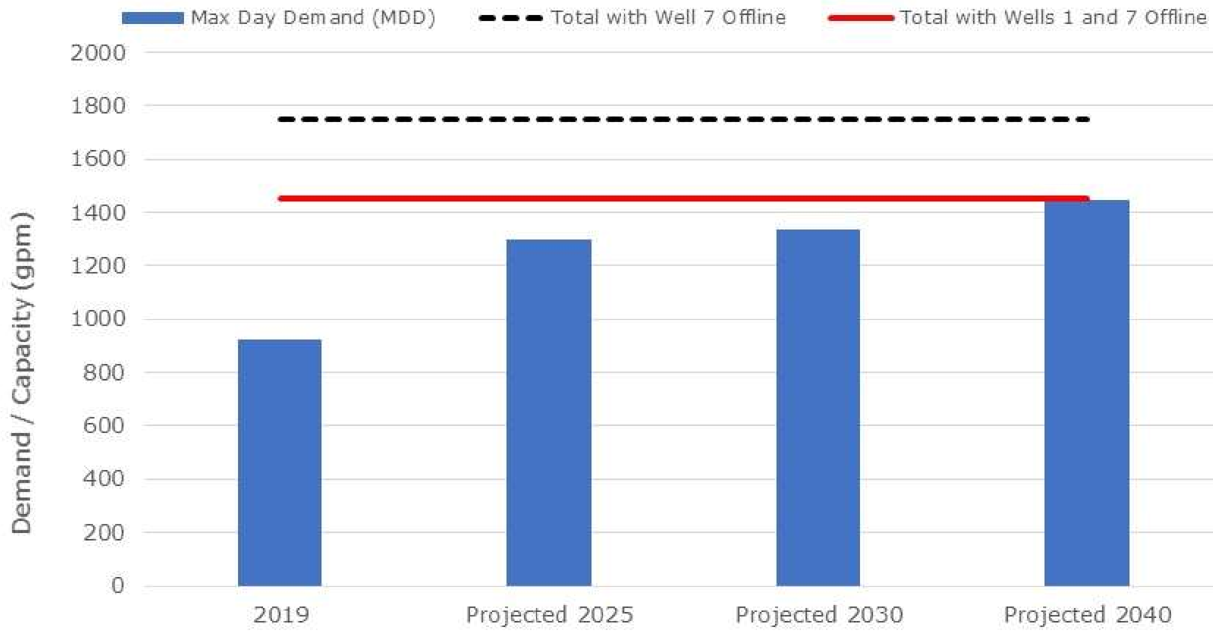


Figure 4-1: Supply Capacity at MDD and Max Authorized Daily Withdrawal Rates

TABLE 4-2
Uxbridge System - Pumping Capacity Evaluation Data at Current Production Rates

Facility Name		Demand / Capacity (gpm) (1)			
		2019	**Projected 2025**	**Projected 2030**	**Projected 2040**
Max Day Demand (MDD)		925	1,301	1,336	1,447
Peak Hour Demand (PHD=1.75X MDD)		1,619	2,277	2,338	2,532
Fire Flow		3,500	3,500	3,500	3,500
	Current Production Rate (2)	*% of Current MDD*	*% of 2025 MDD*	*% of 2030 MDD*	*% of 2040 MDD*
Bernat Well #4	155	17%	12%	12%	11%
Bernat Well #5	155	17%	12%	12%	11%
Bernat Well #6	155	17%	12%	12%	11%
Blackstone Well #1	0	0%	0%	0%	0%
Blackstone Well #2	193	21%	15%	14%	13%
Blackstone Well #3	193	21%	15%	14%	13%
Rosenfeld Well #7	507	55%	39%	38%	35%
Total with Well #1 offline	1357	147%	104%	102%	94%
Total with Wells #1 and #7 offline	850	92%	65%	64%	59%

Comparison to Criteria (Well #1 and Well #7 Offline)		
Pumping Capacity Minus Largest Pump > MDD	850	Criteria not met under current and future demands
Pumping Capacity Minus Largest Pump > PHD	N/A	Peak hour demands on max day met from storage (3)
Ability to meet fire flow	N/A	Fire flow met from storage (3)

(1) Projections based on Scenario C and UAW reduced to 10%, Section 3.
(2) Based on production rate for the wellfield observed in July 2019, divided by number of wells.
(3) Fire flow and peak hour demands provided by High Street Tank.
(4) Current operational capabilities allow for remote automatic operation of only two wellfields at a time.

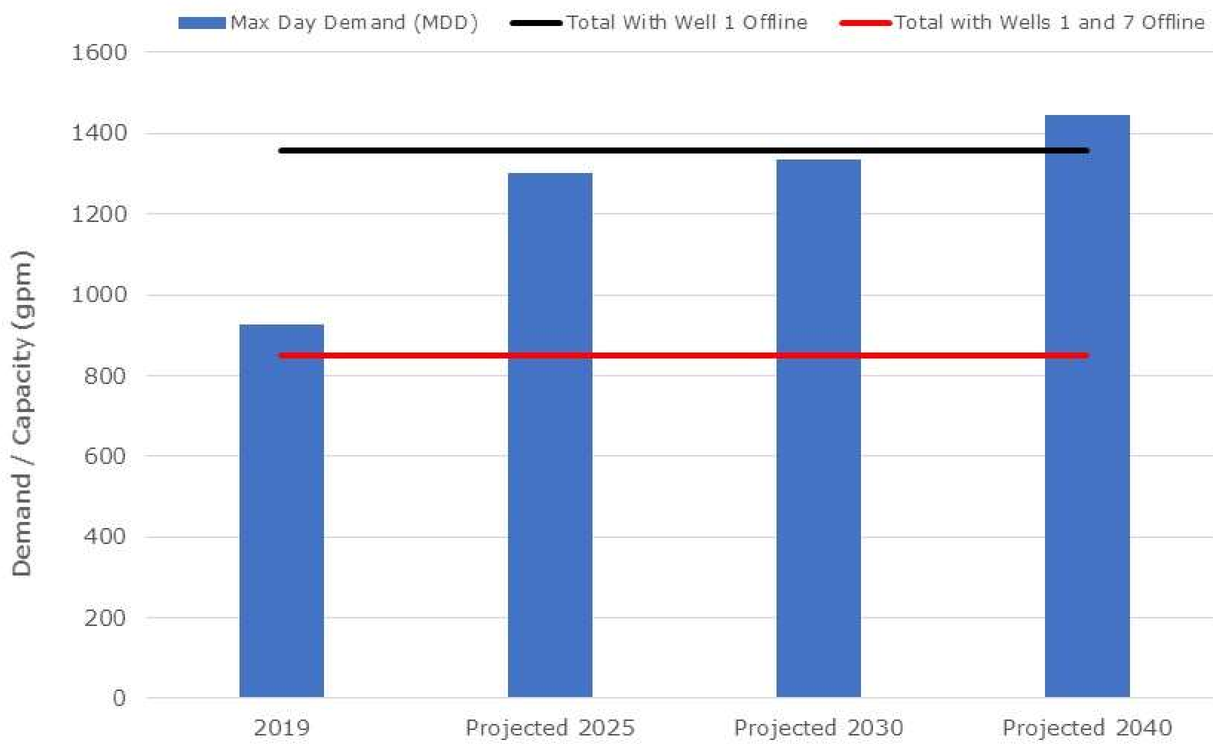


Figure 4-2: Supply Capacity at MDD and Current Production Rates

4.1.2 Existing Supply Capacity

If Blackstone and Bernat Wellfields produce up to their maximum authorized daily withdrawals, then the existing sources can meet max day demands through 2040 with Well #1 currently offline due to water quality concerns and with the largest source offline per MADEP guidelines (Rosenfeld Well #7) (assuming demands increase as projected).

However, at current production rates for Blackstone and Bernat Wellfields, the wells cannot meet existing and projected max day demands with both Well #1 and Well #7 offline. With only Well #1 offline and the existing sources at their current production capacities, max day demands for 2040 cannot be met (assuming demands increase as projected).

This analysis indicates that current and future demands cannot be met if an additional source were taken offline or if production from the wellfields is reduced due to water quality concerns related to iron and manganese exceedances. The town should begin to consider options for increasing capacity, such as: 1) replacement wells or well rehabilitation to restore capacity up to the permitted withdrawal rates; 2) treatment to return Well #1 to service; or, 3) development of a new source of supply.

Additionally, the town should obtain a better understanding of the actual production capacity of each well by conducting pump flow tests. Because the current production rates presented in this analysis are based on the daily logs from the wells, flow test results would be helpful to understand if the capacity is diminishing or if current capacity is adequate for meeting projected demands.

4.1.2.1 Replacement Wells or Well Rehabilitation

Replacement wells or well rehabilitation should be considered to restore the capacity of the existing wellfields up to their maximum authorized daily withdrawal rates, particularly at Bernat Wellfield where capacity has declined over the years due to retrofits. A replacement well could be permitted for the full permitted capacity of an existing well without new source permitting requirements.

This should be based on monitoring the conditions at Bernat Wellfield (for example, capacity continues to decline) in conjunction with monitoring demands in the system to determine whether demands are increasing as projected.

4.1.2.2 Water Treatment

As discussed in Section 1, the wells occasionally or regularly experience iron and manganese concentrations above the respective SMCLs. Treatment for iron and manganese will be required to return Well #1 to service and/or reduce concentrations in the remaining wells while maintaining current production. Alternatively, a new source will be required to meet demands.

Existing treatment at the wellfields consists of chemical injection for metals sequestration. According to the American Water Works Association (AWWA) *Iron and Manganese Removal Handbook, 2nd Edition,* sequestration for drinking water treatment of iron and manganese is generally limited to sources where the iron is less than 0.6 mg/L and manganese is less than 0.1 mg/L. Sequestration of source water concentrations above these values may result in aesthetic issues in the distribution system. Sequestration does not remove manganese and thus does not address health concerns.

As summarized in Table 1-6, some of the wells experience concentrations above these recommended values for sequestration, as listed below.

- Sources with iron concentrations greater than 0.6 mg/L
    - Well #6 has had iron concentrations greater than the 0.6 mg/L recommendation
    - Wells #2 and #3 have had iron concentrations that approach this value at approximately 0.443 mg/L and 0.447 mg/L, respectively
- Sources with manganese concentrations greater than 0.1 mg/L
    - Average manganese samples at Well #3 are above the 0.1 mg/L recommendation
    - Wells #2 and #3 have had manganese concentrations greater than the recommendation
    - Wells #6 and #7 have had manganese concentrations that approach this value at approximately 0.072 mg/L and 0.085 mg/L, respectively

This indicates a potential limitation in the current treatment capacity. Treatment technologies other than chemical treatment may be required, such as greensand filtration or biological filtration.

Well #7 would benefit the most from additional treatment because it is the largest producing well, it has the highest manganese concentrations, and iron is not a concern. Treatment at the Blackstone Wells would also be beneficial because the treatment system would target the three sources with the highest manganese concentrations and with some of the highest iron concentrations. Treatment at Bernat Well #6 would not be as beneficial, because this source can be blended with Wells #4 and #5, which have little to no iron and manganese.

4.1.2.3 Potential Source of Supply

An 8-inch diameter test well was drilled and pump tested in 1984. The well is located off Route 146A and is known as the Cnossen Well. Reportedly, operating the well as a source of supply for the town would require purchasing the parcel. The well is in the southern area of town, near the Quaker Highway. Therefore, this source could potentially feed the commercial area.

According to the 1984 pump tests, the estimated safe yield of the well is 980 gpm (1.41 mgd). Water quality tests conducted in 1984 indicated iron and manganese concentrations below the SMCLs and pH of 5.8, which would require adjustment upward.

In 2003, water quality testing conducted on a 2.5-inch diameter observation well adjacent to the Cnossen Well indicated iron and manganese concentrations above the SMCLs and low pH of 5.3. Treatment for iron and manganese removal may be required, as well as pH adjustment.

The pump test was approved by MADEP in 1985, and the well was approved for a maximum daily withdrawal volume of 75,000 gpd in 1989 to use as a drinking water supply for the Quaker Industrial Park. The required Zone I radius was 380 feet due to the approved daily withdrawal volume. The site is reportedly 17 acres. If properly configured with respect to the pumping well, the site should have the required 400-foot radius.

If the well's maximum daily withdrawal can be increased up to the well's safe yield of 980 gpm by reconfiguring the radius, then the Cnossen Well source would become the system's largest source. The total with Well #1 offline would be 2,337 gpm. The total with both Well #1 offline and the largest source offline would be 1,357 gpm, which is greater than projected max day demands for 2025 and 2030, and slightly less than projected max day demands for 2040.

Due to its proximity to the Rosenfeld Well, an evaluation should be conducted to determine the possibility of interference between the two wells with respect to influencing water levels and yields.

Developing this well as a potential source of supply for the town would require completing new source permitting requirements, including a pump test and environmental permitting, purchasing the parcel from the property owners, and potentially installing a treatment system for iron/manganese removal and pH adjustment (based on water quality test results).

4.1.3 Supply Capacity of High Service Areas

The remaining evaluation below considers the pumping capacities of the two booster pump stations that supply the high-pressure zones in the system (Tables 4-3 and 4-4). Average and max day demands for the pressure zones are based on the demands assigned in the distribution system hydraulic model based on customer billing data. Peak hour demands are based on applying a peaking factor of 1.75 to the maximum day demands, like the peaking factor used in the hydraulic model.

The High Service Area is served by the Fafard Booster Pump Station and atmospheric storage is provided by the Richardson Street Tank. Table 4-3 compares maximum day demands against the station's pumping capacity with the largest pump out of service. This area of the distribution system provides fire protection.

Under existing demands, the Fafard Booster Pump Station meets the pumping capacity criteria. Fire flow and peak hour demands in this service area are provided from the Richardson Tank, as discussed further below.

Under projected 2040 demands, the pumping capacity of the pump station would need to be increased, if max day demands increase as projected.

TABLE 4-3

Pumping Capacity Evaluation Data - High Service Area

Facility Name	Demand / Capacity (gpm)	
	2019	**2040 Scenario C**
Max Day Demand (MDD)	331	518
Peak Hour Demand (PHD=1.75X MDD)	580	907
Fire Flow	3,000	3,000
Fafard Booster Pump Station	175	
	175	
	175	
Comparison to Criteria		
Pumping Capacity Minus Largest Pump > MDD	350	Criterion Met under Existing Demands
Pumping Capacity Minus Largest Pump > PHD	N/A	Peak hour demands on max day met from storage (2)
Ability to meet fire flow	N/A	Fire flow met from storage (2)

(1) PS is equipped with back-up power

(2) Fire flow and peak hour demands provided by Richardson Tank

The East Street Service Area is served by the East Street Booster Pump Station. There is no atmospheric storage at this water level; therefore, the pump station should meet fire flows and peak hour demands if storage is not provided. Table 4-4 compares maximum day demands and peak hour demands against the station's pumping capacity with the largest pump out of service. This area of the distribution system provides fire protection.

Under existing demands, the East Street Booster Pump Station meets the pumping capacity criterion for max day demands but cannot provide peak hour demands or fire flows in excess of 200 gpm.

Under projected 2040 demands, the pumping capacity of the pump station would need to be increased, if demands increase as projected.

An alternatives assessment was conducted in 2015 to evaluate options for improvements for the East Street pump station. Refer to Section 4.2.3 below for further details.

TABLE 4-4

Pumping Capacity Evaluation Data – East Street Service Area

Facility Name	**Demand / Capacity (gpm)**	
	2019	**2040 Scenario C**
Max Day Demand (MDD)	47	74
Peak Hour Demand (PHD=1.75X MDD)	82	129
Fire Flow	750	750
East Street Booster Pump Station	50	
	150	
Comparison to Criteria		
Pumping Capacity Minus Largest Pump > MDD	50	Criterion Met under Existing Demands
Pumping Capacity Minus Largest Pump > PHD	50	Criterion Not Met
Ability to meet fire flow	200	Criterion Not Met

(1) PS is equipped with back-up power

4.2 Storage Assessment

The Massachusetts Guidelines for Public Water Systems (April 2014) indicate that "storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and fire flow demands where fire protection is provided. Fire flow requirements established by the National Fire Protection Association (NFPA) should be satisfied where fire protection is provided. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems."

Regarding pressure in the distribution system related to storage, the guidelines note "all service connections shall have a minimum residual water pressure at street level of at least 20 psi under all design conditions of flow," and "the minimum working pressure in the distribution system should be 35 psi and the normal working pressure should be approximately 60-80 psi."

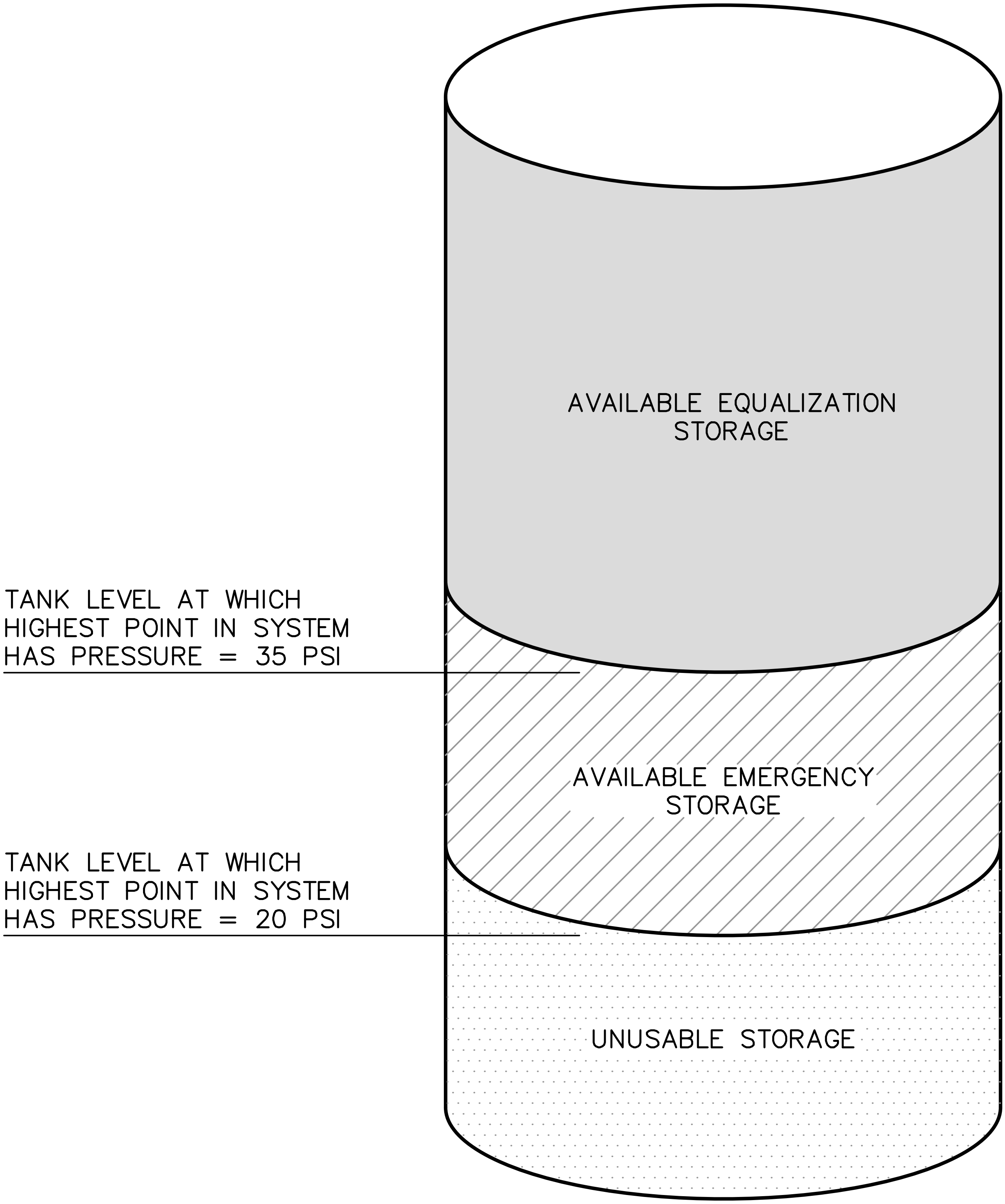
The High Street storage tank provides pressure to the Low Service Area, which comprises most of the distribution system. The Richardson storage tank provides pressure to the High Service Area. The storage tanks were evaluated as follows:

- Available usable storage compared to total required storage (the larger of required turnover equalization storage or required peaking equalization storage, plus the required fire storage).
    - Usable equalization storage is defined as storage above the elevation that provides 35 psi static pressure at the high point in the system. Required equalization storage is based on the greater of 20% of the maximum day demand (peaking equalization) or 20% of the total useable volume (equalization volume that provides a 5-day turnover).
    - Usable fire storage is defined as storage above the elevation that provides 20 psi static pressure at the high point in the system. Required fire storage is determined based on the highest ISO identified needed fire flow in the system multiplied by the ISO recommended flow duration.
    - These general storage compartments are illustrated in Figure 4-3. Supporting calculations are included in Appendix C.

The system's storage tanks are illustrated in Figures 4-4 (High Street Tank) and 4-5 (Richardson Tank). Tables 4-5 and 4-6 compare the available usable storage to the required storage for the High Street Tank and Richardson Tank, respectively. The characteristics of the storage tanks are:

- The High Street Tank is a rectangular concrete tank with a length of 150 feet (approximately 145 feet excluding interior walls), width of 100 feet (approximately 97 feet excluding interior walls), and total height of 17 feet. The tank's overflow elevation is at an elevation of 498 feet. Assuming 1-foot freeboard below the overflow, the tank has an operating volume of 1.464 MG.

- The Richardson Tank is a standpipe with a diameter of 59 feet and total height of 50 feet. The tank's overflow elevation is at an elevation of 591 feet. Assuming 1-foot freeboard below the overflow, the tank has an operating volume of 1.002 MG.



2020 WATER SYSTEM EVALUATION

FIGURE 4-3
GENERAL STORAGE COMPARTMENTS

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4.2.1 High Street Tank Assessment

The required equalization storage of 0.293 MG is based on the 5-day tank turnover volume (20% of total tank volume) and corresponds to a required equalization depth of 3 feet and elevation of 494 feet at the bottom of the equalization storage, including 1 foot of freeboard. At this water level elevation, approximately 11 of the highest customers in the system receive less than 35 psi of static pressure. The elevation that provides 35 psi of static pressure at the highest points of the system is above the tank overflow. Therefore, the tank does not meet the equalization storage criterion.

The highest customer in the system would receive 19 psi with the tank drawdown to the bottom of the required equalization storage. The highest customer in the system is at an elevation of approximately 450 feet.

Figure 4-6 illustrates the location of the high services (in orange) that receive less than 35 psi with the High Street Tank drawdown to the required equalization depth. At the bottom of the required equalization elevation, these services, ranging in elevation from 450 feet to 499 feet, receive 19 to 34 psi of static pressure. These customers are located in vicinity of the tank where low pressures can be expected.

The elevation that provides 20 psi of static pressure for the highest customer is 2 feet above the bottom of the required equalization storage. Therefore, the volume below the required equalization storage of 1.172 MG is considered unusable for providing fire protection and flow during emergencies while maintaining required minimum pressures.

The required emergency storage volume is based on providing a fire flow of 3,500 gpm for 3 hours, or 0.630 MG. This corresponds to a required emergency depth of 6 feet to an elevation of 488 feet at the bottom of the required emergency storage. At this water elevation approximately 4 customers receive less than 20 psi of static pressure. The highest customer in the system receives 16 psi.

The remainder of the tank volume, below required equalization and fire, is 0.542 MG. This storage volume could provide up to 19 hours of flow at average day demands. At the bottom of the storage tank, 4 customers in the system receive less than 20 psi and the highest customer receives 14.

As shown in Figure 4-4 and in Table 4-5, although the total storage is greater than the required storage, the High Street Tank does not provide the required pressures for a small number of customers in the system (up to 11 customers, or <0.5% of customers in the Low Service Area). These customers are located near the tank and may receive adequate pressure when the tank is filling. The town could consider providing a small booster pump system for these 11 customers, as a medium to low priority since all customers receive at least 20 psi at the bottom of equalization and 16 psi at the end of a design fire.

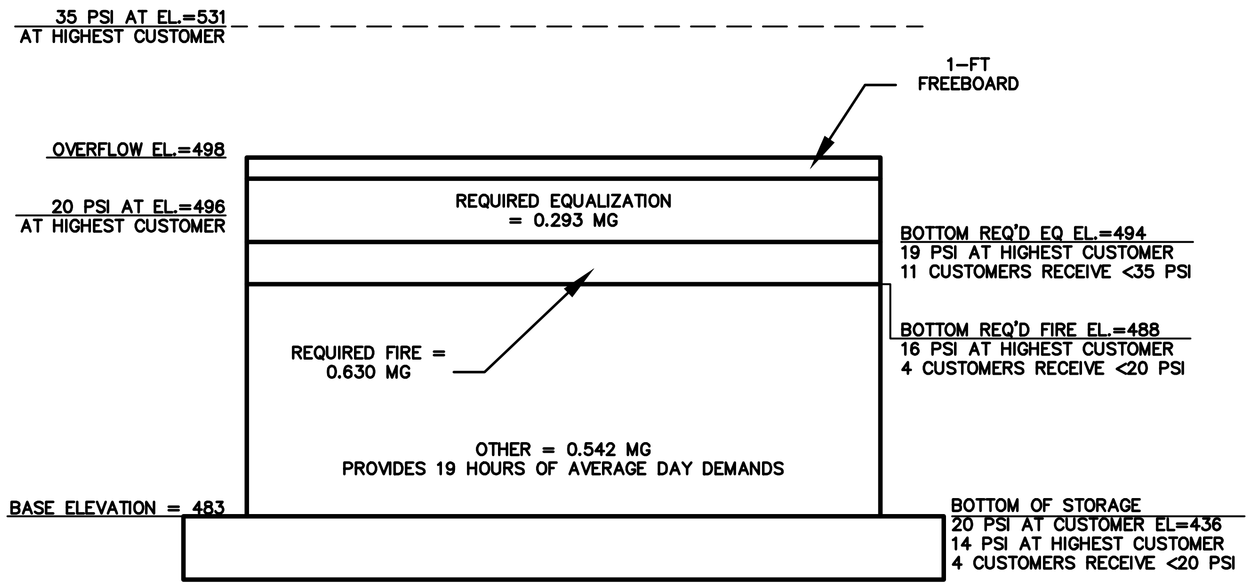
TABLE 4-5

High Street Tank – Storage Capacity Evaluation Data (million gallons)

	Required	**Amount Meeting Criterion**
Equalization Storage	0.293 (1)	0.293 (3)
Emergency/Fire Storage	0.630 (2)	0.630 (4)
Remaining Volume	--	0.542 (5)
Total	0.923	1.465

(1) At bottom of the required EQ storage, highest 11 customers in the Low Service Area receive less than 35 psi; highest customer receives 19 psi.
(2) Required fire storage of 3,500 gpm for 3 hours. At bottom of the required Fire storage, highest 4 customers receive less than 20 psi; highest customer receives 16 psi.
(3) Set equivalent to Required Equalization for comparison purposes. However, water elevation that provides 35 psi at the highest customer is above the tank overflow elevation.
(4) Set equivalent to Required Fire for comparison purposes.
(5) Remaining volume below equalization and emergency/fire. Provides 19 hours of ADD.

REQUIRED TANK LEVELS



TOTAL CAPACITY	=	1.464 MG (WITH FREEBOARD)
1 FT STORAGE	=	104,604 GAL
LENGTH X WIDTH	=	150 X 100 FT
HEIGHT	=	17 FT

NOTES:

1. REQUIRED EQUALIZATION STORAGE BASED ON TURNOVER EQUALIZATION (20% OF TOTAL TANK VOLUME).
2. REQUIRED FIRE STORAGE BASED ON 3,500 GPM FIRE FLOW AND 3-HOUR DURATION.

2020 WATER SYSTEM EVALUATION

FIGURE 4-4
HIGH STREET TANK

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4.2.2 Richardson Tank Assessment

The required equalization storage of 0.200 MG is based on the 5-day tank turnover volume (20% of total tank volume) and corresponds to a required equalization depth of 10 feet and elevation of 580 feet at the bottom of the equalization storage, including 1 foot of freeboard. At this water level elevation, approximately 8 of the highest customers in the system receive less than 35 psi of static pressure. The highest customer in the system receives 23 psi with the tank drawdown to the bottom of the required equalization storage. The elevation that provides 35 psi of static pressure at the highest points of the system is above the tank overflow. Therefore, the tank does not meet the equalization storage criterion.

Figure 4-6 illustrates the location of the high services (in purple) that receive less than 35 psi with the Richardson Tank drawdown to the required equalization depth. At the bottom of the required equalization elevation, these services, ranging in elevation from 499 feet to 527 feet, receive 23 to 34 psi of static pressure. These customers are primarily located in vicinity of the tank.

The elevation that provides 20 psi of static pressure for the highest customer is above the bottom of the tank. Therefore, 0.658 MG of the tank volume is considered unusable for providing fire protection and flow during emergencies while maintaining required minimum pressures.

The required emergency storage volume is based on providing a fire flow of 3,500 gpm for 3 hours, or 0.630 MG. This corresponds to a required emergency depth of 31 feet to an elevation of 549 feet at the bottom of the required emergency storage. At this water elevation approximately 5 customers receive less than 20 psi of static pressure. The highest customer in the system receives 10 psi.

The remainder of the tank volume, below required equalization and fire, is 0.172 MG. This storage volume could provide up to 63 hours of flow at average day demands for the High Service Area. At the bottom of the storage tank, the highest customer receives 6 psi.

As shown in Figure 4-5 and in Table 4-6, although the total storage is greater than the required storage, the Richardson Tank does not provide the required pressures for a small number of customers in the system (up to 8 customers, or 1.5% of customers in the High Service Area. As with the Low Service Area, these customers are located near the tank and may receive adequate pressure when the tank is filling. The town could consider providing a small booster pump system for these 8 customers, as a medium to low priority since all customers receive at least 23 psi at the bottom of equalization and 10 psi at the end of a design fire.

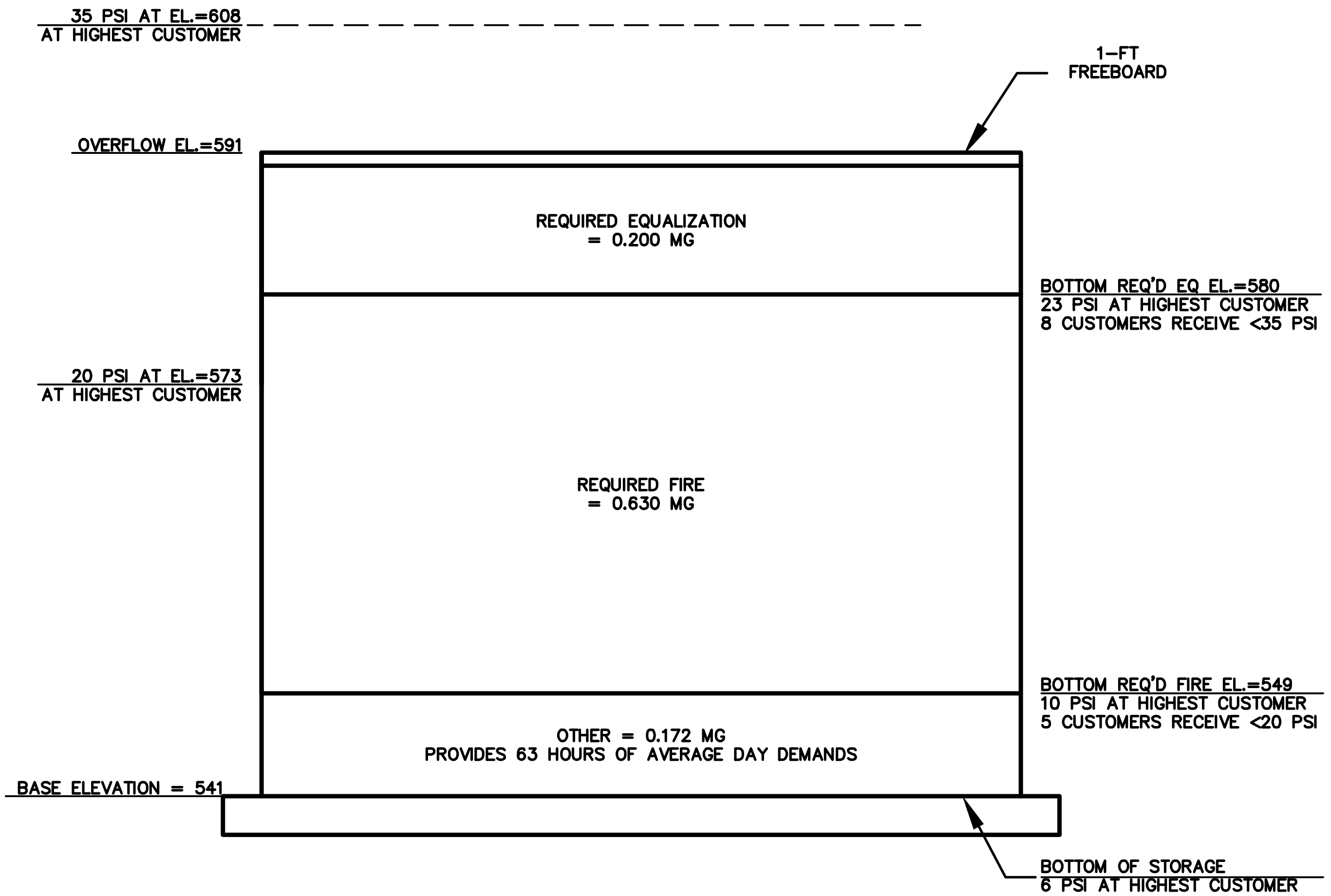
TABLE 4-6

Richardson Tank – Storage Capacity Evaluation Data (million gallons)

	Required	Amount Meeting Criterion
Equalization Storage	0.200 (1)	0.200 (3)
Emergency/Fire Storage	0.630 (2)	0.630 (4)
Remaining Volume	--	0.172 (5)
Total	0.830	1.002

(1) At bottom of the required EQ storage, highest 8 customers in the High Service Area receive less than 35 psi; highest customer receives 23 psi.
(2) Required fire storage of 3,500 gpm for 3 hours. At bottom of the required Fire storage, highest 5 customers receive less than 20 psi; highest customer receives 10 psi.
(3) Set equivalent to Required Equalization for comparison purposes. However, water elevation that provides 35 psi at the highest customer is above the tank overflow elevation.
(4) Set equivalent to Required Fire for comparison purposes.
(5) Remaining volume below equalization and emergency/fire. Provides 63 hours of ADD.

REQUIRED TANK LEVELS



TOTAL CAPACITY	=	1.002 MG (WITH FREEBOARD)
1 FT STORAGE	=	20,450 GAL
DIAMETER	=	59 FT
HEIGHT	=	50 FT

NOTES:

1. REQUIRED EQUALIZATION STORAGE BASED ON TURNOVER EQUALIZATION (20% OF TOTAL TANK VOLUME).
2. REQUIRED FIRE STORAGE BASED ON 3,500 GPM FIRE FLOW AND 3-HOUR DURATION.

2020 WATER SYSTEM EVALUATION

FIGURE 4-5
RICHARDSON TANK

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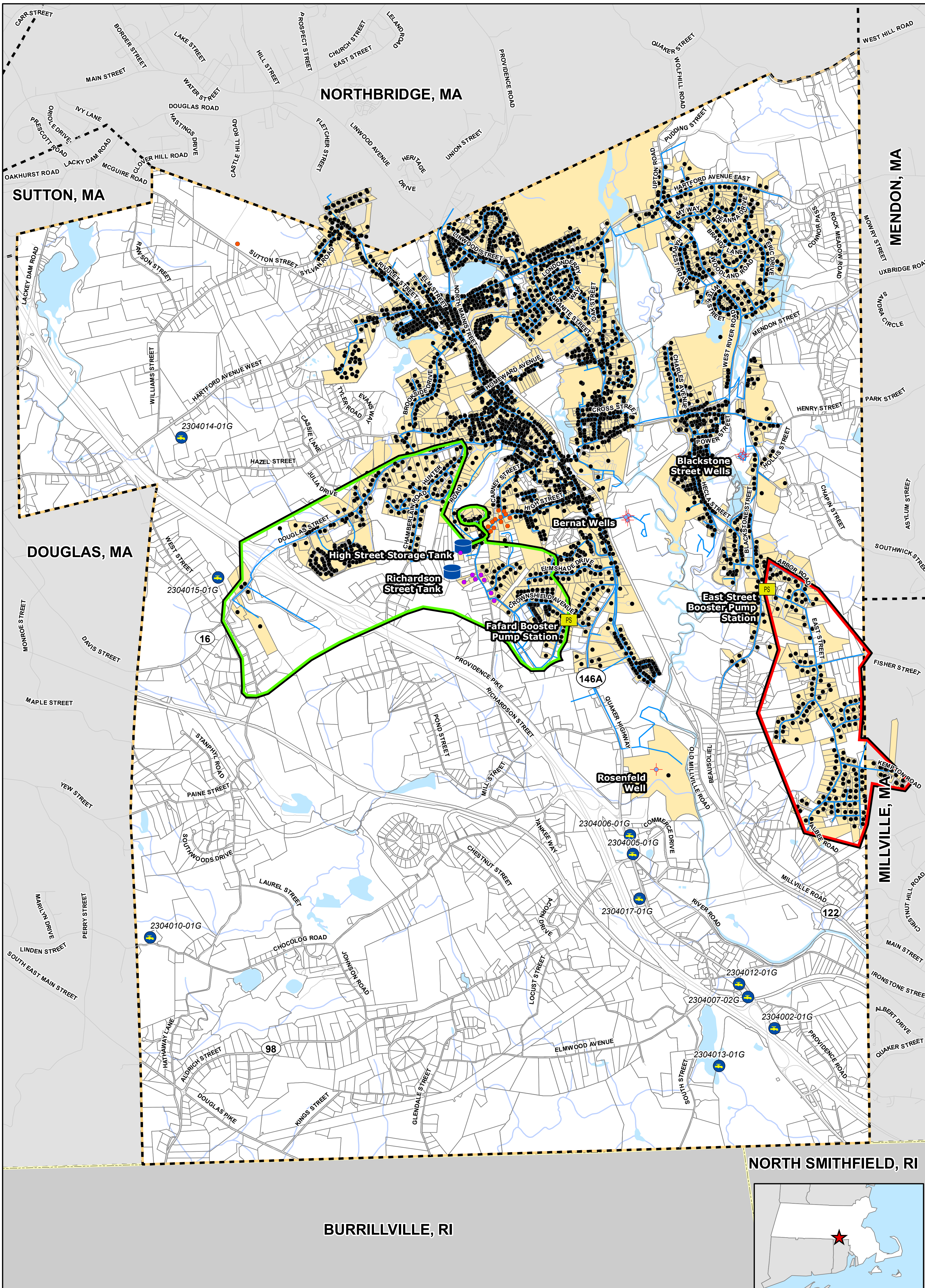

Other Small Public Water Systems	East Street Service Area
Pump Station	High Service Area
Storage Tank	Service Area
Well	Parcel Boundary
Water Mains	Uxbridge Town Boundary
Water Bodies	Other MA Town Boundary
	RI Town Boundary

- Customer Point
- High Service Area Customers Receive <35 psi
- Low Service Area Customers Receive <35 psi

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.
2. Parcels (FY2020) downloaded by MassGIS and are approximate.
3. Other Small Public Water Systems data provided by MassGIS.

0 1,500 3,000
Feet
N
1:36,000

FIGURE 4-6
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Pumping Storage
Uxbridge, Massachusetts

September 2020

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4.2.3 East Street Service Area

The East Street Service Area does not have water storage facilities. Preliminary storage calculations for this area are presented below based on the comparison criteria utilized for evaluating the High Street and Richardson Tanks.

- Total Storage based on Equalization Storage and Fire Storage
  - Equalization storage based on 20% of max day demands is approximately 14,000 gallons (based on 2019 max day demands of 67,680 gpd for this service area)
  - Fire storage based on 750 gpm fire flow for 2 hour duration is 90,000 gallons
  - Total storage of approximately 104,000 gallons

An alternatives assessment was conducted in 2015 to evaluate options for improvements for the East Street pump station and for an elevated water storage tank. The assessment considered system improvements necessary to meet peak hour demands in the East Street Service area and for providing added fire protection. The analysis provided budget estimates for design and construction of a new booster pump station to meet peak hour and fire flow demands, upgrades to the existing booster pump station, and a new elevated water storage tank.

Of the two options considered, the analysis recommended a new pump station consisting of a prefabricated building containing 100 gpm, 350 gpm, and 750 gpm pumps constructed at the site of the existing underground booster pump station. The proposed pumping capacities would meet the pumping capacity criteria presented in Table 4-4 previously. The analysis recommended a new water storage tank with a capacity of 150,000 gallons for added fire protection. This storage volume would meet the storage capacity criteria presented above.

The recommendations in Section 8 include the budget costs from the 2015 analysis in 2020 dollars for a new pump station and water storage tank.

Section 5
Hydraulic Evaluation

5.1 System Evaluation

System hydraulics were evaluated under MDD conditions using the updated hydraulic model. This section presents the results of our evaluation. During these simulations, the following operating conditions were used:

- Richardson Street Tank level: 47 feet (588 feet elevation)
- High Street Tank level: 16 feet (497 feet elevation)
- Fafard Booster Pump Station status: Off
- East Street Pump Station status: Smaller Pump On
- Wellfields: Blackstone Wells #2 and #3 On; Bernat Wells #4 & #5 On; Rosenfeld Well #7 Off

5.1.1 Pressure

Figure 5-1 shows system pressure under existing MDD conditions with the operating assumptions outlined in Section 5.1. As shown on the figures, the majority of the system falls within recommended pressure ranges (>35 psi and <90 psi). Low pressure can result in low available fire flow, susceptibility to cavitation during low pressure surges, and potential water quality issues. Areas with high pressure can result in water main breaks and susceptibility to high pressure surges.

Areas with low pressure are mostly located around the High St Tank. This is not uncommon since storage tank siting is typically selected for higher elevation. Low pressure areas adjacent to storage tanks are typically not a concern because proximity to the tank acts to stabilize pressure since there is minimal system headloss between the tank and nearby customers.

Some high-pressure areas are located near the Bernat Wells and the East Street Booster Pump Station. Pressure can be reduced with the use of pressure reducing valves at customers' connections.

The high and low-pressure areas are largely elevation driven and are not cause of immediate concern but should be taken into account when designing distribution system upgrades or redefining service area boundaries during future system expansion.

5.1.2 Head Loss Gradient

An analysis was performed to assess the head loss gradient in the system. The color-coded results can be seen in Figure 5-2. Headloss gradient was calculated in units of headloss in feet per 1,000 feet of pipe (ft/1,000 ft). Evaluating system headloss gradient normalizes for differences in pipe length to identify hydraulic constrictions in the distribution system.

Under MDD conditions, most pipes in the system had headloss values of less than 1 ft/1,000 ft. Some of the pipes had head loss values between 1 and 5 ft/1,000 ft and very few pipes had head loss values over 5 ft/1,000 ft.

Almost all the pipes that had headloss values greater than 1 ft/1,000 ft but less than 5 ft/1,000 ft were installed between 1920 and 1950, including the pipes on North Main Street, West River Road, Mendon Street, and near the Bernat Wells. Pipes that had headloss values greater than 5 ft/1,000 ft were located near the Bernat Wells.

5.1.3 Pipe Velocity

An analysis was performed to assess the flow velocity in the system. The color-coded results can be seen in Figure 5-3. Flow velocity was calculated in units of feet per second (ft/s). Under MDD conditions, most pipes in the system had flow velocities of less than 1 ft/s. Nearly all the pipes that had flow velocities greater than 1 ft/s were installed between 1920 and 1950, including the pipes on Blackstone Street, Brown Terrace, and Henry Street. Very few pipes in the system had flow velocities greater than 2 ft/s.

5.1.4 Available Fire Flow

The 2013 ISO Fire Flow Survey was used to identify Needed Fire Flows (NFF) at the 12 ISO Sites. Based on data that was obtained and the model results, six of the ISO test locations did not have available fire flow values higher than ISO recommendations. Table 5-1 below shows the ISO data and whether the ISO needed fire flow was available before and after improvements. Total Available Fire Flow (AFF) improves by over 32,300 gpm system-wide with the recommended improvements. Additionally, the average AFF of all nodes increases by 55 gpm with improvements. While there is a significant AFF improvement overall, the NFF is not met for some ISO test locations due to factors other than distribution system headloss such as elevation and low pressures.

TABLE 5-1
Modeled Available Fire Flow at ISO Locations (4)

ISO Site (1)	Location	Fire Flow at 20 psi (gpm) Needed (3,5)	Available (2,6)	Available with Improvements (7)
1	Mendon Street and Patrick Henry Street	1,750	1,750	1,750
2	Mendon Street and Cross Street	7,000/1,750	2,150	2,150
3	Rivulet Street and Brookside Drive	6,500/2,500	1,200	1,200
4	Capron Street at High School	4,000/500	1,750	1,750
5	On Depot/400ft S. of Mendon Street	3,500	2,000	2,000
6	Douglas Street and Rte 146	3,000	400	2,750
7	East Hartford/5000ft E. of Deanna Drive	500	1,050	1,050
8	End of Bacon Street/Off Elmdale	1,250	1,050	1,050
9	E. Hartford Ave and Oak Street	3,000	850	850
10	S. Main Street and Quaker Hwy	3,000	3,650	3,650
11	S. Main Street and Park Street	2,500	3,000	3,000
12	N. Main Street and Sayles Street	1,500	1,500	1,550

(1) Test locations are shown on Figure 2-1.

(2) Available flow was calculated using a 20-psi minimum constraint at the flowing node.

(3) For locations where ISO provides multiple Needed Fire Flows, the range of ISO Needed Fire Flows are shown, and the lower value is used based on ISO guidelines.

(4) Predicted AFF was calculated using a hydraulic model of Uxbridge, MA's water distribution system. The available flow rates are based on the node closest to each hydrant. Predicted flows are based on various assumptions in the model as to pump status, tank levels, water main condition, and demand distribution. As actual field conditions may vary from what is assumed in the model, available fire flow rates may differ from calculated values. A summary of operational assumptions is included in Figure 5-4.

(5) Data obtained from ISO Hydrant Flow Data Summary (2013).

(6) Highlighted cells indicate sites that do not meet ISO Needed Fire Flow.

(7) Recommended distribution system improvements are shown in Figure 8-1. AFF results with recommended improvements are presented in Figure 5-5.

Fire flow analysis was performed under MDD system demand conditions and the results are presented in Figure 5-4. AFF is defined as the maximum flow that can be withdrawn while maintaining pressure at 20 psi or greater at all points in the system. AFF is represented by color-coded model junctions. Under the scenario shown in Figure 5-4, the initial water level at the Richardson Street Tank is 39 feet (580 feet elevation), the initial water level at the High Street Tank is 15 feet (496 feet elevation), the Fafard Booster Pump Station is off, the East Street Pump Station is on, Blackstone Wells 2 and 3 are on, and Bernat Wells 4 & 5 are on. Initial tank water levels are based on elevations at the bottom of equalization storage determined in the Storage Capacity and Supply Evaluation described in Section 4. Under these conditions, most nodes have available fire flows between 500 and 2,000 gpm. Many nodes at system dead ends have available fire flows less than 500 gpm.

There were two areas of low pressure with three nodes in total that were excluded from the AFF analysis. Nodes J-734 and J-784 are located near the High Street Tank. Low pressure can be expected near tanks as they are typically located at the highest elevation in the system, which is true for the Uxbridge system.

Figure 5-5 shows the impact of proposed improvements on available fire flow. Proposed improvements to address deficiencies in available fire flow are presented in Section 8.

5.2 Other Considerations

5.2.1 Bare Naked Greens Cultivation Facility

The Town provided development estimates for water, sewer, and fire flow needs for the new Bare Naked Greens Cultivation Facility to be located at 290 Millville Road in Uxbridge. According these documents, the facility will be in staffed in three shifts for operation 24 hours per day. Equalization storage will be installed at the site (multiple 10,000-gal tanks) to offset peak demands. Table 5-2 summarizes the planned water and fire protection needs of the facility.

TABLE 5-2

Projected Water Use at Bare Naked Greens Cultivation Facility

Average Domestic Demand	900	gpd
Average Irrigation Demand	20,000	gpd
Total Average Day Demand	20,900	gpd
Max Day/Peak Hour Demand (1)	83,600	gpd

(1) Planning documents assume consistent 24-hour staffing with a projected MDD equal to peak hour demand (4x multiplier).

The projected max day demand of the facility of 58 gpm (83,600 gpd) was added to the existing MDD scenario in the model and evaluated for any potential hydraulic constraints as a result of the new facility. Millville Road has parallel 6-inch and 12-inch water mains. This analysis assumes service to the new facility will be tapped off the 12-inch main. Pressure at the model node representing the facility (J-955) was unchanged with the added facility demand (110 psi), flow velocity remained low (<0.5 ft/s) and headloss was negligible.

The fire protection needs of the facility require 750 gpm at 40 psi (at service connection) to operate the sprinkler system, plus and additional 500 gpm from street hydrants. This was simulated in the MDD model as a total fire demand of 1,250 gpm at the representative node. As summarized in Table 5-3, pressure at the service connection is predicted to remain well above the 40-psi minimum. Total available fire flow at the facility is modeled as >3,500 gpm during MDD conditions (20 psi system-wide minimum pressure constraint).

TABLE 5-3

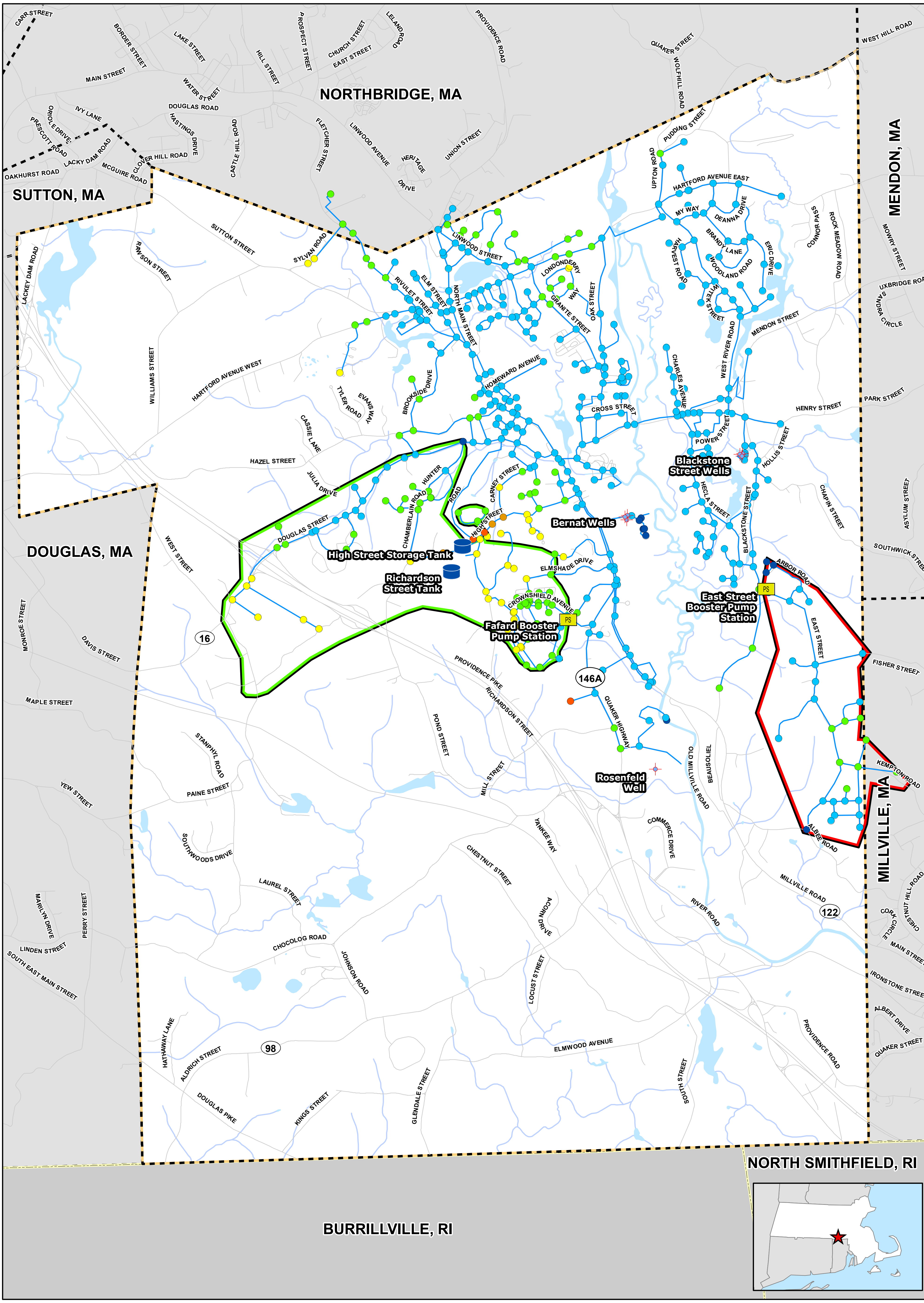
Modeled Fire Flows at the Bare Naked Greens Cultivation Facility

	Fire Flow Needed [1]	Pressure Needed	Simulated Pressure During Fire Flow
Sprinkler System Demand (40 psi minimum)	750 gpm		
Fire Hydrant Demand	500 gpm		
Total Fire Protection Demand	1,250 gpm	40 psi	99 psi
Total Available Fire Flow [2]	>3,500 gpm		

[1] The indicated fire flow and pressure need is based on planning documents provided by the Town and is not equivalent to Needed Fire Flow as determined by ISO.

[2] 20-psi minimum pressure constraint at the flowing node and 20-psi minimum pressure constraint at all other nodes in the system.

The findings of this hydraulic model analysis show the existing water distribution system is able to provide the projected 83,600 gpd MDD and that both pressure requirements and fire flow demands will be able to be met.



PS Pump Station	East Street Service Area	**Pressure (psi)**
Storage Tank	High Service Area	< 20
Well	Uxbridge Town Boundary	≥ 20 and < 35
Water Main	Other MA Town Boundary	≥ 35 and < 60
Water Bodies	RI Town Boundary	≥ 60 and < 90
		≥ 90 and < 125
		≥ 125

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet

N
1:36,000

FIGURE 5-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Pressure
2019 Maximum Day Demand Conditions
Uxbridge, Massachusetts

September 2020

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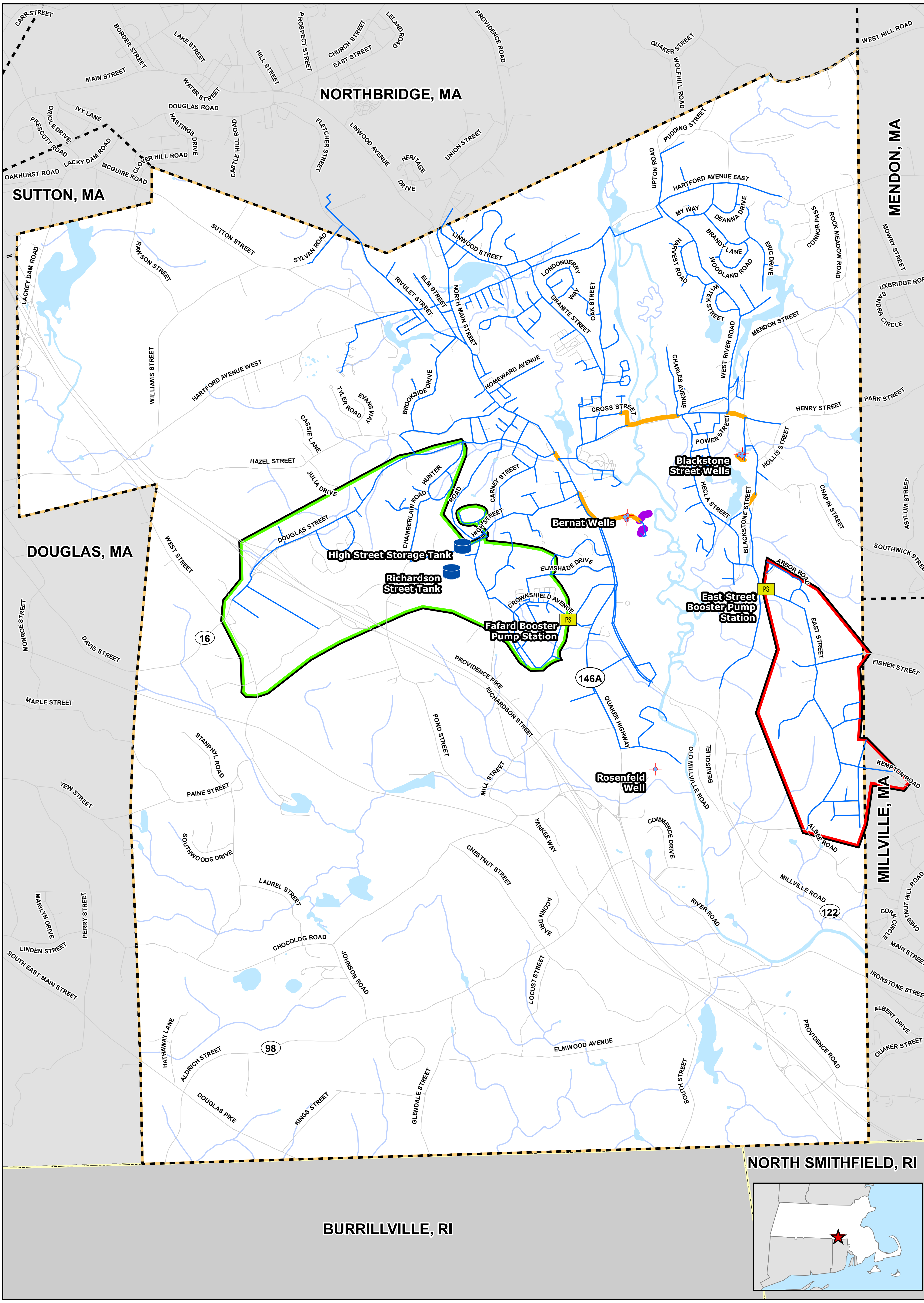

PS Pump Station
Storage Tank
Well
Water Bodies
East Street Service Area
High Service Area
Uxbridge Town Boundary
Other MA Town Boundary
RI Town Boundary

Headloss Gradient (ft/1,000 ft)

- < 1
- ≥ 1 and < 5
- ≥ 5

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet

N

1:36,000

FIGURE 5-2
UXBRIDGE WATER DISTRIBUTION SYSTEM

Headloss Gradient
2019 Maximum Day Demand Conditions
Uxbridge, Massachusetts

September 2020

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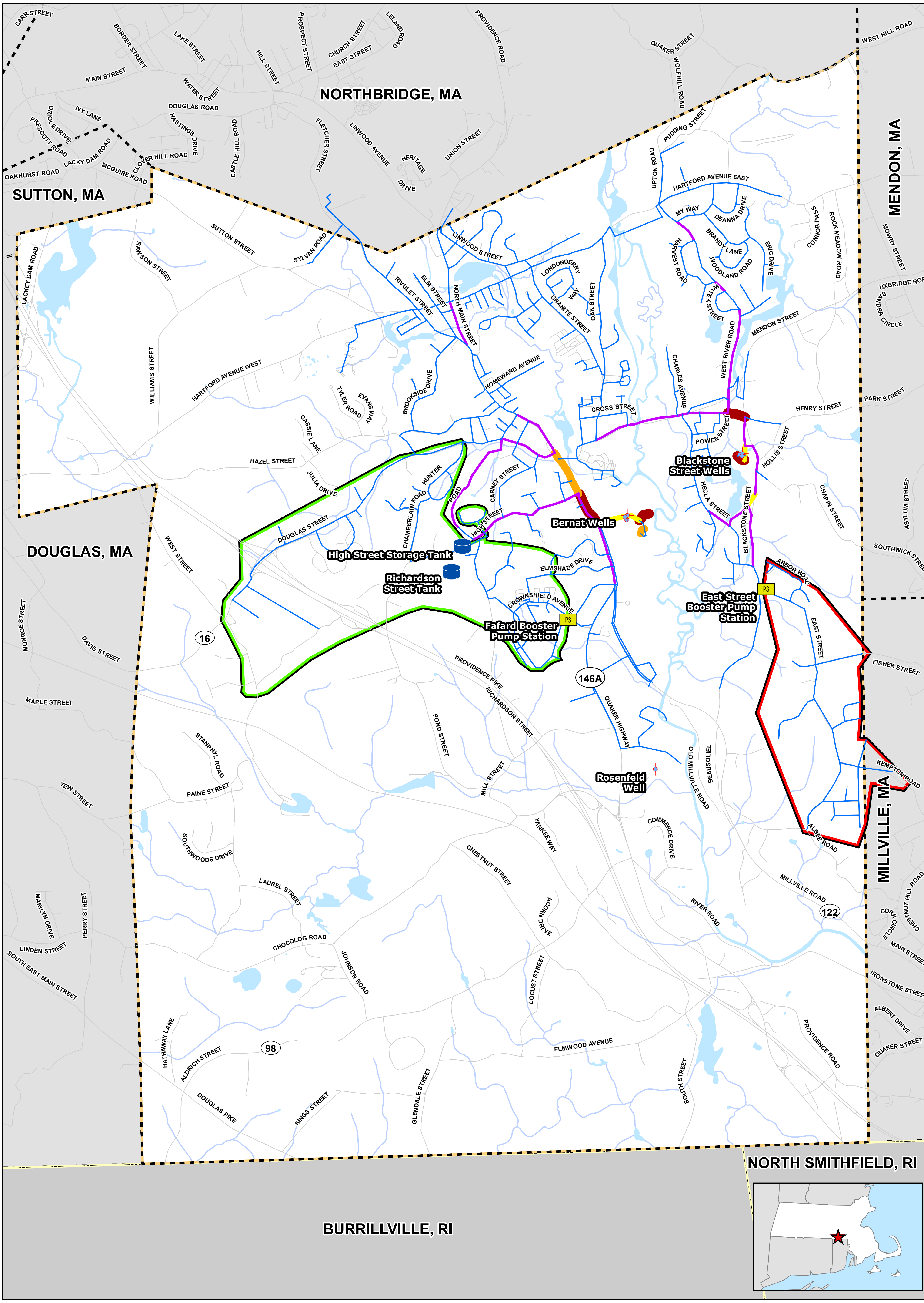

Pump Station
Storage Tank
Well
Water Bodies
East Street Service Area
High Service Area
Uxbridge Town Boundary
Other MA Town Boundary
RI Town Boundary

Flow Velocity (ft/s)

- < 0.5
- ≥ 0.5 and < 1
- ≥ 1 and < 1.5
- ≥ 1.5 and < 2
- ≥ 2

0 1,500 3,000
Feet
1:36,000

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

FIGURE 5-3
UXBRIDGE WATER DISTRIBUTION SYSTEM

Flow Velocity
2019 Maximum Day Demand Conditions
Uxbridge, Massachusetts

September 2020

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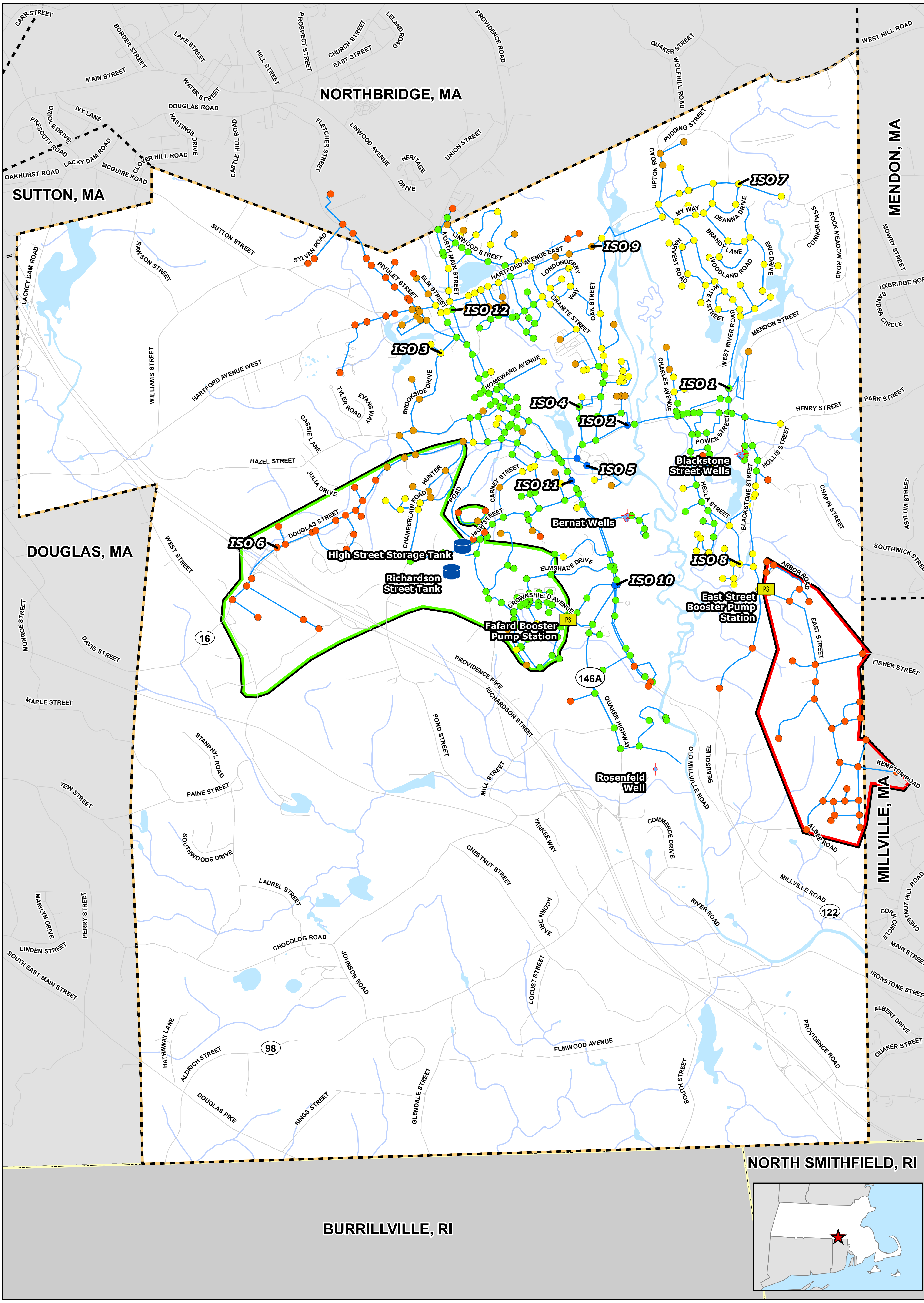

PS Pump Station	East Street Service Area
Storage Tank	High Service Area
Well	Uxbridge Town Boundary
Water Main	Other MA Town Boundary
Water Bodies	RI Town Boundary

Available Fire Flow (gpm)

- < 500
- ≥ 500 and < 1,000
- ≥ 1,000 and < 1,500
- ≥ 1,500 and < 2,000
- ≥ 2,000

1. Water main data provided by The Town of Uxbridge Department of Public Works.
2. For this analysis, the initial water level at the Richardson Street Tank is 549 feet. The initial water level at the High Street Tank is 490 feet. All pumps are off including pumps at the Faffard Booster Pump Station and all wells, except for one pump at the East Street Pump Station

0 1,500 3,000
Feet

N

1:36,000

Tighe&Bond

FIGURE 5-5
UXBRIDGE WATER DISTRIBUTION SYSTEM

Available Fire Flow with Improvements
2019 Maximum Day Demand Conditions
Uxbridge, Massachusetts

September 2020

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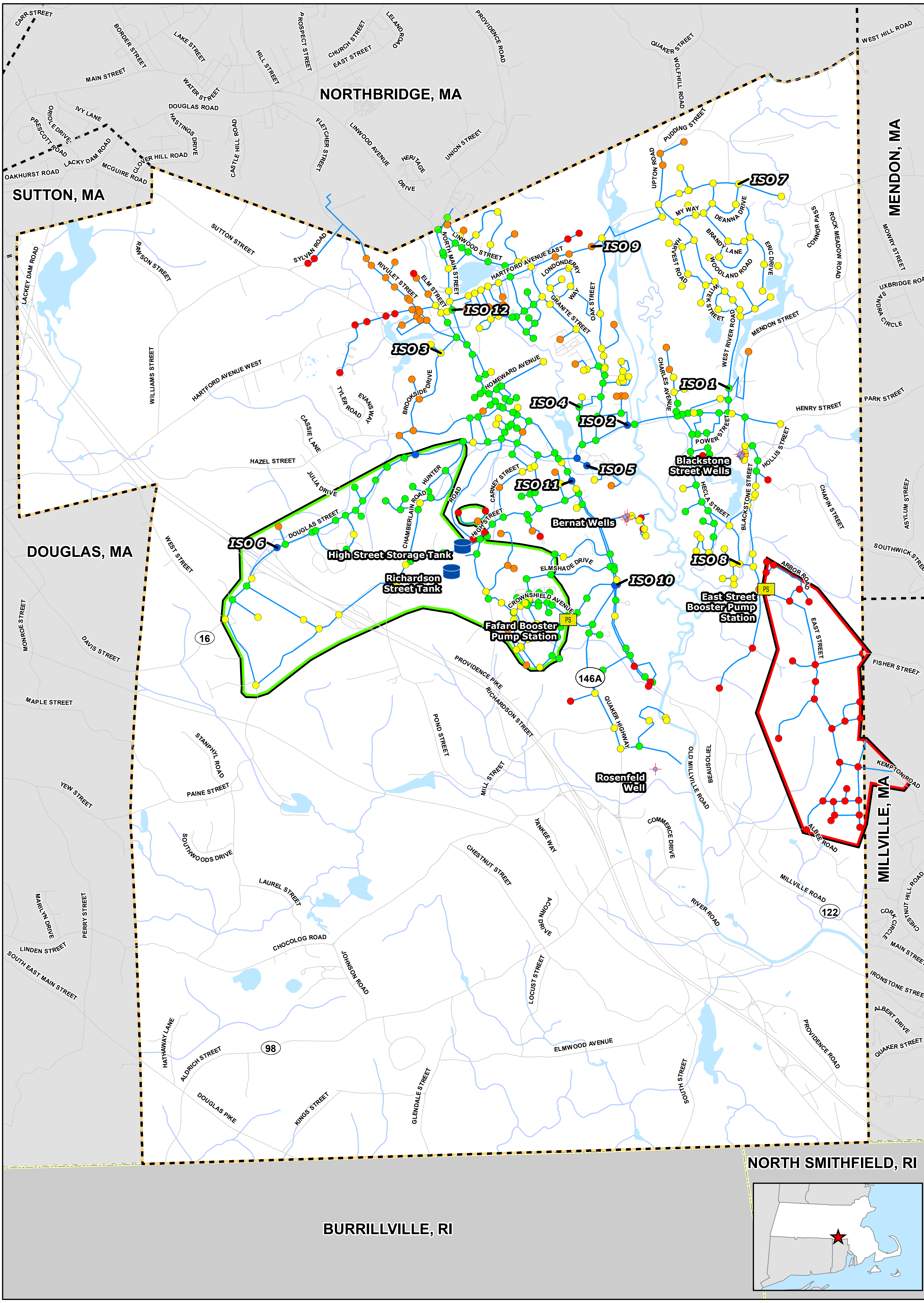

PS Pump Station
Storage Tank
Well
Water Main
Water Bodies
East Street Service Area
High Service Area
Uxbridge Town Boundary
Other MA Town Boundary
RI Town Boundary

Available Fire Flow (gpm)

- < 500
- ≥ 500 and < 1,000
- ≥ 1,000 and < 1,500
- ≥ 1,500 and < 2,000
- ≥ 2,000

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.
2. For this analysis, the initial water level at the Richardson Street Tank is 549 feet. The initial water level at the High Street Tank is 490 feet. All pumps are off including pumps at the Faffard Booster Pump Station and all wells, except for one pump at the East Street Pump Station

0 1,500 3,000
Feet

N

1:36,000

FIGURE 5-5
UXBRIDGE WATER DISTRIBUTION SYSTEM

Available Fire Flow with Improvements
2019 Maximum Day Demand Conditions
Uxbridge, Massachusetts

September 2020

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Section 6
Criticality Analysis

A criticality analysis was performed for the water distribution system to evaluate the impact of potential water main failures on the water distribution system. The criticality analysis includes identification of critical areas served, critical water mains, and the need for redundant mains.

6.1 Critical Customers

Critical customers served are locations in the distribution system that require continuous water supply for public health, welfare or financial reasons. Critical customers were identified and evaluated for service redundancy. Critical customers include medical centers, schools, nursing homes, and other facilities that could experience disproportionate health and/or safety impacts with the loss of water service. A list of critical customers is included in Table 6-1. A map of critical customers and system components is included in Figure 6-1. Water mains impacting critical customers with loss of service are highlighted in Figure 6-1.

TABLE 6-1
Critical Customers

Location(1)	Address	Phone Number	Type of Facility	Service Redundancy? (2)
Tri-River Family Health Care	281 East Hartford Avenue	(508) 278-5573	Healthcare	Yes
Lydia Taft House	60 Quaker Highway	(508) 278-9500	Healthcare	Yes
Whitin Elementary School	120 Granite Street	(508) 278-8640	School	Yes
Taft Early Learning Center	16 Granite Street	(508) 278-8643	School	Yes
Uxbridge High School	300 Quaker Highway	(508) 278-8633	School	No
Our Lady of the Valley Regional School	75 Mendon Street	(508) 278-5851	School	Yes
VCA Blackstone Valley Animal Hospital	615 Douglas Street	(508) 278-6581	Veterinarian	No
AC Technology	660 Douglas Street	(508) 278-9100	Manufacturer	No
Interconnection with Whitinsville	North Main Street	(508) 234-7358	Inter-connection	No

(1) See Figure 6-1 Critical Customers and Components
(2) For this analysis, a customer has service redundancy if there is more than one supply connection between the customer and source that can be used to satisfy customer demand in the event that one supply connection fails, such as during a water main break.

6.2 Critical System Components

Critical system components were identified based on necessity for full water distribution system operation, including active wellfields, treatment facilities, storage tanks, booster pump stations, and transmission mains. Tanks and primary sources are considered critical components because they supply water and maintain pressure to service areas. Table 6-2 presents a list of critical components in the distribution system.

TABLE 6-2

Critical Components

Location[1]	**Address**	**Type of Facility**
Blackstone Wells #1, 2 & 3	Blackstone Street	Wellfield
Bernat Wells #4, 5 & 6	South Main Street	Wellfield
Rosenfeld Well	308 Quaker Highway	Wellfield
East Street Pump Station	East Street	Pump Station
Fafard Pump Station	Crownshield Avenue	Pump Station
Richardson Street Tank	Richardson Street	Tank
Low Service Area Tank	High Street	Tank
Interconnection with Whitinsville Water Company	North Main Street	Interconnection

[1] See Figure 6-1 Critical Customers and Components

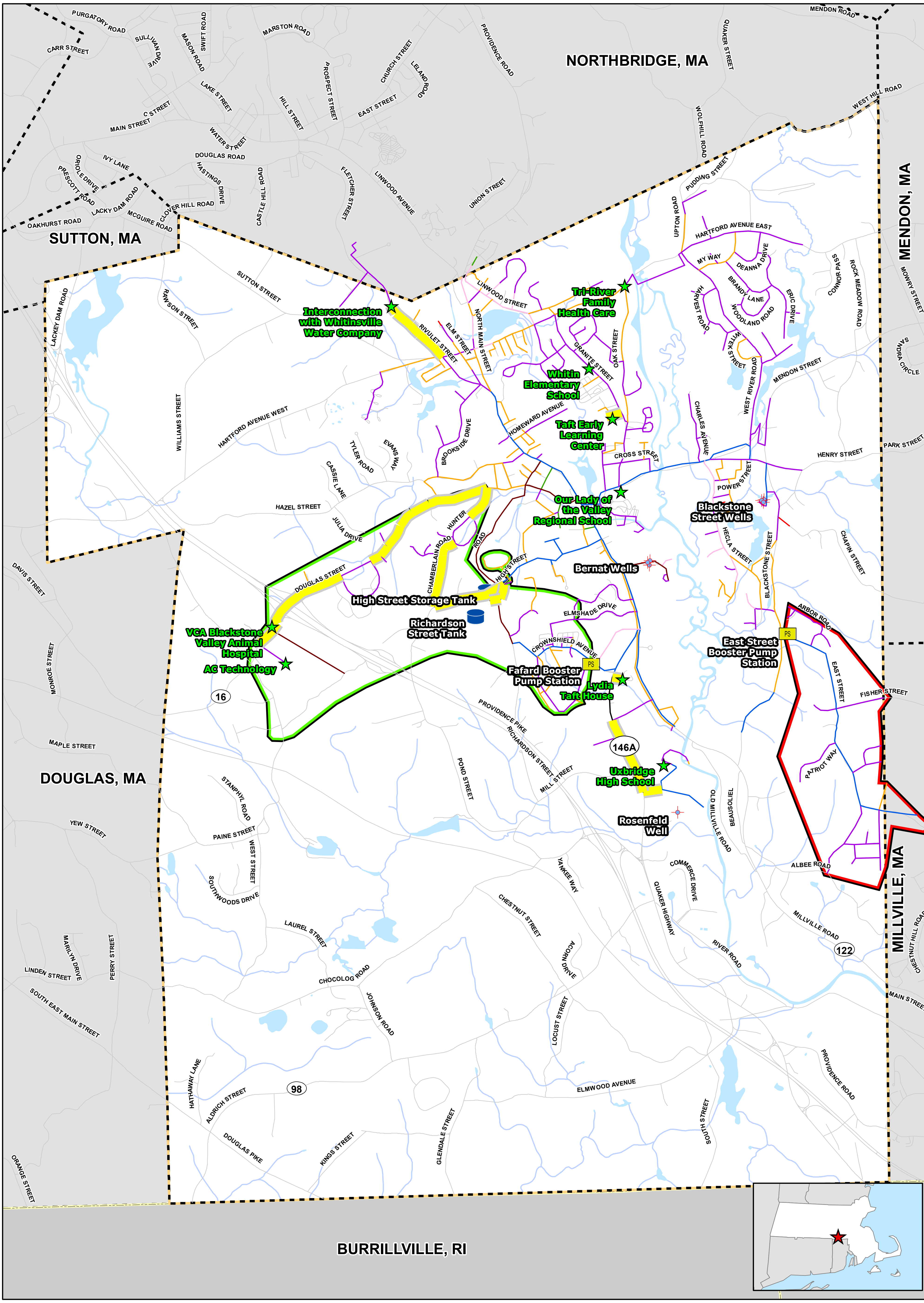
6.3 Water Main Criticality Analysis

A water main criticality analysis was performed using the WaterGEMS Criticality tool to identify customer impact with loss of service along each modeled pipe, such as from a main break. The criticality analysis was used to identify water mains impacting >5% of total system demand with loss of service.

The WaterGEMS Criticality tool runs a series of steady-state simulations that "break" each pipe in the model to calculate how much of the total system demand has been completely isolated from supply elements (tanks, wellfields, and pump stations). This analysis was performed assuming all wellfields and the Fafard Pump Station were off (storage supply only) to provide a more conservative result. During the simulation, a pipe was considered critical if the simulated break impacted more than five percent of the total system demand.

In total, the model identified 11,825 linear feet (LF) of water main that could potentially isolate >5% of the system demand if service was interrupted. Shown in Figure 6-2, these mains are primarily located around the Richardson Street Tank in the High Service Areas and on the suction and discharge sides of the East Street Pump Station.

Table 7-1 in the following section summarizes water mains impacting >5% of total system demand with loss of service and water mains that impact critical customers with loss of service, as well as recommended improvements and priority rank. Recommended improvements based on these findings are presented in Figure 8-1 and Table 8-1.



Critical Customers	Water Bodies	**Water Main Size**	
Critical Water Mains	East Street Service Area	2"	10"
Pump Station	High Service Area	4"	12"
Storage Tank	Uxbridge Town Boundary	6"	16"
Well	Other MA Town Boundary	8"	20"
	RI Town Boundary		

NOTE:
FOR THIS ANALYSIS, "CRITICAL WATER MAINS" ARE DEFINED AS WATER MAINS IMPACTING A CRITICAL CUSTOMER WITH LOSS OF SERVICE. "CRITICAL CUSTOMERS" INCLUDE CUSTOMERS THAT COULD EXPERIENCE DISPROPORTIONATE HEALTH/SAFETY IMPACTS WITH LOSS OF SERVICE.

0 1,500 3,000
Feet
1:36,323

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

FIGURE 6-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Critical Customers and Components
Uxbridge, Massachusetts

September 2020

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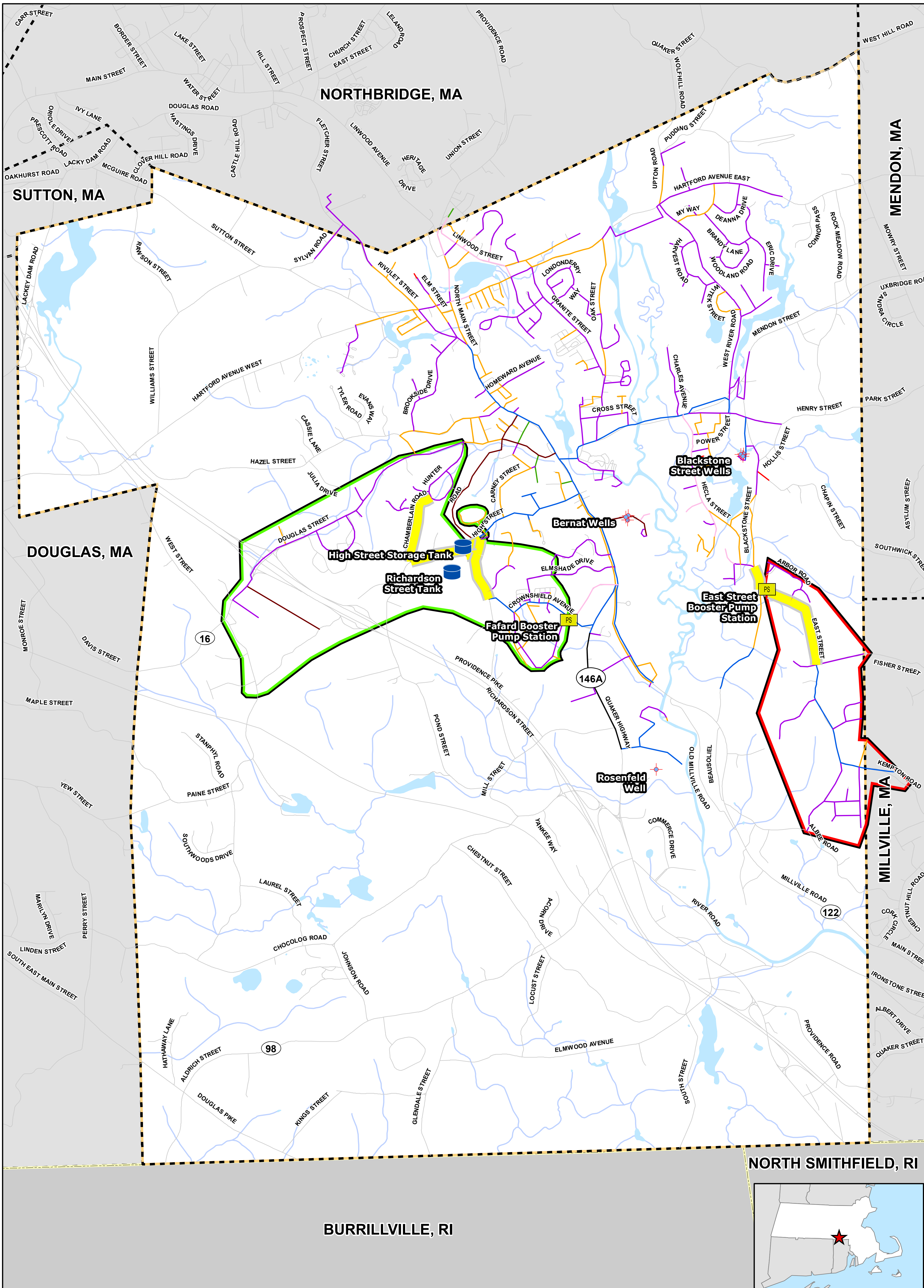

PS	Pump Station
	Storage Tank
	Well
	Critical Water Main
	Water Bodies
	East Street Service Area
	High Service Area
	Uxbridge Town Boundary
	Other MA Town Boundary
	RI Town Boundary

Water Main Size

2"	10"
4"	12"
6"	16"
8"	20"

NOTE:
FOR THIS ANALYSIS, "CRITICAL WATER MAINS" ARE DEFINED AS WATER MAINS IMPACTING >5% OF TOTAL SYSTEM DEMAND WITH LOSS OF SERVICE.

0 1,500 3,000
Feet
1:36,000

FIGURE 6-2
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Critical Water Mains
Uxbridge, Massachusetts

August 2020

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

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Section 7
Water Main Asset Management

7.1 Water Main Inventory and Ranking

The attributes included in the model pipe inventory, including material, age, and break history were used in combination with modeled results to rank water mains based on criticality and risk of failure.

Tighe & Bond worked with the DPW to create an asset scoring method. Scores associated with each pipe were used to prioritize assets and support decisions regarding capital planning. Table 7-1 includes results from the criticality analysis, pipe attributes such as size, material, and installation year, potential AFF improvements, and a priority ranking of Low, Medium, or High. Table 7-1 also indicates whether or not each critical water main impacts >5% of total system demand with loss of service or impacts critical customers with loss of service. Recommended improvements based on these findings are presented in Figure 8-1 and Table 8-1. Table 7-2 below includes further information about pipe material and installation year.

TABLE 7-2

Pipe Material By Installation Year

Installation Year	Unlined Cast Iron	Universal (1)	Cement Lined Cast Iron	PVC	Ductile Iron	Total
Before 1930	14,872	32,693				47,565
1930 - 1949	6,357	112,206				118,563
1950 - 1959						0
1960 - 1969			3,888			3,888
1970 - 1979						0
1980 - 1989				23,499	27,785	51,284
1990 - 2015				1,217	106,385	107,602
Unknown					11,968	11,968
Total	**21,229**	**144,899**	**3,888**	**24,716**	**146,138**	**340,870**

(1) Universal pipe material refers to a type of unlined cast iron pipe

TABLE 7-1
Asset Management Database

Location	Service Area	Size (in)	Material	Installation Year	Length (LF)	Asset ID	AFF Improvement with Replacement or Upsizing?	Impact Critical Customer Service? (1)	Impact Significant Demand? (2)	Priority
Blackstone Street	Main	6	Universal	1929	791	P-420	No	No	Yes	High
Chamberlain Road	High	8	Ductile Iron	1993	1201	P-732	No	Yes	No	Low
Chamberlain Road	High	8	Ductile Iron	1995	2418	P-742, P-740(2), P-740(1)	Yes - Upsize to 12"	Yes	Yes	Medium
Douglas Street	High	8	Universal	1929	4913	P-938, P-940, P-966, P-980, P-982, P-660, P-936	Yes - Upsize to 12"	Yes	No	High
Douglas Street	High	8	Universal	1929	1122	P-960, P-974	No	Yes	No	High
Douglas Street (3)	High	8	Ductile Iron	2000	967	P-670, p	No	Yes	No	Low
Douglas Street (4)	High	8	PVC	1981	1742	P-830, P-828	No	Yes	No	Low
East Street	East Street	12	Ductile Iron	1990	3622	P-1140, P-428, P-1139, P-962	No	No	Yes	Low
Granite Street	Main	8	Ductile Iron	1990	520	P-132, P-134	No	Yes	No	Low
High Street (5)	High	16	Ductile Iron	2004	2488	P-868, P-870	No	Yes	Yes	Low
High Street (6)	High	12	Cast Iton	1904	4025	P-920, P-992, P-698, P-700, P-702, P-704, P-696	No	No	No	Low
Quaker Highway	Main	8	Ductile Iron	2000	364	P-1063	No	Yes	No	Low
Quaker Highway	Main	12 - 20	Ductile Iron	2011	3294	P-1049, P-1143, P-1144	No	Yes	No	Low
Richardson Street	High	16	Ductile Iron	2004	872	P-902, P-900	No	Yes	Yes	Low
Richardson Street	High	16	Ductile Iron	2004	1634	P-898(2), P-898(1)	No	No	Yes	Low
Rivulet Street	Main	6 - 8	Universal	1940	2459	P-8, P-790, P-792, P-858, P-794(1), P-794(2)	Yes - Upsize to 12"	Yes	No	High

(1) See Figure 6-1 Critical Customers and Components
(2) See Figure 6-2 Critical Water Mains
(3) Ductile Iron appears to be installed from the intersection of Douglas Street/Snowling Road to the intersection of Douglas Street/North Main Street, and from the intersection of Douglas Street/Route 146 to 640 Douglas Street
(4) PVC appears to be installed on Douglas Street under Route 146
(5) Refers to the water mains on High Street from Pine Grove Circle towards Chamberlain Road
(6) Refers to the water mains on High Street from South Main Street towards Pine Grove Circle

Section 8 Recommendations

8.1 Recommended Improvements

This Section presents the proposed capital improvements to address system deficiencies identified in the assessments presented in the prior sections. Proposed improvements are classified into the recommended action categories of Low, Medium, and High Priority.

Recommended water main improvements were developed based on findings from this hydraulic evaluation (Section 5), criticality analysis (Section 6), water main asset management (Section 7), and projected development and system expansion (Section 3) to select priority distribution system improvement projects to meet the current and future needs of the Town. Other system improvements listed are based on the supply capacity and storage capacity evaluations, and water quality assessment.

Budgetary cost estimates were developed for capital planning budgeting purposes. Budgetary costs include equipment costs, demolition/removal of existing equipment (if applicable), allowances for installation, contractor overhead and profit (10%), general conditions (15%), engineering (20%), and contingency (20%). The budgetary costs are based on the August 2020 ENR Construction Cost Index of 11,455.

Recommended improvements do not include costs associated with hazardous materials abatement. Prior to any renovation project, an inspection should be completed for the areas where proposed improvements will occur, and suspect materials should be tested for the presence of hazardous substances such as lead, asbestos, and PCBs.

Prioritization and packaging of projects should be performed in conjunction with the Town's ongoing efforts to monitor and adjust rates to ensure that funding is in place as needed. The Town recently completed an update to the rate model.

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TABLE 8-1

Summary of Category Item Capital Cost ($ Thousands)

Recommended Improvements	Low	Medium	High	Total [3]
Evaluate Alternatives to Increase Source of Supply (Section 4.1)				
Alternatives Analysis – Evaluate Options Below			$75	$75
Replacement Well(s) or Rehabilitation at Bernat Wellfield to Restore Capacity (cost for three wells)			$800	$800
Develop Cnossen Well with Treatment System [1]		$7,000		--
Treatment for Iron/Manganese Removal at Rosenfeld and/or Blackstone Wellfields		$6,000		--
Design and Construction of new Pump Station and Storage Tank to Increase Supply and Storage Capacity of East Street Service Area (Sections 4.1.4 / 4.2.3) [6]				
New Booster Pump Station		$750		$750
New 150,000 gallon Storage Tank		$2,000		$2,000
Evaluate Alternatives to Boost Low Pressures in Main (Low) Service Area (Section 4.2.1)				
Alternatives Analysis – Evaluate Options Below [2]	$35			$35
Small Booster Pump System near High Street Tank	$150			$150
Individual Booster Pumps at Customers	$100			--
Evaluate Alternatives to Boost Low Pressures in High Service Area (Section 4.2.2)				
Alternatives Analysis – Evaluate Options Below	$35			$35
Small Booster Pump System near Richardson Tank	$150			$150
Individual Booster Pumps at Customers	$100			--
Distribution System Expansions (Section 3.1.3.2) [4,5]				
Rt 122 (Millville Road) and Albee Road Expansion - Install 17,000 LF of new 6-inch Ductile Iron water main			$3,825	$3,825
Quaker Highway Expansion - Install 16,100 LF of new 6-inch Ductile Iron water main	$3,625			$3,625
Rt 16/Douglas Street Expansion - Install 4,700 LF of new 8-inch Ductile Iron water main			$1,295	$1,295

TABLE 8-1

Summary of Category Item Capital Cost ($ Thousands)

Recommended Improvements	Low	Medium	High	Total (3)
Distribution System Improvements (Sections 5.1.4 / 6.3)				
High Street - Replace 4,025 LF of 12-inch Cast Iron water main with new 12-inch Ductile Iron water main			$1,310	$1,310
Blackstone Street - Replace 790 LF of 6-inch Universal water main with new 6-inch Ductile Iron			$180	$180
Chamberlain Road - Replace 2,400 LF of 8-inch Ductile Iron water main with new 12-inch Ductile Iron		$780		$780
Douglas Street - Replace 4,000 LF of 8-inch Universal water main with new 12-inch Ductile Iron			$1,595	$1,595
Douglas Street/Rt146 Loop - Install 9,400 LF of new 16-inch Ductile Iron water main			$3,760	$3,760
Douglas Street - Replace 2,250 LF of 8-inch Universal water main with new 8-inch Ductile Iron			$620	$620
Rivulet Street - Replace 2,500 LF of 6-inch/8-inch Universal water main with new 12-inch Ductile Iron			$815	$815
Total (3)	**$3,995**	**$3,530**	**$14,275**	**$21,800**

(1) Does not include costs to acquire property.

(2) Analysis should also evaluate conditions at the highest customer in the Main Service Area, located on Sutton Street at an elevation approximately 49 feet higher than the second highest customer in the service area.

(3) Based on only one of the potential alternatives.

(4) Based on cost per linear foot of $225 for 6-inch water main, $275 for 8-inch water main, $325 for 12-inch water main, and $400 for 16-inch water main (all Ductile Iron).

(5) A map of recommended improvements is presented in Figure 8-1.

(6) Based on recommendations from Tata & Howard evaluation dated June 23, 2015; costs converted from 2015 to 2020 dollars.

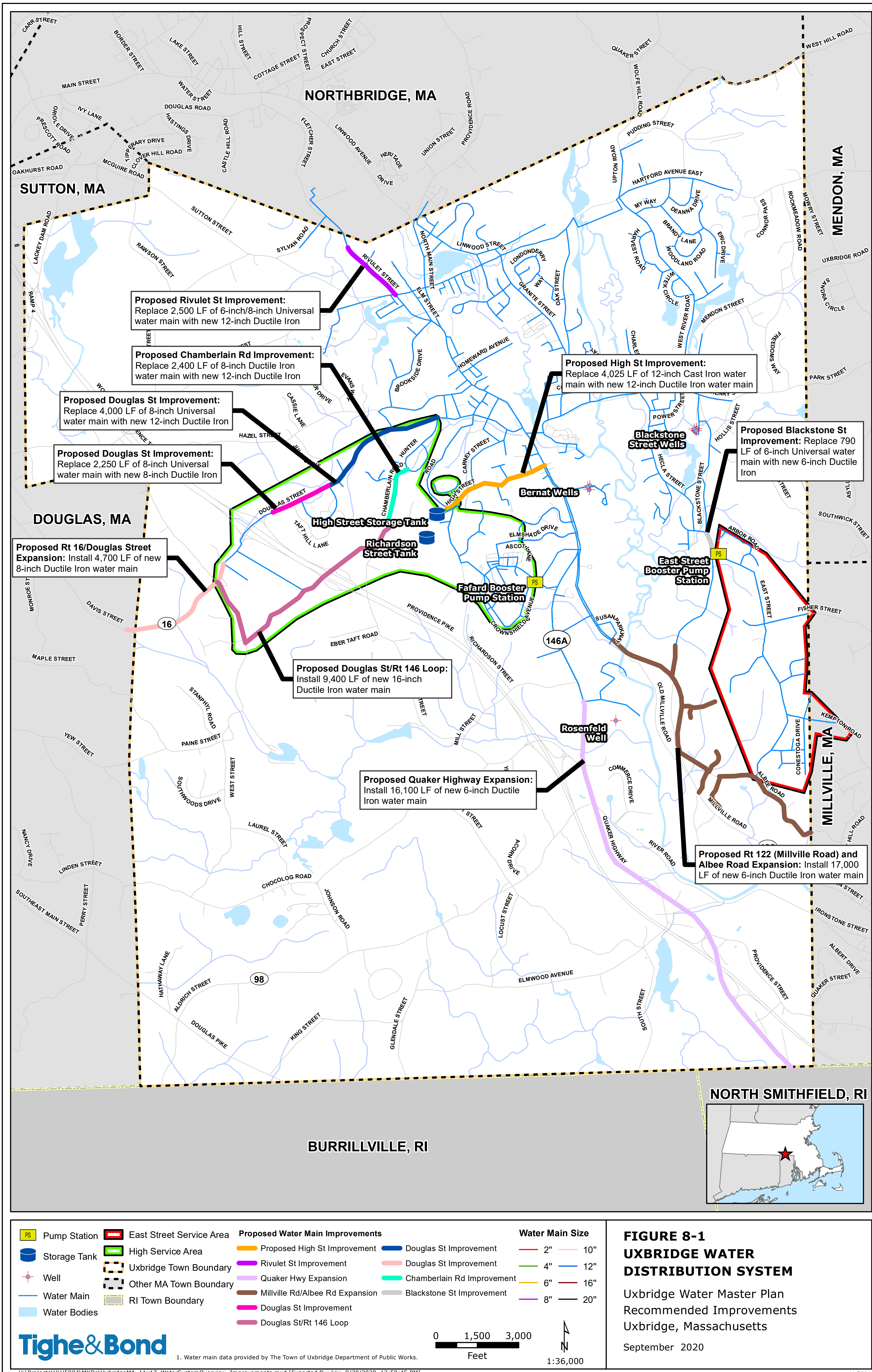
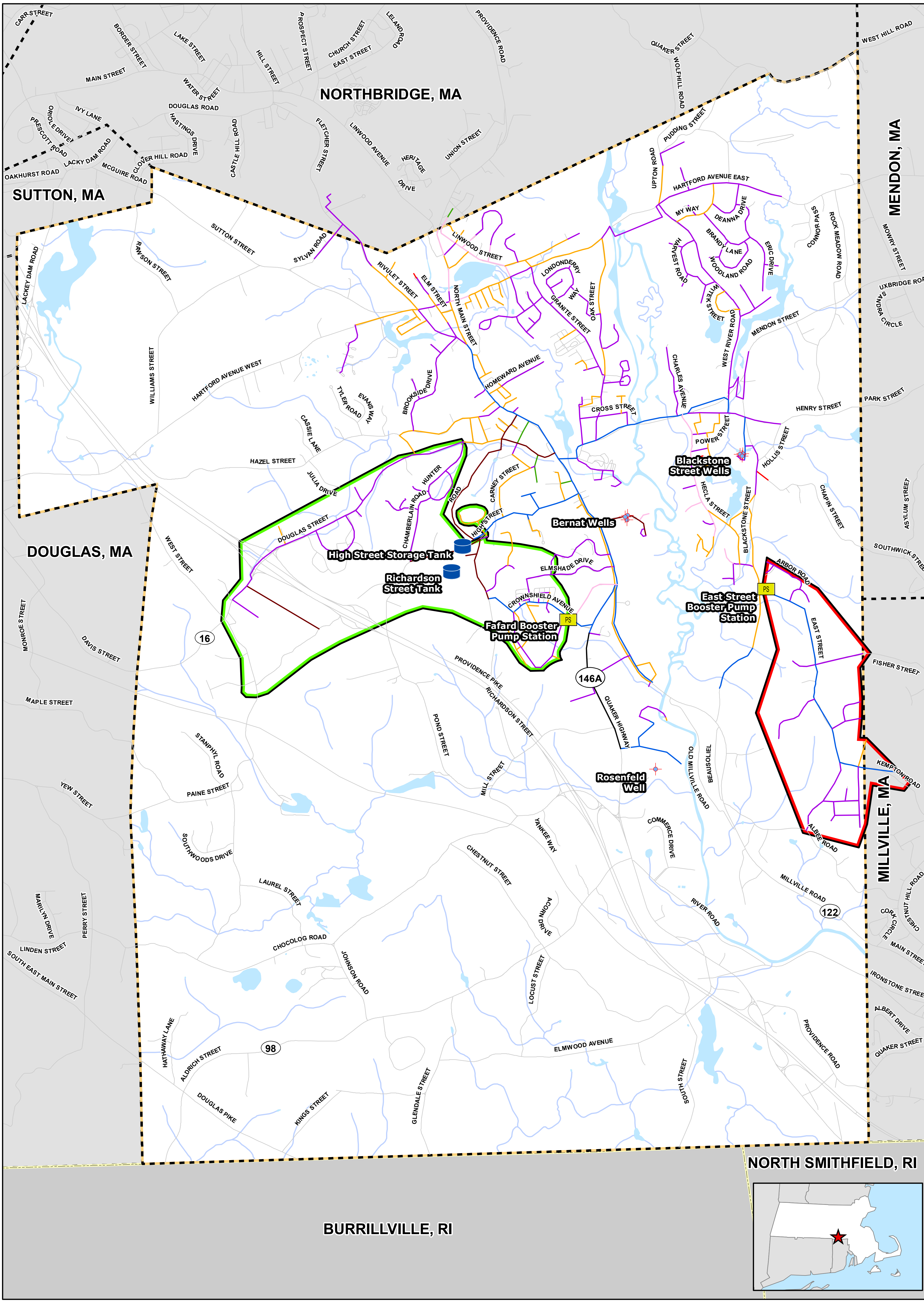


FIGURE 8-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Recommended Improvements
Uxbridge, Massachusetts

September 2020

APPENDIX A



PS Pump Station
Storage Tank
Well
Water Bodies
East Street Service Area
High Service Area
Uxbridge Town Boundary
Other MA Town Boundary
RI Town Boundary

Water Main Size

2"	10"
4"	12"
6"	16"
8"	20"

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet
1:36,000

FIGURE A-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Water System Size
Uxbridge, Massachusetts

June 2020

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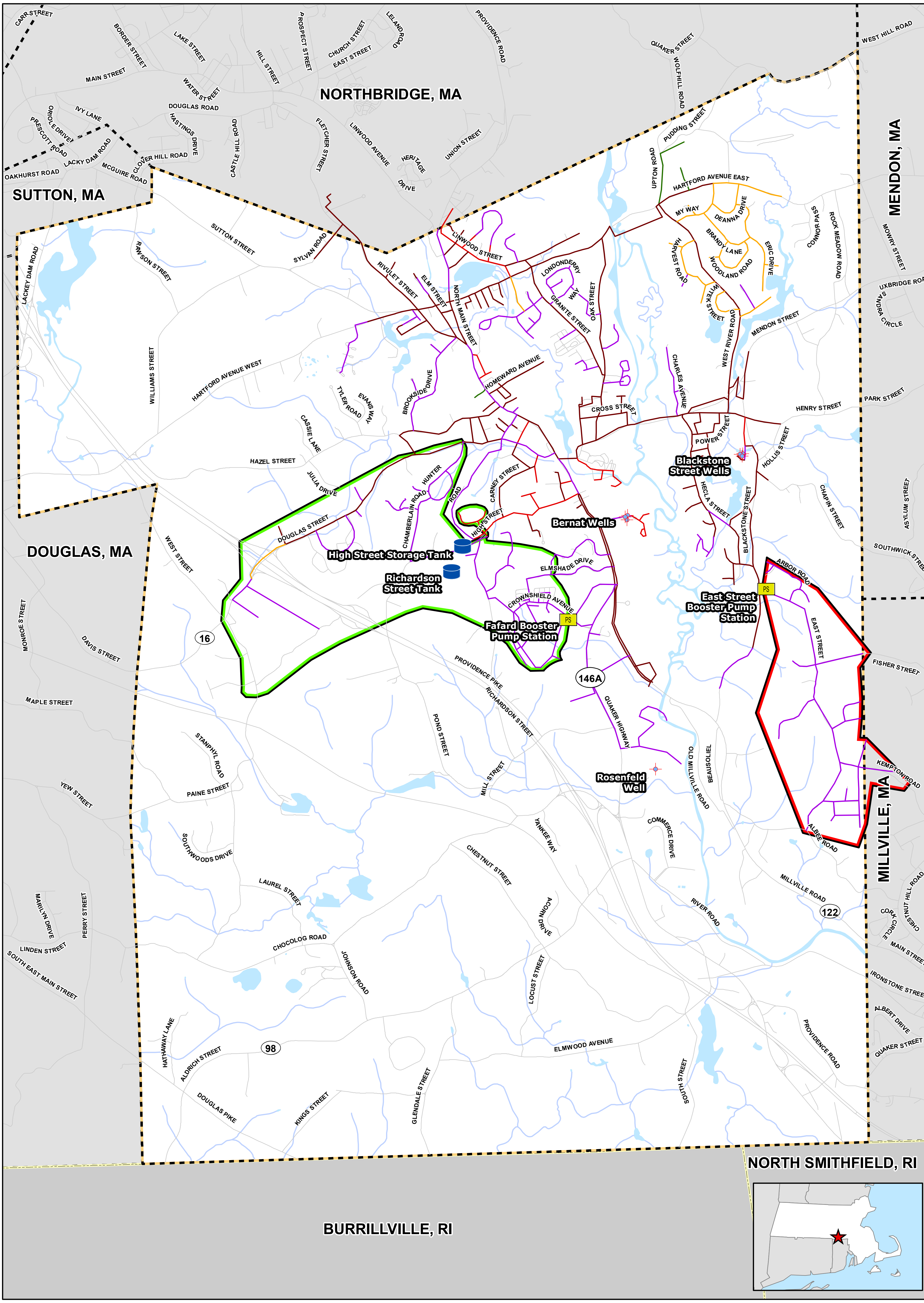

PS Pump Station	East Street Service Area	**Water Main Material**
Storage Tank	High Service Area	Cast Iron
Well	Uxbridge Town Boundary	Cement Lined Cast Iron
Water Bodies	Other MA Town Boundary	Ductile Iron
	RI Town Boundary	PVC
		Universal

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet

N

1:36,000

FIGURE A-2
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Water System Material
Uxbridge, Massachusetts

June 2020

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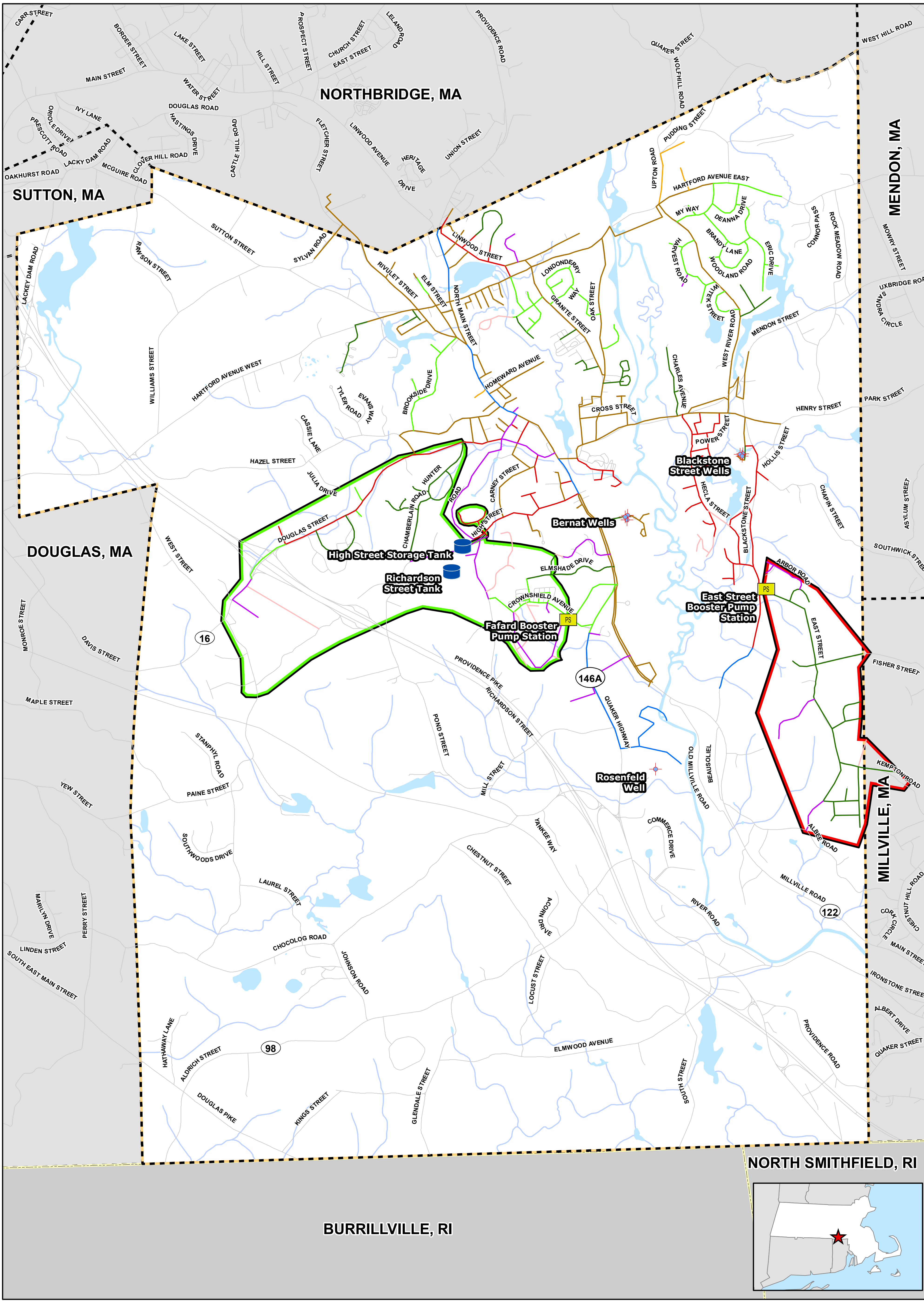

PS Pump Station	East Street Service Area
Storage Tank	High Service Area
Well	Uxbridge Town Boundary
Water Bodies	Other MA Town Boundary
	RI Town Boundary

Water Main Year Installed

Unknown	1980-1989
Pre 1930	1990-1999
1940-1949	2000-2009
1960-1969	2010-Present

Tighe&Bond

1. Water main data provided by The Town of Uxbridge Department of Public Works.

0 1,500 3,000
Feet

N

1:36,000

FIGURE A-3
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Water Master Plan
Water System Age
Uxbridge, Massachusetts

June 2020

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U-5004

APPENDIX B

APPENDIX B - HISTORICAL POPULATION SERVED BASED ON RESIDENTIAL CONNECTIONS AND ACS ESTIMATES OF AVERAGE HOUSEHOLD SIZE

Account Type	Remarks	2014 # CONNECTIONS	2014 HOUSEHOLDS PER CONNECTION	2014 People served	2015 # CONNECTIONS	2015 HOUSEHOLDS PER CONNECTION	2015 People served	2016 # CONNECTIONS	2016 HOUSEHOLDS PER CONNECTION	2016 People served
Single family	ACS Estimate	2,828	2,828	8,060	2,849	2,849	8,234	2,867	2,867	8,429
Two family	ACS Estimate	261	522	1,488	261	522	1,509	260	520	1,529
Three family	ACS Estimate	60	180	513	60	180	520	60	180	529
Code 111 (4-8 units)	assume 2 ppl/unit	41	199	398	42	204	408	42	204	408
Code 112 (>8 units)	assume 2 ppl/unit	3	32	64	3	32	64	3	32	64
24 Units/meter (Qkr Village Condos)	assume 2 ppl/unit	2	48	96	2	48	96	2	48	96
30 Units (Calumet Ct)	elderly housing, assume 1 ppl/unit	1	30	30	1	30	30	1	30	30
56 Units (Centennial Ct)	elderly housing, assume 1 ppl/unit	1	56	56	1	56	56	1	56	56
61 Units (Crown & Eagle)	assume 2 ppl/unit	1	61	122	1	61	122	1	61	122
25 Units (Blanchard)	assume 2 ppl/unit	0	0	0	0	0	0	0	0	0
TOTAL RESIDENTIAL		3,198	3,956	10,827	3,220	3,982	11,038	3,237	3,998	11,263

Account Type	Remarks	2017 # CONNECTIONS	2017 HOUSEHOLDS PER CONNECTION	2017 People served	2018 # CONNECTIONS	2018 HOUSEHOLDS PER CONNECTION	2018 People served	2019 # CONNECTIONS	2019 HOUSEHOLDS PER CONNECTION	2019 People served
Single family	ACS Estimate	2,911	2,911	8,413	2,965	2,965	8,599	2,990	2,990	8,671
Two family	ACS Estimate	261	522	1,509	258	516	1,496	258	516	1,496
Three family	ACS Estimate	58	174	503	56	168	487	56	168	487
Code 111 (4-8 units)	assume 2 ppl/unit	43	209	418	43	209	418	43	209	418
Code 112 (>8 units)	assume 2 ppl/unit	3	32	64	3	32	64	3	32	64
24 Units/meter (Qkr Village Condos)	assume 2 ppl/unit	2	48	96	2	48	96	2	48	96
30 Units (Calumet Ct)	elderly housing, assume 1 ppl/unit	1	30	30	1	30	30	1	30	30
56 Units (Centennial Ct)	elderly housing, assume 1 ppl/unit	1	56	56	1	56	56	1	56	56
61 Units (Crown & Eagle)	assume 2 ppl/unit	1	61	122	1	61	122	1	61	122
25 Units (Blanchard)	assume 2 ppl/unit	0	0	0	0	0	0	1	25	50
TOTAL RESIDENTIAL		3,281	4,043	11,210	3,330	4,085	11,368	3,356	4,135	11,491

ACS ESTIMATE OF PPL/HH -->			
	2014	2.85	
	2015	2.89	
	2016	2.94	
	2017	2.89	
	2018	2.90	(also used for 2019)

APPENDIX B: Proposed Non-Residential Developments - Uxbridge, MA

Development Type	Quantity for Flow Estimate	310 CMR 15.00: Septic Systems ("Title 5") (1) Title 5 Corresponding Type of Establishment	Title 5 Estimated Wastewater Flow Rates	WW Flow Units	Total WW	Total Water
			gpd		gpd	gpd
2025 Planning Period						
Zipp Industrial Park, 290 Millville Road - Bare Naked Greens Cultivation Facility, commercial factory with 60 employees	**60**	Commercial, Factory, Industrial Plant, Warehouse, or Dry Storage space without cafeteria	15	per person	900	529
Zipp Industrial Park, 290 Millville Road - Bare Naked Greens Cultivation Facility, cultivation facility 75,200 sq.ft. (2)	**--**	N/A	--	--	--	20,000
Campanelli Business Park, 100 Campanelli Drive - Cultivate, cultivation facility 128,932 sq.ft. (3)	**--**	N/A	--	--	--	25,072
TDJ Materials, 300 Mendon Street - 102,000 sq.ft. self storage (4)	**5**	Commercial, Factory, Industrial Plant, Warehouse, or Dry Storage space without cafeteria	15	per person	75	44
Rt 16 Corridor near Rt 146 to Douglas town border - expansion to serve existing businesses (1 office Industrial Zoned)	**720**	Office building (200 gpd minimum allowable for system design)	75	per 1,000 sq.ft.	200	118
Rt 16 Corridor near Rt 146 to Douglas town border - expansion to serve existing businesses (1 community day camp (Venture Community Services) Industrial Zoned) (5)	**135**	Camp, day, mess hall, washroom and toilets	13	per person	1,755	1,032
Rt 16 Corridor near Rt 146 to Douglas town border - expansion to serve existing businesses (2 warehouses Industrial Zoned) (5)	**10**	Commercial, Factory, Industrial Plant, Warehouse, or Dry Storage space without cafeteria	15	per person	150	88
515 Douglas Street - redevelopment of existing parcel inito 500,000 sq.ft. sorting facility	**400**	Commercial, Factory, Industrial Plant, Warehouse, or Dry Storage space without cafeteria	15	per person	6,000	3,529
2025 - Water Projection Method: water demand calculated using sewage flow estimates listed above						
		Total Wastewater			**9,080**	
		Total Water = Total Wastewater*0.5*(1/85%) + Other Water Estimates				**50,413**
2030 Planning Period						
North and South Main Street - Master Plan in progress to encourage mixed-use, assumes expansion to existing businesses not currently served (3 offices Business Zoned)	**3,678**	Office building (200 gpd minimum allowable for system design)	75	per 1,000 sq.ft.	276	162
2030 - Water Projection Method: water demand calculated using sewage flow estimates listed above						
		Total Wastewater			**276**	
		Total Water = Total Wastewater*0.5*(1/85%) + Other Water Estimates				**162**

Notes:

(1) Water Demand Calculations are based on wastewater flow projections using the Massachusetts Title 5 of the State Environmental Code ("Septic Systems"). These wastewater flow projections are then divided in half as the wastewater flow projections are typically a peak flow number. This number is then divided by 0.85 because the water discharged into the wastewater system excludes consumption, which is typically 15%. By dividing by 0.85, this 15% component is added back in to provide the total water demand.

(2) Water usage for cultivation provided by developer.
(3) Final buildout water usage and square footage as reported in "DRAFT: Water Supply Resiliency, Town of Uxbridge, MVP Action Grant Project" dated January 6, 2020. Assume water usage includes employee use plus cultivation use.
(4) Number of employees assumed based on similar-sized existing self-storage facilities.
(5) Quantity for flow estimate based on website description of community day program at Uxbridge.

APPENDIX C

APPENDIX C
High Street Tank Calculations

2019 Demands - Low Service Area		
ADD =	**0.676**	**mgd**
MDD =	**1.332**	**mgd**

Service Area	**Low Service Area**	
Length (not including interior walls)	145 ft	
Width (not including interior walls)	97 ft	
Total Height	15 ft	
Total Height minus 1 ft freeboard	14 ft	
Total Capacity with freeboard	1.464 MG	
Capacity per vertical foot	0.105 MG/ft	104604 gal/ft
Overflow elevation	498 ft	
Overflow elevation minus 1 ft freeboard	497 ft	
Ground elevation	483 ft	
Highest Customer that receives 20/35 psi	418 ft	
20 psi Elevation	464 ft	
35 psi Elevation	499 ft	
Actual highest customer	450 ft	at 170 High Street
20 psi Elevation	496 ft	
35 psi Elevation	531 ft	
Usable Equalization Storage	0.000 MG	Elevation that provides 35 psi at highest customer is above overflow
Usable Fire Storage	0.084 MG	Storage above elevation that provides 20 psi at highest customer
Unusable Storage	1.381 MG	
Required Turnover EQ Storage	0.293 MG	20% of total tank volume
Required Peaking EQ Storage	0.266 MG	20% of max day
Required EQ Storage (max of above)	**0.293 MG**	
Required Equalization Depth	3 ft	
Elevation at bottom of EQ storage	494 ft	
Highest customer that receives 35 psi at bottom of EQ	413 ft	
No. of customers receive <35 psi at bottom of EQ	11 customers	
PSI at highest customer at bottom of EQ	19 psi	
Needed fire flow (ISO)	3500 gpm	
Needed fire duration (ISO)	3 hr	
Required Fire Storage	0.630 MG	
Required Fire Storage Depth	6 ft	
Elevation at bottom of Fire storage	488 ft	
Highest customer that receives 20 psi at bottom of Fire	442 ft	
No. of customers receive <20 psi at bottom of Fire	4 customers	
PSI at highest customer at bottom of Fire	16 psi	
Storage Depth below required Fire, above tank floor elevation	5 ft	Cannot be lower than tank ground elevation
Storage Volume below required Fire, above tank floor elevation	0.542 MG	
Hours of ADD provided	19.23 hrs	

Customers that receive less than 35 psi at bottom of required equalization storage

Address	Account	Owner	FY19 Usage CCF	Type	Meter
170 HIGH ST	1575	TROTTIER TRISTAN LAUREL	5180	Residential	Water
165 HIGH ST	1192	KNAPP MARY	3890	Residential	Water
138 HIGH ST	2497	GALLUZZO LYNNE GARY TE	3772	Residential	Water
162 HIGH ST	905	GONDEK ROBERT M EDWARD P JT	829	Residential	Water
142 HIGH ST	1973	STORMONT BRIAN C	3058	Residential	Water
155 HIGH ST	1831	POWERS JOHN B KATHLEEN M	1416	Residential	Water
137 CARNEY ST	1361	LIBERTY LEO J BEVERLY C	2418	Residential	Water
149 HIGH ST	1942	SMITH MELISSA A	2533	Residential	Water
130 HIGH ST	549	CZUPRYNA ROBERT BETSY JUNE	8393	Residential	Water
129 HIGH ST	5621	LOFTUS KELLY L	4863	Residential	Water
127 CARNEY ST	2264	VALENTINA JULIANNA	7960	Residential	Water

APPENDIX C
Richardson Street Tank Calculations

2019 Demands - High Service Area		
ADD =	**0.109**	**mgd**
MDD =	**0.477**	**mgd**

Service Area	**High Service Area**		
Diameter	59	ft	
Total Height	50	ft	
Total Height minus 1 ft freeboard	49	ft	
Total Capacity with freeboard	1.002	MG	
Capacity per vertical foot	0.020	MG/ft	20450 gal/ft
Overflow elevation	591	ft	
Overflow elevation minus 1 ft freeboard	590	ft	
Ground elevation	541	ft	
Highest Customer that receives 20/35 psi	505	ft	Excludes 3 customers located next to tank
20 psi Elevation	551	ft	
35 psi Elevation	586	ft	
Actual highest customer	527	ft	
20 psi Elevation	573	ft	
35 psi Elevation	608	ft	
Usable Equalization Storage	0.000	MG	Storage above elevation that provides 35 psi at highest customer
Usable Fire Storage	0.344	MG	Storage above elevation that provides 20 psi at highest customer
Unusable Storage	0.658	MG	
Required Turnover EQ Storage	0.200	MG	20% of total tank volume
Required Peaking EQ Storage	0.095	MG	20% of max day
Required EQ Storage (max of above)	**0.200**	**MG**	
Required Equalization Depth	10	ft	
Elevation at bottom of EQ storage	580	ft	
Highest customer that receives 35 psi at bottom of EQ	499	ft	
No. of customers receive <35 psi at bottom of EQ	8	customers	
PSI at highest customer at bottom of Required EQ	23	psi	6.060606061
Needed fire flow (ISO)	3500	gpm	
Needed fire duration (ISO)	3	hr	
Required Fire Storage	0.630	MG	
Required Fire Storage Depth	31	ft	
Elevation at bottom of Fire storage	549	ft	
Highest customer that receives 20 psi at bottom of Fire	503	ft	
No. of customers receive <20 psi at bottom of Fire	5	customers	
PSI at highest customer at bottom of Required Fire	10	psi	
Storage Depth below required Fire but above elevation that provides 0 psi at highest customer, or tank floor elevation	8	ft	Cannot be lower than tank ground elevation
Storage Volume below required Fire but above elevation that provides 0 psi at highest customer, or tank floor elevation	0.172	MG	
Hours of ADD provided	37.74	hrs	
Storage Depth below 0 psi elevation	0	ft	No further storage
Storage Volume below 0 psi elevation	0	MG	

Customers that receive less than 35 psi at bottom of required equalization storage

Address	Account	Owner	FY19 Usage CCF	Type	Meter
18 SUMMIT WAY	2500	COLONNA PAUL M COLONNA DEBRA A	6375	Residential	Water
59 RICHARDSON ST	7490	KNAPPER BARBARA J	4264	Residential	Water
65 RICHARDSON ST	2488	BLAKISTON JANICE A	1805	Residential	Water
228 HIGH ST	1632	NEWHALL RUTH 70 LIFE EST PAUL 30	729	Residential	Water
11 COTTON MILL WAY	7241	MOCHWART SCOTT ANDREA	3644	Residential	Water
96 RICHARDSON ST	2460	MCISAAC JOHN T LILLA B TE	7666	Residential	Water
60 RICHARDSON ST	2457	MCGUIRK SEAN	5517	Residential	Water
70 RICHARDSON ST	2449	GILLIS RICHARD J GAYLE K TE	5470	Residential	Water