Uxbridge, Massachusetts

Groundwater Well Facilities Planning Report

Uxbridge Department of Public Works
Water Division

July 2022

Tighe&Bond
Engineers | Environmental Specialists

100% Recyclable

Executive Summary

In 2020, Tighe & Bond performed an evaluation of the Town of Uxbridge's (Town) Water System. This study included a review of existing facility permits and records, and an evaluation of the existing water distribution system infrastructure using the Uxbridge hydraulic model. Among other findings, this evaluation stated that the Town's projected demands are close to or exceed current production capacities and that the existing groundwater well facilities are critical to meeting the system demand.

On November 9, 2021, Tighe & Bond conducted an on-site evaluation of the Town's groundwater well facilities to catalog and document the conditions of the existing facilities. During the evaluation, Tighe & Bond staff evaluated pumps, valves, tanks, and other major assets to determine their condition and possible repair/replacement needs. The assessment was based largely on the visual observations. The purpose of this study is to provide the Town with a planning level estimate of capital costs necessary to maintain the existing level of operation of the water system. For the purposes of this study, we evaluated potential capital costs associated with a 20-year planning period. Assets with a remaining useful life of greater than 20 years have not been included but will eventually require a capital investment by the Town beyond this study's planning period.

The major assets at the Blackstone and Bernat well facilities are near the end of their service lives, while the Rosenfeld facility is newer and appears to be in good working condition. The three groundwater wells at the Blackstone and Bernat sites need replacement as they have been redeveloped and sleeved multiple times since their initial construction. The Blackstone and Bernat sites will also require rehabilitation of the existing structures within the next decade. Priority should be given to refurbishment of the existing three well houses at both sites, as visual deterioration was present during the on-site evaluation. We recommend a project budget of approximately $2 million per well site to replace the existing six groundwater wells with new submersible wells.

In addition to maintaining the Town's facility assets to meet current and growing demands, if additional wells need to be taken offline due to water quality issues, current and projected max day demands will likely not be met. The Town's Blackstone Well #1 was removed from service in 2014 when manganese levels exceeded the Massachusetts Department of Environmental Protection's (MassDEP) drinking water Office of Research and Standards Guideline for manganese of 0.3 mg/L. This offline well potentially represents 400,000 gallons per day of unused production capacity. Manganese treatment system is needed to return this well to an active source for the Town.

In addition, per- and polyfluoroalkyl substances (PFAS) contaminated drinking water has become a significant emerging issue due to the chemicals' persistence, widespread detection in the environment and link to harmful health effects. On October 2, 2020, MassDEP published a Massachusetts Maximum Contamination Level (MMCL) of 20 nanograms per liter (ng/L) or parts per trillion (ppt) for six PFAS chemicals (PFAS6): perfluorooctane sulfonic acid (PFOS); perfluorooctanoic acid (PFOA); perfluorohexane sulfonic acid (PFHxS); perfluorononanoic acid (PFNA); perfluoroheptanoic acid (PFHpA); and perfluorodecanoic acid (PFDA). These compounds are a group of chemicals that have been produced since the 1950s for a variety of consumer, commercial, and industrial products. Based on 2020 sampling, the Town's Blackstone wells had PFAS6 concentrations of 15.56 ppt .

To prepare the Town for restoring Well #1 to service and to takes steps to safeguard the water supply against changing PFAS regulations, Tighe & Bond documented an approach for iron and manganese treatment followed by treatment of PFAS at the Town's Blackstone Wells. GreensandPlus™ and biological filtration technologies were both evaluated for iron and manganese treatment, with both technologies equally suitable for the conditions at the Blackstone Wells. For PFAS treatment, Granular activated carbon (GAC) and ion exchange (IX) technologies were evaluated for PFAS treatment. Both technologies are capable of removing PFAS from the Blackstone source, however, GAC may be more suitable for this site due to the need for manganese treatment upstream. Both manganese and PFAS treatment systems will require a pilot study for permitting through MassDEP. We recommend a project budget of $300,000 for an on-site pilot study of GreensandPlus™ and biological filtration technologies for manganese treatment and laboratory rapid small-scale column testing (RSSCT) for PFAS treatment. Based on market conditions and similar projects, we recommend a project budget of approximately $15 million dollars to design and construct these new treatment systems, tanks, building, and site improvements at the Blackstone well site.

These projects and the recommended capital improvements identified during the evaluation will require capital investments over the next 20-year period. To assist with prioritizing these expenditures, we have assigned each of the recommended projects one of the following classifications:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.

Category A - High Priority Items (implement within 5 years)

Category B - Medium Priority Items (implement within 10 years)

Category C - Low Priority Items (implement within 20 years)

Budgetary cost estimates for each item are developed for consideration in the Town's capital planning budgets. Budgetary costs include equipment costs, demolition/removal of existing equipment (if applicable), allowances for contractor markup, installation, general conditions, engineering and contingency. A contingency allowance of 40% is used in the development of the total capital costs. In addition, we have assumed an allowance of 25% of construction costs for engineering services through design, permitting, bidding, and construction. The budgetary costs are based on the February 2022 ENR Construction Cost Index of 12,684.

The conceptual level budgetary cost estimates are based on Class 5 level construction cost estimates, as defined by the Association for the Advancement of Cost Engineering (AACE) International. According to these standards, the estimate class designators are labeled Class 1, 2, 3, 4, and 5, where a Class 5 estimate is based on the lowest level of project definition and a Class 1 estimate is closest to full project definition and maturity. The end usage for a Class 5 estimate is project screening or feasibility purposes. The expected accuracy range of a Class 5 estimate is between +50% to -30%. The level of project definition for a Class 5 estimate is between 0% and 2%. Costs listed in Table ES-1 are for planning purposes only.

A summary of recommended capital improvement projects follows in Table ES-1. A breakdown of the recommended improvements can be found in Appendix A – Capital Improvements Costs.

Table ES-1 Capital Improvement Planning Summary

Project Location	Project Name	Probable Construction Cost[1]	Contingency + Engineering[2]	Budget	Action Category
Blackstone	Blackstone Wellhouse Roof Replacement	$70,000	$50,000	$120,000	Immediate
Blackstone	Wells 1-3 Replacement Project	$1,050,000	$690,000	$1,740,000	Immediate
Blackstone	Manganese Pilot and PFAS Bench Scale Test			$300,000	A
Blackstone	Manganese and PFAS WTP	$9,000,000	$6,000,000	$15,000,000	A
Blackstone	Blackstone Wellfield Refurbishments	$940,000	$610,000	$1,550,000	B
Bernat Wellfield	Wells 4-6 Replacement Project	$1,100,000	$720,000	$1,820,000	Immediate
Bernat Wellfield	Bernat Wellfield Refurbishments	$1,580,000	$1,030,000	$2,610,000	A
Rosenfeld Wellfield	Rosenfeld Wellfield Refurbishments	$520,000	$340,000	$860,000	C
Rosenfeld Wellfield	New Groundwater Source	$1,200,000	$780,000	$2,000,000	C
			Total	**$26,000,000**	

Action Category Definitions:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.

Category A - High Priority Items (implement within 5 years), and Items that have an expected remaining service life of 6 or fewer years - repair or replacement is expected to be necessary during this period.

Category B - Medium Priority Items (implement within 10 years), and Items that have an expected remaining service life of 7 to 11 years - repair or replacement is expected to be necessary during this period.

Category C - Low Priority Items (implement within 20 years), and Items that have an expected remaining service life of 12 to 20 years - repair or replacement is expected to be necessary during this period.

[1] 25% in General Conditions was included in construction costs.

[2] 25% Engineering and permitting through construction, 30% design, and 10% project contingencies were added.

List of Tables:

List of Figures:

Appendices:

Section 1 System Overview

The Town of Uxbridge Department of Public Works (Town) provides drinking water to approximately 3,492 connections in the Town of Uxbridge and portions of the Towns of Millville and Northbridge. The Town 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 2 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. In 2020, the system had an average daily demand of 0.73 million gallons per day (MGD), with a maximum single day water consumption of 1.44 MGD. The system pressure is maintained between 22-145 PSI. The Town's water facilities are classified as a Grade 2 Distribution System, and Class 1 Treatment.

1.1 Water Management Act

The Town's Water Management Act (WMA) permit defines the maximum authorized annual withdrawal volumes that may be withdrawn. These limits are defined for total annual volume in units of millions of gallons per year (MGY), and daily average volume in units of million gallons per day (MGD). Each permit term lasts five years. The WMA defines the maximum authorized daily withdrawal volumes for the Bernat and Rosenfeld Wells. The maximum average annual withdrawal volumes for the Blackstone Wells are defined in the original registration statement (2-12-304.01).

The Massachusetts Department of Environmental Protection (MassDEP) issued permits for water supplies approved after 1988. Wells that withdraw more than 100,000 gallons per day (gpd) and installed before January 1, 1988 were grandfathered as registered wells. Beyond the safe yields of the wells, these wells do not have individual withdrawal restrictions. Because the Blackstone Wells were installed in the 1940's and 1950's, they were grandfathered as registered wells. The wells at Bernat and Rosenfeld Wellfield are permitted. The Town was issued a WMA permit in 1995 that increased the total authorized withdrawal volume from Bernat Wells #4 and #5 and added Bernat Well #6 as an approved source. The Rosenfeld Well was added through a permit amendment adopted on March 1, 2010. The maximum authorized annual average withdrawals are provided in Table 1-1 for the remaining periods 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 residential gallons per capita per day (rgpcd) and 10% UAW performance standards, but has met the functional equivalence requirements included in this permit.

1.2 Drinking Water Supply Sources

The water distribution system is supplied by seven gravel packed wells located at three wellfields:

1. Blackstone Wells #1, #2, and #3 located at the Water Division Office on Blackstone Street
2. Bernat Wells #4, #5, and #6 located on the East Side of South Main Street
3. Rosenfeld Well #7 located off Quaker Highway

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 1-2 provides general information on the wells.

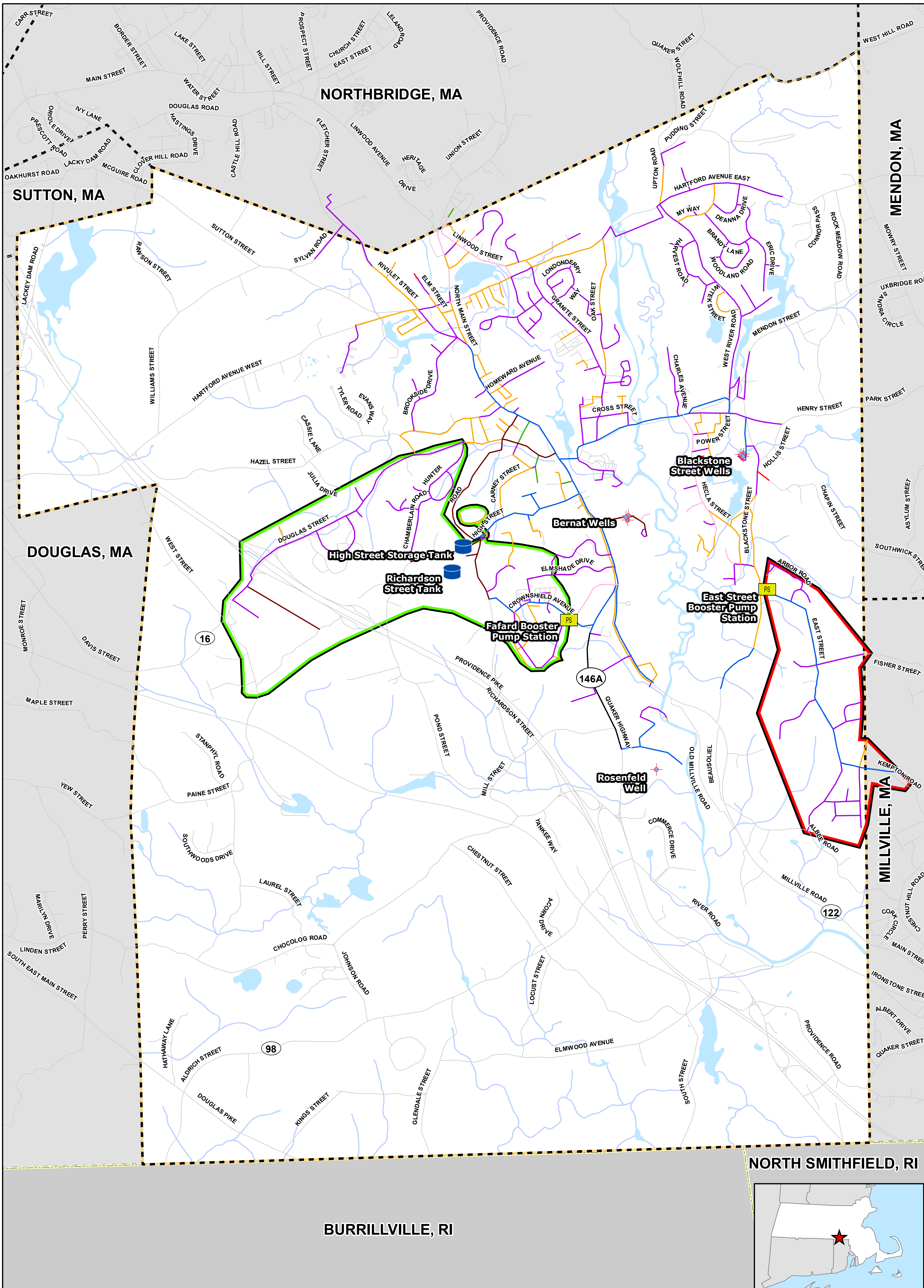
TABLE 1-2
General Information of the Uxbridge Wells

Description		Year Constructed	Well Diameter (inch)	Total Well Depth (feet)	Screen Depth (feet)
Blackstone Wellfield	Blackstone Well #1	1944	12	72	25
	Blackstone Well #2	1946	12	52	16
	Blackstone Well #3	1953	12	63.5	16
Bernat Wellfield	Bernat Well #4	Installed 1946, Acquired by Town in 1989	12 x 18	103	10
	Bernat Well #5		12 x 18	66	10
	Bernat Well #6		12 x 18	103	10
Rosenfeld Well #7		2012	18 x 24	69	15

Maximum approved daily withdrawal rates from groundwater withdrawal points are as summarized in TABLE 1-3 and are not to be exceeded without advance approval from MassDEP. Figure 1-1 presents the Town's water distribution system.

TABLE 1-3
Maximum Authorized Daily Withdrawal Volumes

Groundwater Source		PWS Source ID Code	Approved Maximum Daily Withdrawal (MGD)
Blackstone Wellfield	Blackstone Well #1	2304000-01G	0.43
	Blackstone Well #2	2304000-02G	0.44
	Blackstone Well #3	2304000-03G	0.32
Bernat Wellfield	Bernat Well #4	2304000-04G	1.33
	Bernat Well #5	2304000-05G	
	Bernat Well #6	2304000-06G	
Rosenfeld Well #7		2304000-07G	0.73
TOTAL PERMITTED AUTHORIZED WITHDRAWAL			**3.25**



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

N

1:36,000

FIGURE 1-1
UXBRIDGE WATER DISTRIBUTION SYSTEM

Uxbridge Groundwater Well Facilities Planning Report
Uxbridge, Massachusetts

March 2022

V:\Projects\U\U5004\MXDs\UxbridgeMA_11x17_WaterSystemOverview_Size.mxd [Exported By: KJW, 6/23/2020, 11:35:06 AM]

U-5004

Table 1-4 summarizes the total available supply assuming Blackstone and Rosenfeld wellfield are active and Bernat Wellfield (the largest wellfield) is offline. The current production capacities listed in Table 1-4 are based on the maximum production rates observed for the combined wellfield in June 2021 according to the daily wellfield logs. It is not possible to determine from the data if this rate represents the maximum production that is possible or the maximum rate that was required to meet demands. From well maintenance logs, the capacity of Blackstone Well #1 after chemical treatment and redevelopment in 2007 was 75 gpm. The capacity of Blackstone Well #2 after chemical treatment and redevelopment in 1995 was 225 gpm. The capacity of Blackstone Well #3 after chemical treatment and redevelopment in 2002 was 600 gpm. Well maintenance logs for Bernat and Rosenfeld Wells were not available.

TABLE 1-4
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	0.533 / 370
Blackstone Well #3			
Bernat Well #4			
Bernat Well #5	1.33 / 925	1.33 / 924	0.681 / 473
Bernat Well #6			
Rosenfeld Well #7	0.73 / 510	0.73 / 507	0.621 / 431
Total Operating (Bernat Offline)	**1.92 / 1,335**	**1.92 / 1,333**	**1.15 / 801**

(1) The max authorized withdrawal rates reflect the MASSDEP approval
(2) Based on max production rate observed for combined wellfield in June 2021.
(3) Offline since 2014 (not included in current production capacity).

Figure 1-2 shows the maximum day source production compared to permitted withdrawal. Withdrawal rates were calculated based on daily wellfield logs. Blackstone Well #1 is not shown because it has been offline since 2014 due to high manganese levels. The Bernat Wellfield has a permitted withdrawal of 1.33 MGD but had a maximum withdrawal of only 0.84 MGD in 2020. The Blackstone Wellfield has a permitted withdrawal of 1.19 MGD but had a maximum withdrawal of 1.03 MGD in 2020, partially because Well #1 is offline.

Rosenfeld Well #7 was the largest producer in 2020, likely because the Bernat and Blackstone wells could not meet their permitted withdrawal rates. Historically, the Blackstone and Rosenfeld sources withdraw up to their permitted rates, and on occasion have exceeded their permitted withdrawals.

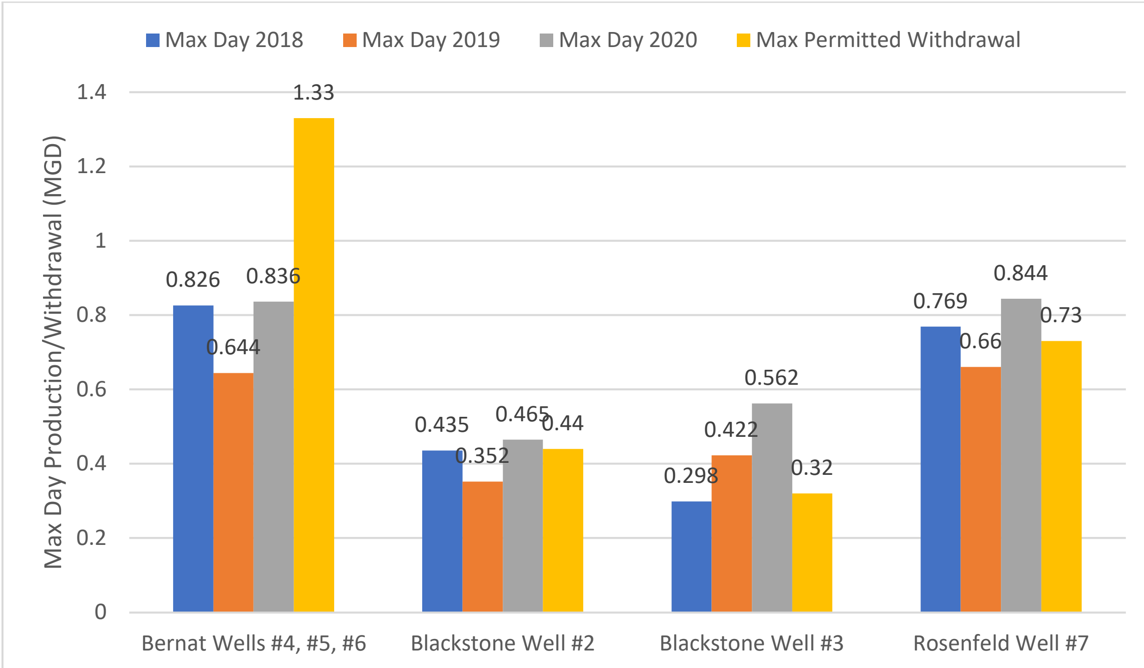


Figure 1-2 Maximum Day Source Production Compared to Permitted Withdrawal

1.3 System Supply Capacity

As part of Tighe & Bond's 2020 Uxbridge Distribution System Evaluation Report, the capacity of the Town's sources to meet current and projected needs was evaluated under different source production scenarios and compared to demands. The need for potential future sources of supply was also considered.

Our report found that at current production rates for Blackstone and Bernat Wellfields, the wells cannot meet existing and projected maximum day demands with both Well #1 and Well #7 offline (Table 1-5). With only Well #1 offline and the existing sources at their current production capacities, maximum day demands projected for 2040 cannot be met. This analysis indicated 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, manganese, or PFAS exceedances.

TABLE 1-5
Pumping Capacity Evaluation Data at 2019 Production Rates

Facility Name		Demand / Capacity (gpm) [1]	
		2019	**Projected 2040**
Max Day Demand (MDD)		925	1,447
	2019 Production Rate [2]	*% of Current MDD*	*% of 2040 MDD*
Bernat Well #4	155	17%	11%
Bernat Well #5	155	17%	11%
Bernat Well #6	155	17%	11%
Blackstone Well #1	0	0%	0%
Blackstone Well #2	193	21%	13%
Blackstone Well #3	193	21%	13%
Rosenfeld Well #7	507	55%	35%
Total with Well #1 offline	1357	147%	94%
Total with Wells #1 and #7 offline	850	92%	59%

(1) Projection based on evaluations made in Tighe & Bond's 2020 Uxbridge Distribution System Evaluation Report.
(2) Based on production rate for the wellfield observed in July 2019, divided by number of wells.

Because the current production rates presented in this analysis were 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. Also, due to the age and historical rehabilitations of the existing well replacement of the reduced capacity wells may also assist in meeting projected demands. However, if production capacity needs to be increased to meet project demands, it is also possible that water quality may deteriorate as a result of increased drawdown at individual wells.

1.4 Water Quality

The primary water quality issues for the Town's wells are elevated levels of iron, manganese, and PFAS. The Town treats all well sources with sodium hypochlorite for disinfection, potassium hydroxide for corrosion control, and phosphate addition for metals sequestration.

1.4.1 Iron and Manganese

The US EPA has 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.

In 2013, MassDEP established a regulatory limit pertaining to manganese. MassDEP set a drinking water Office of Research and Standards Guideline (OSRG) 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.

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

	Manganese		Iron	
Source	**Range**	**Average**	**Range**	**Average**
Well #1[(2)]	0 - **1.25**	**0.676**	0 – **0.354**	0.162
Well #2[(3)]	0 – **0.494**[(3)]	**0.055**	0 - **0.443**	0.087
Well #3[(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[(4)]	0.037 – **0.085**	**0.065**	0	0

(1) SMCLs: 0.3 mg/L for Iron, 0.05 mg/L for Manganese. Numbers in bold exceed the SMCL.
(2) Well #1 data from 2011 to 2014. Well #1 was removed from service in early 2014 when manganese levels exceeded 1.2 mg/L.
(3) Manganese and iron data from 2015 to 2020.
(4) Manganese data from 2015 to 2020. Iron data from 2015 to 2019.

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:
  - Wells #2 and #3 have had manganese concentrations greater than the recommendation. Well #1 is also offline due manganese levels exceeding 1.2 mg/L.
  - 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.

1.4.2 PFAS

In 2020, The Town began testing for per- and polyfluoroalkyl substances (PFAS). PFAS are a group of chemicals that have been produced since the 1950s for a variety of consumer, commercial, and industrial products. PFAS-contaminated drinking water has become a significant emerging issue due to the chemicals' persistence, widespread detection in the environment and link to harmful health effects.

On October 2, 2020, MassDEP published a Massachusetts Maximum Contamination Level (MMCL) of 20 nanograms per liter (ng/L) or parts per trillion (ppt) for six PFAS chemicals: perfluorooctane sulfonic acid (PFOS); perfluorooctanoic acid (PFOA); perfluorohexane sulfonic acid (PFHxS); perfluorononanoic acid (PFNA); perfluoroheptanoic acid (PFHpA); and perfluorodecanoic acid (PFDA). These compounds are also known as PFAS6. Table 1-7 summarizes average concentrations for the six regulated PFAS compounds (PFAS6) and unregulated PFAS concentrations from water samples taken in 2021.

TABLE 1-7
PFAS Concentrations

Name	Abbrev.	Regulated	Blackstone Wells Average Conc. (ng/L)[1]	Bernat Wells Average Conc. (ng/L)[2]	Rosenfeld Well Average Conc. (ng/L)[3]
Perfluorooctane-sulfonate	PFOS	Yes	6.72	4.24	0.47
Perfluorocotanoic acid	PFOA	Yes	2.55	2.50	1.40
Perfluorohexane-sulfonate	PFHxS	Yes	5.49	1.69	ND
Perfluorononanoic acid	PFNA	Yes	ND	0.50	ND
Perfluoroheptanoic acid	PFHpA	Yes	0.80	0.53	0.74
Perfluordecanoic acid	PFDA	Yes	ND	ND	ND
Total of Average Regulated PFAS6[4]			**15.56**	**9.46**	**2.61**
Perfluorobutane-sulfonate	PFBS	No	3.54	1.11	2.07
Perfluorohexanoic acid	PFHxA	No	0.98	0.63	0.73
N-ethyl perfluorooctanesulfonamido acetic acid	NEtFOSAA	No	ND	1.38	ND
N-methyl perfluorooctanesulfonamido acetic acid	NMeFOSAA	No	ND	0.99	ND
Total of Average Non-Regulated PFAS[4]			**4.52**	**4.11**	**2.80**
Total of Average Regulated and Non-Regulated PFAS[4]			**20.11**	**13.57**	**5.41**

[1] PFAS concentrations are an average of sampling taken on April 4, 2021, May 20, 2021, June 16, 2021, July 21, 2021, August 25, 2021, and September 23, 2021 from Blackstone Wells #2 and 3 blend.
[2] PFAS concentrations are an average of sampling taken on April 4, 2021 and July 21, 2021 from Bernat Wells #4, #5, and #6 blend.
[3] PFAS concentrations are an average of sampling taken on April 4, 2021 and July 21, 2021.
[4] Total concentrations include concentration results below the Minimum Reporting Level (MRL) of 2.0.

While none of the Town's wells are in violation of the 20 ppt MCL, increased pumping at the Town's Blackstone or Bernat sites may impact the detectable PFAS6 concentrations. In addition, changing regulations such as a lower PFAS6 limit, individual chemical limits, or expansion of existing regulations to include other compounds such as PFBS may impact the Town's water supply resiliency.

Section 2 Facilities Evaluation

On November 9, 2021, Tighe & Bond conducted an on-site evaluation of the Town wellfields to review existing conditions. During the evaluation, Tighe & Bond staff evaluated pumps, valves, tanks, and other process equipment to determine their condition and possible repair/replacement needs. The assessment was based largely on the visual evaluation of existing equipment. The following locations were assessed:

- Blackstone Wellfield
- Bernat Wellfield
- Rosenfeld Wellfield

2.1 Blackstone Wellfield

2.1.1 Site Overview

The Blackstone Wellfield includes Blackstone Wells #1, #2, and #3 (source IDs 2304000-01G, 2304000-02G, and 2304000-03G, respectively). A layout of the Blackstone Wellfield can be seen in Appendix B. The wellfield is at 105 Blackstone Street, where the Uxbridge Water Division office is located. Blackstone Wellfield was the first of the Town's water supply sources. The wells at Blackstone replaced the original wellfield of 32 2-1/2-inch diameter wells. The Town added treatment for corrosion control and made upgrades to the electrical system, Motor Control Center (MCC), and motors in 1998.

Figure 2-1 Blackstone Wells #1 and 3 Pump Station Buildings

Five small diameter wells were located during the site visit: one behind Well #2, two behind Well #3, one in between Wells #2 and 3, and one in front of the parking area. There are three antennas on site. The antenna behind the garages records all Neptune meter readings, the antenna on the roof of the office is for the Town radio, police, fire, and DPW transmissions, and the antenna next to the office building is used to transmit SCADA info.

The Uxbridge Water Division office building is 19' by 26' and has an original slate roof. The building houses the MCC, SCADA, HOA switches, office space, and storage. There are two garages onsite. The MCC is fully integrated into the SCADA system. The SCADA system has an alarm system and a backup alarm. In case of a power failure, there is an emergency 125 kW propane-fueled generator that can provide power to the office, chemical treatment facility,

Figure 2-2 MCC in Water Division Office

and one well. An 8-foot by 5-foot concrete pad outside of the office holds the propane tank that supplies fuel for the generator and the office building heater. The electrical service consists of a 480V, 3-phase power distribution. The utility power service is fed from a 3-pole, 400A main circuit breaker located within the MCC. Along with the emergency generator, the major electrical equipment at the Blackstone WTP includes a 208/120V distribution panelboard, a GE SpectraSeries 13-section motor control center (MCC), a 400A automatic transfer switch (ATS), a 400A utility metering socket, as well as (2) transformers sized 25kVA and 15kVA. New conduits were installed to feed the existing well pumps in 1998. The existing lighting fixtures, approximately 17 interior fixtures, are LEDs replaced in 2019.

Well #1 was installed in 1944. The 12-inch diameter gravel packed well is approximately 72 feet deep, with a 42-foot-long casing and a 25-foot-long screen. The well had an original estimated 400 gpm pumping capacity, but the capacity was reduced after the original screen was replaced with a smaller screen in 2002. The well's original pump and motor were replaced in 1985 with a Pomona vertical turbine pump with a 50 horsepower (HP) 3-phase electric driven motor. The well has been offline since 2014 due to high levels of manganese in the raw water, as discussed in Section 1.4.1.

Well #2 was installed in 1946. The 12-inch diameter gravel packed well is approximately 52 feet deep, with a 37-foot-long casing and a 25-foot-long screen. The well had an original estimated 500 gpm pumping capacity. The well's original pump and motor were replaced in 2007 with a Pomona vertical turbine pump with a 50 hp motor with a 400 gpm pumping capacity. Due to vibrations in the pump, the Town plans to replace Well #2's pump in the summer of 2022.

Figure 2-3 Vertical Turbine Pump in Wellhouse #3

Well #3 was installed in 1953 as a backup supply source to Wells #1 and #2. The 12-inch diameter gravel packed well is approximately 63.5 feet deep with a 49-foot-long casing and a 16-foot-long screen. The well has an original estimated 610 gpm pumping capacity. The well's original pump and motor were replaced in 2001 with a Pomona vertical turbine pump with a 100 hp 3-phase electric driven motor. Wells #2 and #3 are in a close proximity to each other. Previous documents indicate the operation of Well #3 may be interfering with the total capacity of Well #2. Based on the maximum production rate observed for the wellfield in June 2020, the production capacity of the wells is 385 gpm, with two wells online and one well offline. Individually, the maximum production rates observed for Wells #2 and #3 in June 2020 were 323 and 390 gpm, respectively.

All three wells have a 400-foot Zone I Protective Radius, a Zone II that was approved in 2001, and a WMA Permit. MassDEP has approved pumping rates for Wells #1, #2, and #3 of 0.43, 0.44, and 0.32 MGD, respectively.

The pump stations consist of brick buildings with flat roofs and vinyl siding. Pump stations #1 and #2 are 9-feet by 10-feet, and pump station #3 is 10-feet by 12-feet. Each pump station contains a Pomona vertical turbine pump of fabricated underground head type. The first floor contains the motor, electrical panels, Dayton Model 3UF80 electric Unit Heater, KPSI pressure transmitter, HOA switch, and a Teco F510 variable frequency drive (VFD) installed between 2018 and 2019. The each well has a buried metering vault containing process piping, check valve and flow meter.

Water from all the wells are metered individually outside the pump houses in subsurface metering vaults before combining in a 12-inch diameter ductile iron water main. Water from Well #1 is conveyed in an 8-inch diameter ductile iron water main that runs under the pond on site and is metered before combining with Wells #2 and 3 in the 12-inch diameter water main. The 12-inch diameter main passes through a chemical injection pit where water is treated with potassium hydroxide, sodium hypochlorite, and polyphosphate. Water originally entered the distribution system after chemical treatment through a 10-inch diameter cast iron pipe that heads north towards Henry Street. In 1997, a 12-inch diameter ductile iron pipe was added after the chemical injection pit that directs the water into the distribution system east towards Blackstone Street. The typical pressure at the distribution system is between 90 and 125 psi.

The potassium hydroxide feed system includes one polyethylene 2,000-gallon bulk tank and two 45-gallon day tanks within a 10-feet by 10-feet concrete secondary containment area with painted walls, two original Milton Roy chemical feed metering pumps, and a Model ATT Q46 pH/ORP analyzer for continuous pH monitoring. The operating range of the pH analyzer is 0- 14 pH, and concentration is recorded using a chart recorder and SCADA. Potassium hydroxide is supplied by Borden & Remington and used for pH adjustment and corrosion control. Potassium hydroxide is used at a strength of 45%. The raw water is treated to a target pH of 7.3, and there are low and high pH level alarms set at 6.2 and 8.6, respectively. Iwaki MDH-400 transfer pumps fill the day tanks simultaneously. There is no high-level shutoff when filling the tanks. There is a high-level switch, but it is not currently functional due to over-exposure to chemical drips. There is no day tank level or weight measurement instrument. Operators use visual observation to estimate the chemical day tank levels through the side of the semi-translucent tank sidewall. The chemical feed pumps and well pumps are interlocked and there must be positive flow before the hydroxide and chlorine pumps begin operating. The chemical feed pumps are connected to CTI Dynamix hand-off-auto (HOA) control stations to provide critical chemical control compliance for operating chemical metering pumps in manual for testing, to prevent overfeeds.

The polyphosphate feed system includes a 45-gallon day tank within a plastic secondary containment tank, an original Milton Roy chemical feed metering pump, a day tank low level alarm, and a Hach Bench Top analyzer for grab analysis. Carus™ 1000 water treatment chemical is used for iron and manganese sequestration. Target phosphate residual is 1.0 mg/L. The chemical feed pump and well pump are interlocked, and there must be positive flow before the phosphate pump begins operating. The chemical feed pumps have audible and visual alarms while operating in manual mode and are configured to prevent manual mode operation greater than 10 minutes.

The sodium hypochlorite feed system includes a 45-gallon day tank within a plastic secondary containment tank, a LMI Series C911-D60HI chemical feed metering pump that replaced the original metering pump, and an ATI Model Q46 free chlorine monitor for continuous chlorine residual monitoring. The operating range of the chorine analyzer is 0-2 mg/L, and concentration is recorded using a chart recorder and SCADA. Sodium hypochlorite used for disinfection is supplied by Univar and used at a strength of 13%. The target chlorine residual is 1.1 mg/L. The low and high chlorine residual alarms are set at 0.25 and 1.50 mg/L, respectively. The chemical feed pump and well pump are interlocked, and there must be positive flow before the sodium hypochlorite pump begins operating. The chemical feed pump is connected to a local HOA. Chlorine is hand delivered from the Rosenfeld Well Facility to Blackstone in 60-gallon drums.

The treatment plant is equipped with high and low chlorine and pH alarms, intrusion alarms, emergency alarms, and an autodialer. The main control panel is located in the Water Division Office with a HMI/SCADA computer. A manual restart is required for all system alarms that result in facility shut down. There is an emergency shower/eyewash station in the treatment facility.

Figure 2-4 Water Damage in Wellhouse #3

2.1.2 Evaluation

Wells and Pump Stations:

The wells at this site were installed over 70 years ago and have reached the end of their useful life. They have been sleeved, reducing the interior well diameter which has impacted the well production capacity. The piping in the wellhouses is in good condition. The Town's operator commented that the 8-inch ductile water main that conveys water under the pond from Well #1 was installed in 1998 and is in good condition.

The well house roofs at the Blackstone facility are in poor condition and are showing signs of deterioration. There are visible water stains and leaks in Wellhouse #3. According to the operator, the roofs may also contain asbestos. The exterior of the wellhouses also show signs of aging and should be rehabilitated at the time of roof replacement. A *Roof Assessment and Recommendation Report* was conducted by Tremco in 2015 and 2016 was reviewed. This assessment recommended replacement removal and replacement of the existing well house roofs. Precautions for all asbestos containing building materials (ACBM)*Site:*

The Blackstone Wellfield Facility is surrounded by trees that are regularly maintained. There is sufficient lighting at the site, which is gated and alarmed. Each well has its own hydrant available for blowoff of poor-quality water that can occur following standby of the well for long periods or during new equipment startup. The operator noted that the three Badger flow meters on site were installed in 1998 and should be replaced.

Building Systems:

No major deficiencies were noted for the facilities heating and cooling systems, which are relatively new. No major deficiencies were noted for the chemical building and Water Division building structures. The building roofs are at least 20 years old and are reaching the end of their typical asphalt shingle life expectancy. The slate roof over the office building is showing signs of wear but is a very durable material that should offer a long life span if consistently maintained by re-anchoring any loose slates, replacing any cracked slates, and maintaining the ridge and hip flashings through periodic recoating or replacement.

The interior finishes in buildings with roof leaks will exhibit some local damage as a result of the leaks and should be touched up at the time of roof replacement. The existing interior finishes, doors, windows and vinyl siding appear to be in good condition but have been included as part of future upgrades as these systems approach the end of their useful life.

Chemical Feed and Storage Systems:

There are spare chemical drums in the chemical treatment room that are not in secondary containment. The emergency shower/eyewash water is not tempered. Table 2-1 presents Blackstone Wellfield's summer chemical usage from 2019 to 2021.

TABLE 2-1
Blackstone Wellfield Summer Chemical Usage[1]

Chemical	Average Monthly Usage (gal/month)	Average Daily Usage (gpd)	Feed Rate (gph)	Dosage (mg/L)[2]
Potassium Hydroxide	411.1	21.77	1.22	54.02
Polyphosphate	19.2	1.41	0.07	7.02
Sodium Hypochlorite[3]	68.1	4.36	0.23	2.53

[1] Values calculated using daily chemical usage data from June, July, and August from 2019, 2020, and 2021.
[2] Potassium hydroxide and sodium hypochlorite dosages adjusted based on chemical strength.
[3] The average chlorine residual is 1.05 mg/L. Target chlorine residual is 1.1 mg/L.

Potassium Hydroxide [KOH] (Caustic):

There is currently no instrumentation used to measure chemical levels for the day tanks. Visual observation is used to take readings and the operator requested a scale to measure chemical levels for the day tanks. There is not a high-level shutoff to prevent overflow when filling the day tanks. There is a high-level switch, but it is not used due to an incident where the chemical reportedly dripped onto it, almost causing a fire.

The bulk storage tank was installed in 1998 and has exceeded the typical service life for chemical storage tanks. Based on the average summer monthly caustic usage from 2019 to 2021, the bulk storage tank is not adequately sized for 30 days of storage.

Polyphosphate [PO_4^{3-}]:

The day tank is adequately sized for more than 30 days of chemical storage.

Sodium Hypochlorite [NaOCl] (Chlorine):

The LMI C911-D60HI metering pump is a replacement pump and is in adequate condition. The current day tank can store enough sodium hypochlorite for about 20 days.

Electrical Equipment:

The three wellhouses each contain a main disconnect switch, a GE disconnect switch for the 480V heat, a GE disconnect switch for the well pump, a 5kW electric heater, a pump variable frequency drive (VFD), and a 15kVA transformer. The VFDs at Wellhouses 1 and 2 are each 50HP VFDs at 58 full-load amps (FLA), and the VFD at Wellhouse 3 is a 100HP VFD at 124 FLA. The lighting fixtures are LEDs. The equipment is approximately 24 years old. Electrical equipment has a typical reliable lifespan of approximately 30 years. As it extends beyond this lifespan, it becomes old and unreliable, possibly causing disruptions or failure to power of the facility and pumps.

Major Asset Summary

The assumed ages of the major assets at the Blackstone Wellfield are summarized in Table 2-2.

TABLE 2-2
Blackstone Wellfield Major Asset Summary

Asset Type	Year Installed	Age (years)
Vertical Turbine Well Pump*	2007	14
Sodium Hypochlorite Chemical Feed & Storage	1998	23
Caustic Chemical Feed & Storage	1998	23
Polyphosphate Chemical Feed & Storage	1998	23
Piping & Valves	1998	23
Flow Meter	1998	23
Instrumentation & Controls	1998	23
Wellhouses Building & Roof	1998	23
Chemical Building & Roof	1998	23
Electrical Equipment	1997	24
Variable Frequency Drives	2019	3
HVAC & Plumbing	1998	23
Propane Generator	1997	24

*Expected Well #2 pump replacement 2022

2.1.3 Recommendations

The Blackstone Wellfield will require major renovations in the near term. A new roof should be installed immediately at each wellhouse to prevent water damage to the interior process and electrical equipment. It is recommended a built-up flat roof system be utilized with a seamless fluid applied top coat. This type of roofing system is intended to provide a monolithic, puncture resistant, long-term roofing solution.

The existing wells are nearing the end of their useful service life and should be replaced. Section 3 details the process to permit and install replacement wells. The existing generator, as well as all other significant electrical equipment, should be replaced when it reaches the end of its useful life in approximately 5-7 years. All existing lighting is outdated and inefficient and should be replaced with LED fixtures. The potassium hydroxide chemical feed should be upgraded with a new scale, instrumentation system, larger bulk tank, and day tank. The sodium hypochlorite chemical feed system should also be upsized to a larger storage capacity. The polyphosphate feed should also be replaced as it is reaching the end of its useful life. Based on test results and evolving regulatory requirements. The Town should add PFAS and manganese treatment, which is discussed in Section 4. Other major renovations include replacing the flow meters for each well and adding tempered water to the emergency shower/eyewash station. In lieu of recommending individual upgrades of the existing chemical systems, we recommend including new chemical systems as part of the Blackstone Wells Water Treatment Plant project to treat manganese and PFAS. A capital cost summary of these renovations is included in Section 5. Additional details on these recommendations are provided in Appendix A.

2.2 Bernat Wellfield

2.2.1 Site Overview

Bernat Wellfield includes Bernat Wells #4, #5, and #6 (Source IDs 2304000-04G, 2304000-05G, 2304000-05G, respectively) and a chemical treatment facility. A layout of the Bernat Wellfield can be seen in Appendix B. The wellfield is located off of South Main Street and requires entering a private storage facility to access the site.

An extended pump test was conducted at Bernat Wellfield in 1988. The drawdown data from the test calculated estimated safe yields of 1,900, 600, and 1,000 gpm for Bernat Wells #4, #5, and #6, respectively. During the pump test, the wells were not pumped at these rates; they were pumped at a combined rate of 925 gpm. As a result, the MassDEP approved combined pumping rate is 925 gpm for the three Bernat wells. Based on the maximum production rate observed for the wellfield in June 2021, the production capacity of all three wells is 473 gpm. The maximum production rate observed for Well #4 was 747 gpm and occurred in July 2021. The maximum production rate observed for Well #5 was 360 gpm and occurred in October 2021. The maximum production rate observed for Well #6 was 594 gpm and occurred in June 2021 This is significantly less than the capacity measured in the 1988 pump test.

Figure 2-5 Bernat Wellfield's Chemical Treatment Facility

The wells were constructed in 1946 for the Bachmann Uxbridge Worsted Company, now known as the Bernat Mill. The Town acquired these wells in 1989 as additional water sources.

Well #4 is a 12-inch by 18-inch diameter gravel packed well, approximately 103 feet deep with a 46-foot-long casing and a 10-foot-long screen. In 1991, a vertical turbine pump with a 100 hp three phase motor was installed.

Well #5 is a 12-inch by 18-inch diameter gravel packed well, approximately 66 feet deep with a 46-foot-long casing and a 10-foot-long screen. In 1991, a vertical turbine pump with a 75 hp motor was installed.

Well #6 is a 12-inch by 18-inch diameter gravel packed well, approximately 103 feet deep with a 90-foot-long casing and a 10-foot-long screen. In 1991, a vertical turbine pump with a 100 hp motor was installed.

All three wells have a 400-foot Zone I Protective Radius, a Zone II that was approved in 1988, and a WMA permit that limits total production of all three wells to 1.33 MGD.

Figure 2-6 Bernat Well #6 Pump Station Building

Each of the three pump stations consist of a 8'-2" by 10'-3" brick building. Each pump station contains a vertical turbine pump. The first floor contains the pump motor, electrical panels, Siemans Sitrans pressure transmitter, and unit heater. The lower level contains the sump pump, check valve, HOA switch, venturi flow meter, and dehumidifier. All equipment was installed in 1991.

Water from Well #4 discharges to a 10-inch ductile iron pipe that was installed in 1946. Water from Wells #5 and 6 discharge to an 8-inch diameter ductile iron pipe. The raw water originally combined into a 16-inch diameter cast iron pipe that was installed when the water supply was developed. In 1990, the 16-inch diameter cast iron pipe was replaced by a 16-inch diameter ductile iron water main that connects the discharge line and the distribution system. The water main passes through a chemical injection vault where water is treated with potassium hydroxide, sodium hypochlorite, and polyphosphate before entering the distribution system through a 16-inch diameter cast iron pipe that heads northwest towards Route 122. The typical pressure at the distribution system is between 90 and 125 psi.

The control building includes a control room, treatment room, and generator room. The building is 30'-8" by 23'-4" with a fenced gate and alarm system. A new roof was installed in 2015. The control room consists of an MCC, 600A automatic transfer switch (ATS), (3) Teco Westinghouse VFDs for the pumps in the 3 wellhouses, and an instrumentation panel with SCADA and an Allen-Bradley PanelView Plus 1000 HMI. Within the panel is an Allen-Bradley MicroLogix 1400 PLC with (7) I/O Modules as well as an unmanaged network switch. There is also a radio antenna on the building with an associated telemetry system in the building

The generator room is located next to the chemical feed room. The room houses an emergency KatoLight 115 kW propane-fueled three-phase four-wire generator. There is a 1,000-gallon propane tank west of the building. In case of power failure, the generator will start and power one pre-selected pump until power is restored. When the generator is turned on, the garage door in the room automatically opens for ventilation. The panic buttons in the chemical feed room alert both the Uxbridge Water Department and Custom Alarm Company in case of an emergency.

The Bernat electrical service consists of a 277/480V, 3-phase power distribution system. The utility power service is being fed from a 600A, 3P main circuit breaker located within the motor control center. As well as the 115kW propane-fueled generator, the significant electrical equipment located at the Bernat site includes a 120/208V panelboard, a GE 8000-Line 8-section MCC, 600A ATS, a 45kVA transformer, a 600A utility metering socket, and (3) 10kW electric heaters. The existing lighting fixtures, approximately 16 interior fixtures, are fluorescent, which is inefficient and unreliable.

The chemical treatment system includes corrosion control using potassium hydroxide, sequestering with blended phosphate, and disinfection using sodium hypochlorite. The treatment system is equipped with high and low chlorine and pH alarms, intrusion alarms, emergency alarms, and an autodialer. A manual restart is required for all system alarms that result in facility shut down. The chemicals are injected through a chemical injection vault located north of the treatment building.

The potassium hydroxide feed system consists of two Poly Processing 800-gallon bulk tanks and two 45-gallon day tanks within a 15′ by 6′8″ concrete secondary containment area with painted walls, two Milton Roy chemical feed metering pumps, an Iwaki Mag-Drive transfer pump, and a pH/chlorine analyzer for continuous pH and chlorine monitoring. The operating range of the analyzer is 0-14, and concentration is recorded using a chart recorder and SCADA. Potassium hydroxide is supplied by Borden & Remington and used for pH adjustment and corrosion control. Potassium hydroxide is used at a strength of 45%. The raw water is treated to a target pH of 7.3, and there are low and high pH level alarms set at 6.2 and 8.6, respectively. The chemical feed pumps and well pump are interlocked, and there must be positive flow before the hydroxide pump begins operating. The caustic tanks are filled using a drum pump and has a chemical fill line to the bulk tank. The emergency shower/eyewash station does not have tempered water.

The polyphosphate feed system includes a 45-gallon day tank within the same secondary containment area, a Milton Roy chemical feed metering pump, a day tank low level alarm, and a Hach Bench Top analyzer for grab analysis. Carus™ 1000 water treatment chemical is used for iron and manganese sequestration. Target phosphate residual is 1.0 mg/L. The chemical feed pump and well pumps are interlocked, and there must be positive flow before the phosphate pump begins operating. The chemical feed pumps have audible and visual alarms while operating in manual mode and are configured to prevent manual mode operation greater than one hour.

The sodium hypochlorite feed system includes a 45-gallon day tank within the same secondary containment area, a LMI Series C9001-D60HI chemical feed metering pump, and an ATI Model Q46 free chlorine system to continuously monitor chlorine residual. Sodium hypochlorite used for disinfection is supplied by Univar and used at a strength of 13%. The target chlorine residual is 1.1 mg/L. The low and high chlorine residual alarms are set at 0.25 and 1.50 mg/L, respectively. The chemical feed pump and well pump are interlocked, and there must be positive flow before the sodium hypochlorite pump begins operating.

A MassDEP approved Cultec System was installed in 2017 for analyzer waste disposal.

2.2.2 Evaluation

Wells and Pump Stations

The wells at this site were installed over 70 years ago and are near the end of their useful service life. The maximum day production for each well at Bernat is shown in Figure 2-7 Each well has had a new inner steel casing installed due to metal degradation of the original well casing. This has reduced the inner well diameters and impacted production capacity. During our site visit, the Town’s staff noted that the well pumps are worn and cannot meet the maximum authorized withdrawal of 1.3 MGD.

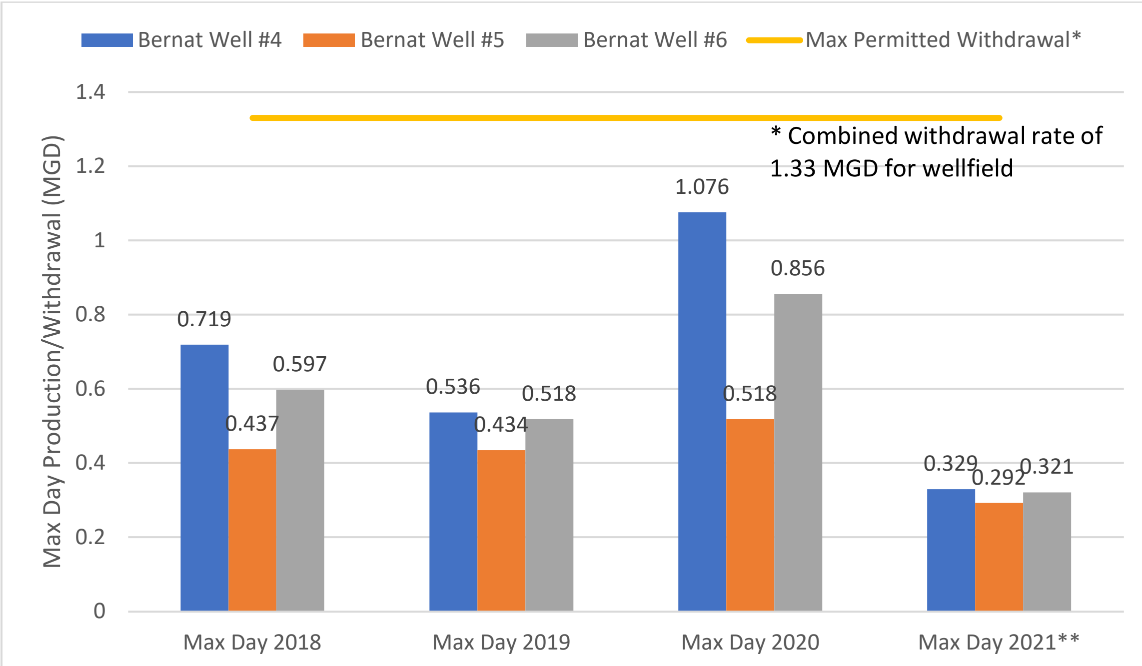


Figure 2-7 Bernat Wellfield Max Day Production Per Well

**Based on data from January 1, 2021 to October 31, 2021

The well houses at Bernat are showing signs of deterioration on the exterior masonry. These facades appear to be due for maintenance, specifically the replacement of cracked brick and repointing of mortar joints. The Town may want to consider installing furring and vinyl siding to protect the brick and match the appearance of the other buildings, while performing minor repairs as required to solidify the masonry and provide adequate support for the furring. The roofs for these wellhouses we replaced in 2017 and have a 20 year warranty. Otherwise, the interior finishes, doors and windows appear to be in good condition. Minor restoration is recommended as these systems are approaching the end of their useful service life. The three wellhouses each contain the following pieces of significant electrical equipment: a main disconnect switch, a GE 480V heat disconnect switch, a GE well pump disconnect switch, a 5kW electric heater, and a GE 15kVA transformer. The wellhouses for Well #4 and 6 have exposed grounding wires which should be encased in a PVC conduit. The flow meters in each pump station are dated.

Site

The Bernat Wellfield has sufficient lighting and is gated and alarmed. There is a yard hydrant near Well #6 for blowoff of poor-quality water. Access to the site is impacted by the storage facility. The storage facility has two gates that need to be unlocked and locked every time they are passed, which interferes with maintenance work.

Building Systems

The treatment building at the Bernat facility is mostly in good condition, It should also be noted that the exterior finish, painted concrete masonry units, is very susceptible to frost damage if the coating is even minimally compromised and therefore should be watched closely and recoated as needed. Otherwise, the interior finishes, doors and windows are in good condition but have been included as part of the upgrades as they are approaching the end of their useful life.

All equipment is approximately 30 years old except for the VFDs, which were installed recently. Electrical equipment has a typical reliable service life of approximately 30 years. As equipment is used beyond this lifespan, it becomes old and unreliable, which can lead to disruptions or failure of power of the facility. The operator indicated noise interference with VFD controls and the signal to the WTP, which may be due to routing of well pump wiring in a common conduit or the lack of a harmonics filter at the WTP. The generator runs on propane and is dated.

Chemical Feed and Storage Systems

Table 2-3 presents Bernat Wellfield's summer chemical usage from 2019 to 2021.

TABLE 2-3
Bernat Wellfield Summer Chemical Usage[1]

Chemical	Average Monthly Usage (gal/month)	Average Daily Usage (gpd)	Feed Rate (gph)	Dosage (mg/L)[2]
Potassium Hydroxide	825.9	30.97	1.77	47.89
Polyphosphate	41.9	2.05	0.12	6.87
Sodium Hypochlorite[3]	121.5	5.58	0.33	2.08

[1] Values calculated using daily chemical usage data from June, July, and August from 2019, 2020, and 2021.
[2] Potassium hydroxide and sodium hypochlorite dosages adjusted based on chemical strength.
[3] The average chlorine residual is 1.13 mg/L. Target chlorine residual is 1.1 mg/L

Potassium Hydroxide [KOH] (Caustic):

The potassium hydroxide system appeared to be in adequate condition although the equipment is nearing the end of its useful life. Visual observation is used to measure chemical levels for the day tanks. The bulk tanks are adequately sized for more than 30 days of chemical storage – about 58 days of storage.

Polyphosphate [PO_4^{3-}]:

The polyphosphate system appeared to be in adequate condition although the equipment has exceeded its typical service life. Based on the average polyphosphate usage from 2019 to 2021, the day tank can hold enough chlorine for 30 days of storage. Drums of spare chemicals are not in secondary containment.

Sodium Hypochlorite [NaOCl] (Chlorine):

The chlorination system appeared to be in adequate condition although the equipment is nearing the end of its useful life. Sodium hypochlorite storage for two to three weeks is recommended. With increased chemical use during the summer, the day tank can hold enough sodium hypochlorite for about 11 days.

Major Asset Summary

The assumed ages of the major assets at the Bernat Wellfield are summarized in Table 2-4.

Figure 2-8 Potassium Hydroxide Bulk Tanks in Secondary Containment at Bernat Wellfield

TABLE 2-4
Bernat Wellfield Major Asset Summary

Asset Type	Year Installed	Age (years)
Vertical Turbine Well Pump	1991	30
Sodium Hypochlorite Chemical Feed & Storage	2017	5
Caustic Chemical Feed & Storage	1998	23
Polyphosphate Chemical Feed & Storage	2017	5
Piping & Valves	1990	31
Flow Meter	1998	23
Instrumentation & Controls	1990	31
Wellhouse Roofs	2017	5
Control Building	1990	31
Control Building Roof	2017	5
Electrical Equipment	1990	31
VFD	2019	3
HVAC & Plumbing	1990	31
Propane Generator	1990	31
Cultec System	2017	5

2.2.3 Recommendations

The Bernat Wellfield will require renovations in the near term. The existing wells are at the end of their useful life and require replacement. The existing wells have been repaired and sleeved previously and the reduction in well diameter may be impacting the overall production capacity of the wells. Section 3 outlines the permitting process to install replacement wells.

The electrical service equipment and generator is dated and should be replaced. Harmonic filters are needed to decrease noise and interference with VFD controls and their signals to the chemical feed building. All new conduits from the WTP to well building may be required to separate feeds to each well All significant electrical equipment as outlined, including the generator, is near the end of its useful service life and should be replaced. All existing lighting is outdated and inefficient and should also be replaced with LED fixtures.

The sodium hypochlorite chemical feed and storage system should be expanded for enough storage capacity for at least two to three weeks of chemical storage. The emergency shower/eyewash station should have tempered water. A capital cost summary of these renovations is included in Section 5. Additional details on these recommendations are provided in Appendix A.

2.3 Rosenfeld Well #7

2.3.1 Site Overview

The Rosenfeld Wellfield includes Rosenfeld Well #7 and a chemical treatment facility. The wellfield is located at 308 Quaker Highway and was constructed in 2012. A layout of the Rosenfeld Wellfield can be seen in Appendix B. This wellfield was established to increase water supply. The chemical treatment facility is 40' by 34' and contains the well pump, pump systems, chemical feed systems, electrical room, and generator room. The pump, motor, and discharge pipe are above finish floor. Treatment consists of potassium hydroxide, phosphate, and sodium hypochlorite. There is an emergency diesel generator on-site in case of power failure.

Figure 2-9 Rosenfeld Pump Station Building

MassDEP approved the Rosenfeld Well #7 with an approved yield of 510 gpm in April 2012. The well is an 18-inch by 24-inch diameter gravel packed well, with a depth of approximately 69 feet with a 54 foot long casing and a 15 foot long screen. Well #7 has a design flow rate of 510 gpm and a total dynamic head of 405 feet. The well has a vertical turbine pump with a 100 hp motor. Based on the maximum production rate observed for the wellfield in July 2020, the production capacity for Well #7 is 836 gpm. The well has a 400-foot Zone I Protective Radius, a Zone II that was approved in 2010, and a Water Management Act Permit.

There is one active well at the Rosenfeld Wellfield, but the chemical treatment facility was designed to treat three additional wells, up to 2 MGD. There is one test well to the west of the building facility. There is a dehumidifier inside the facility. Flow and pressure in the watermain are monitored by a SITRANS FM MAG 5000 flowmeter and SITRANS P300 pressure transmitter. A KPSI level transducer provides level measurement for the well.

Figure 2-10 Future Well Raw Water Connection

Raw water is treated for corrosion control with potassium hydroxide, manganese sequestration with polyphosphate, and disinfection with sodium hypochlorite. The chemicals are injected in the facility.

The potassium hydroxide feed system includes a 3,900-gallon bulk tank and a 200-gallon day tank within a 23'-4" by 18' secondary containment area, two Milton Roy chemical feed metering pumps, transfer pump, and a pH analyzer to continuously monitor pH. The operating range of the analyzer is 0-2 mg/L, and concentration is recorded using a chart recorder and SCADA. Potassium hydroxide is supplied by Borden & Remington and used for pH adjustment and corrosion control. Potassium hydroxide is used at a strength of 45%. The raw water is treated to a target pH of 7.3, and there are low and high pH level alarms set at 6.2 and 8.6, respectively. The chemical feed pumps and well pump are interlocked, and there must be positive flow before the hydroxide pump begins operating.

The polyphosphates feed system includes a 45-gallon drum on a containment scale within the secondary containment area, two LMI chemical feed metering pumps, and a Hach Bench Top analyzer for grab analysis. Carus™ 1000 water treatment chemical is used for iron and manganese sequestration. Target phosphate residual is 1.0 mg/L. The chemical feed pumps and well pump are interlocked, and there must be positive flow before the phosphate pump begins operating. The chemical feed pumps have audible and visual alarms while operating in manual mode and are configured to prevent manual mode operation greater than one hour.

Figure 2-11 Potassium Hydroxide and Sodium Hypochlorite Chemical Tanks in Secondary Containment at Rosenfeld Wellfield

The sodium hypochlorite feed system includes a 800-gallon bulk tank, a 25-gallon day tank within the secondary containment area, two LMI chemical feed metering pumps, a transfer pump, and an ATI Q45H-62 free chlorine transmitter to continuously monitor chlorine residual. Sodium hypochlorite used for disinfection is supplied by Univar and used at a strength of 13%. The target chlorine residual is 1.1 mg/L. The low and high chlorine residual alarms are set at 0.25 and 1.50 mg/L, respectively. The chemical feed pump and well pump are interlocked and there must be positive flow before the sodium hypochlorite pump begins operating.

The treatment facility is equipped with high and low chlorine and pH alarms, intrusion alarms, emergency alarms, and an autodialer. A manual restart is required for all system alarms that result in facility shut down. The facility also contains a switchboard, MCC panel, variable frequency drives, and a radio antenna There is a water heater that provides tempered water for the emergency shower/eyewash station.

2.3.2 Evaluation

Well

Well #7 is less than ten years old and in good condition. The well pump appeared to be in adequate condition during our visit.

Site

The driveway to the site is long and narrow and the operator stated that there have been difficulties maneuvering large trucks to deliver chemicals. There have also been difficulties maneuvering equipment to clean the well. The western facing wall is designated as the knockout wall for bulk tank removal. However, all of the plumbing and piping for the facility is located on that wall, making it difficult to remove if needed.

Building Systems

No major observations were noted for the facilities heating and cooling systems, which are relatively new.

Electrical Equipment:

The electrical equipment at the Rosenfeld site is relatively new and in good condition. The electrical distribution consists of a 277/480V, 3-phase power distribution system. The utility power service is being fed from a 400A main breaker, located within the main switchboard. The significant equipment includes a 400A main switchboard, an Eaton Freedom Flashgard 4-section MCC, a 200kW Kohler generator, (3) 7.5kW heaters, and a 15kVA transformer.

Chemical Feed and Storage Systems

Table 2-5 presents Rosenfeld Wellfield's summer chemical usage from 2019 to 2021.

TABLE 2-5
Rosenfeld Wellfield Summer Chemical Usage[1]

Chemical	Average Summer Usage (gal/month)	Average Daily Usage (gpd)	Feed Rate (gph)	Dosage (mg/L)[2]
Potassium Hydroxide	983.0	39.50	2.68	64.01
Polyphosphate	36.8	1.91	0.12	6.29
Sodium Hypochlorite[3]	112.4	4.60	0.30	1.73

[1] Values calculated using daily chemical usage data from June, July, and August from 2019, 2020, and 2021.

[2] Potassium hydroxide and sodium hypochlorite dosages adjusted based on chemical strength.
[3] The average chlorine residual is 1.13 mg/L. Target chlorine residual is 1.1 mg/L.

Potassium Hydroxide [KOH] (Caustic):

The caustic feed and storage system appeared to be in adequate condition but the operator stated that the Poly Processing 3,900-gallon bulk tank has been repaired for leaks twice. Based on the average summer monthly caustic usage from 2019-2021, the bulk tank can hold enough caustic for more than 30 days of storage – about 119 days.

Polyphosphate [PO_4^{3-}]:

Based on the average summer monthly phosphate usage from 2019 to 2021, the day tank can hold enough phosphate for more than 30 days of storage – about 36 days of storage. Drums of spare chemicals are not in secondary containment.

Sodium Hypochlorite [NaOCl] (Chlorine):

The chlorination system appeared to be in adequate condition and no issues were raised by the operator on size or operations of the existing chlorine feed and storage systems. Based on the average summer monthly hypochlorite usage from 2019 to 2021, the bulk tank can hold enough hypochlorite for more than 30 days of storage – about 127 days of storage. The storage capacity for sodium hypochlorite is significantly greater than the storage capacity at Blackstone and Bernat wellfields because operators receive bulk chemical delivery at Rosenfeld wellfield. The sodium hypochlorite is then delivered to Blackstone and Bernat in 30-gallon drums.

Major Asset Summary

The assumed ages of the major assets at the Rosenfeld Wellfield are summarized in Table 2-6.

Figure 2-12 Potassium Hydroxide and Sodium Hypochlorite Chemical Storage Tanks

TABLE 2-6
Rosenfeld Wellfield Major Asset Summary

Asset Type	Year Installed	Age (years)
Vertical Turbine Well Pump	2012	9
Sodium Hypochlorite Chemical Feed & Storage	2012	9
Caustic Chemical Feed & Storage	2012	9
Polyphosphate Chemical Feed & Storage	2012	9
Piping & Valves	2012	9
Flow Meter	2012	9
Instrumentation & Controls	2012	9
Building & Roof	2012	9
Electrical Equipment	2012	9
HVAC & Plumbing	2012	9
Propane Generator	2012	9

2.3.3 Recommendations

Rosenfeld Well #7 and the treatment facility are less than ten years old. The equipment is in good condition and no immediate work is required. The Town should reevaluate the facilities in the next 10 to 15 years to evaluate the assets as they continue to age. Additional upgrades such as installing a new well should be further considered within this 20-year planning period. A capital cost summary of these renovations is included in Section 5. Additional details on these recommendations are provided in Appendix A.

Section 3 Water Source Supply Planning

3.1 Replacement Well Development

MassDEP approves replacement wells on a case-by-case basis. A replacement well is a new well(s)/wellfield installed to replace or supplement an approved well(s)/wellfield. A replacement well(s)/wellfield can replace an inactivated or abandoned well(s)/wellfield or replace lost yield in the existing and active well(s)/wellfield. Replacement wells can be used together with the existing active well(s)/wellfield to manage the system better without increasing yield. The replacement well(s)/wellfield's approved pumping rate cannot exceed the original source's approved pumping rate.

3.1.1 Permitting

For wells with approved yields of 100,000 gpd or greater, the proposed replacement well must be within 250 feet. Replacement wells cannot significantly alter existing groundwater hydraulics or Zone II boundaries, and negative environmental impacts and potential contamination threats should be minimized. Efforts must be made to obtain the Zone I for all replacement wells; it is typically a best practice to locate a replacement well and maintain the Zone I within the land already owned by the water department. MassDEP must approve proposals for replacement well(s) and may require applicable permit submittals. The submittal includes but is not limited to a Bureau of Resource Protection – Drinking Water Program Water Supply (BRP WS) 17 permit for Exploratory Phase, Site Examination, Land Use Survey, and a Pumping Test. It is our understanding that MassDEP requires a partial BRP WS 17 application consisting of a short justification detailing the need for a new replacement well, and a proposed location for each new well with a map providing a characterization of land uses within the Zone I of the well.

Site plans detailing the Blackstone Wellfield and Bernat Wellfield existing Zones, surrounding parcels, and GIS land use data are provided in Appendices B1 and B2, respectively.

3.1.2 Test Well Investigation

Test well investigations offer additional information on the feasibility, likely capacity and quality of a proposed replacement well. MassDEP recommends test wells be installed to increase confidence that the replacement well will yield the desired quality and quantity. Typically, a drilling contractor will install 2-1/2-inch test wells drilled to the full depth of the existing well or refusal. Each well is equipped with a 5-foot-long by 1-1/4-inch diameter stainless well screen. The driller will conduct preliminary vacuum extraction of the well to determine if the well is suitable for short term pumping.

If the test well indicates feasible yield, an adjacent 2 or 2-1/2-inch diameter observation well is installed to monitor the drawdown of the test well, and for reference during the pump testing of the production well. The driller will then conduct a short-term pump test on the test well of between one to two hours. Water quality samples are typically collected and sent to a laboratory to be analyzed for secondary contaminants and VOCs; in addition, MassDEP has begun recommending PFAS6 sampling for new wells.

3.1.3 Production Well Design

A conceptual replacement design includes new gravel packed wells installed adjacent to the existing wells to act as replacement sources. The replacement wells would consist of new 12-

inch by 18-inch diameter or 18-inch by 24-inch diameter gravel packed wells with submersible pumps installed on spool type pitless adapters. The pitless unit and casing vent pipe will terminate above the elevation of the 100-year flood plain. The water main from the replacement wells will be buried and new instrumentation and discharge valving will be installed in a buried vault. Electrical equipment would be housed in the existing well houses or in suitable external housing.

3.1.4 Well/Pump Performance Test and Sampling

To more accurately size the replacement well pump and verify capacity, a pumping test would be performed with the results provided to MassDEP for review. In some instances, MassDEP will require testing, at minimum water quality sampling, prior to approving the new well. The pumping test typically includes pumping of the production well between 24 and 48 hours and measuring the drawdown in an adjacent monitoring well. MassDEP typically requires, at a minimum, samples for coliform bacteria, volatile organics, secondary contaminants, nitrate, and nitrite be collected at the end of the pumping test. We expect MassDEP to begin requiring PFAS6 samples for all new wells.

MassDEP also requires additional information on the proposed well design and proposed operation scheme, and a plan for disposition of the original source (i.e., the original well will be abandoned and decommissioned, used in conjunction with the replacement well(s), or maintained as an emergency well). A separate BRP WS 36 permit may be required for the abandonment of any public water supply source (refer to section 4.21 Well Abandonment and Decommissioning).

Following the completion of any required pumping tests, groundwater sampling events, and laboratory analytical work, the proponent shall submit a Source Final Report to MassDEP along with the applicable permit to construct. The BRP WS 20 permit shall be submitted for wells with planned yields of 100,000 gpd. The Source Final Report may include record drawings of the well construction diagram, a plan of the Zone I for the replacement well, Geographic coordinates of the well, water quality results, and other information at the discretion of MassDEP. The replacement well(s) or wellfield may not be used for public water supply until MassDEP has granted final approval to do so. MassDEP shall issue applicable public water supply source identification numbers upon final approval.

3.1.5 Replacement Well Development in Uxbridge

Tighe & Bond recommends installing 12”x18” diameter replacement wells at the Blackstone Wellfield, and 18”x24” diameter replacement wells at the Bernat Wellfield. We have developed planning level costs for each replacement well, which include drilling each well, conducting a short-term pumping test, purchase and installation of the well pumps, instrumentation, electrical products, and associated site work.

The costs include markups for general conditions, engineering, design, and bidding contingencies. Costs are presented below in Tables 3-1 and 3-2. This cost opinion is an Association for the Advancement of Cost Estimating (AACE) International Class 5 opinion, which is typical for feasibility or study level projects. We’ve included 25% for contractor general conditions, and 25% engineering, 30% design, and 10% project contingencies to reflect a planning level of detail. These costs are for planning purposes only.

TABLE 3-1
Blackstone Replacement Well Cost Summary

Description	Cost Opinion
Well Drilling (Well No. 1, 2 & 3)	$300,000
Contractor General Conditions, Bonds & Insurance, OH&P (25%)	$150,000
Civil / Site Improvements	$75,000
Pumps and Pitless Adapters	$200,000
Process Piping and Instrumentation	$50,000
Electrical	$275,000
Probable Construction Costs	**$1,050,000**
Engineering & Permitting through Construction (25%)	$262,500
Design Contingency (30%)	$315,000
Project Contingency (10%)	$105,000
Recommended Project Budget (Rounded)	**$1,740,000**

TABLE 3-2
Bernat Replacement Well Cost Summary

Description	Cost Opinion
Well Drilling (Well No. 4, 5 & 6)	$350,000
Contractor General Conditions, Bonds & Insurance, OH&P (25%)	$150,000
Civil / Site Improvements	$75,000
Pumps and Pitless Adapters	$200,000
Process Piping and Instrumentation	$50,000
Electrical	$275,000
Probable Construction Costs	**$1,100,000**
Engineering & Permitting through Construction (25%)	$275,000
Design Contingency (30%)	$330,000
Project Contingency (10%)	$110,000
Recommended Project Budget (Rounded)	**$1,820,000**[1]

[1]Higher Bernat Well costs associated with anticipated deeper wells.

3.2 New Source Approval Process

Rosenfeld Wellfield Facility currently has one well operating and the capacity to add three additional wells. In Massachusetts, the Source Approval process governs the development of a public groundwater source. For the development of a new source at a wellfield site, MassDEP permits exploratory test drilling prior to seeking MassDEP approval. There is one 18-inch, 69-foot deep test well drilled at Rosenfeld. The safe yield of the well is unknown and should be estimated, as the source approval process differs for wells with yields less than 100,000 gpd and wells with yields 100,000 gpd and greater. Site plans detailing the Rosenfeld Wellfield's existing Zones, surrounding parcels, and GIS land use data are provided in Appendix B3.

Before developing a new public water supply source with a planned yield of 100,000 gpd or greater, a thorough analysis of system demand must be conducted, and a water conservation program must be in place. Tighe & Bond conducted an analysis of system demand the 2020 Uxbridge Water Distribution System Evaluation. The water supply development process considers the impacts to natural resources. The Source Approval process and Water Management Act Program (WMA) calls for comprehensive information related to the potential impacts of withdrawal. Figure 3-1 outlines the major components of the Source Approval process for all public water supply wells.

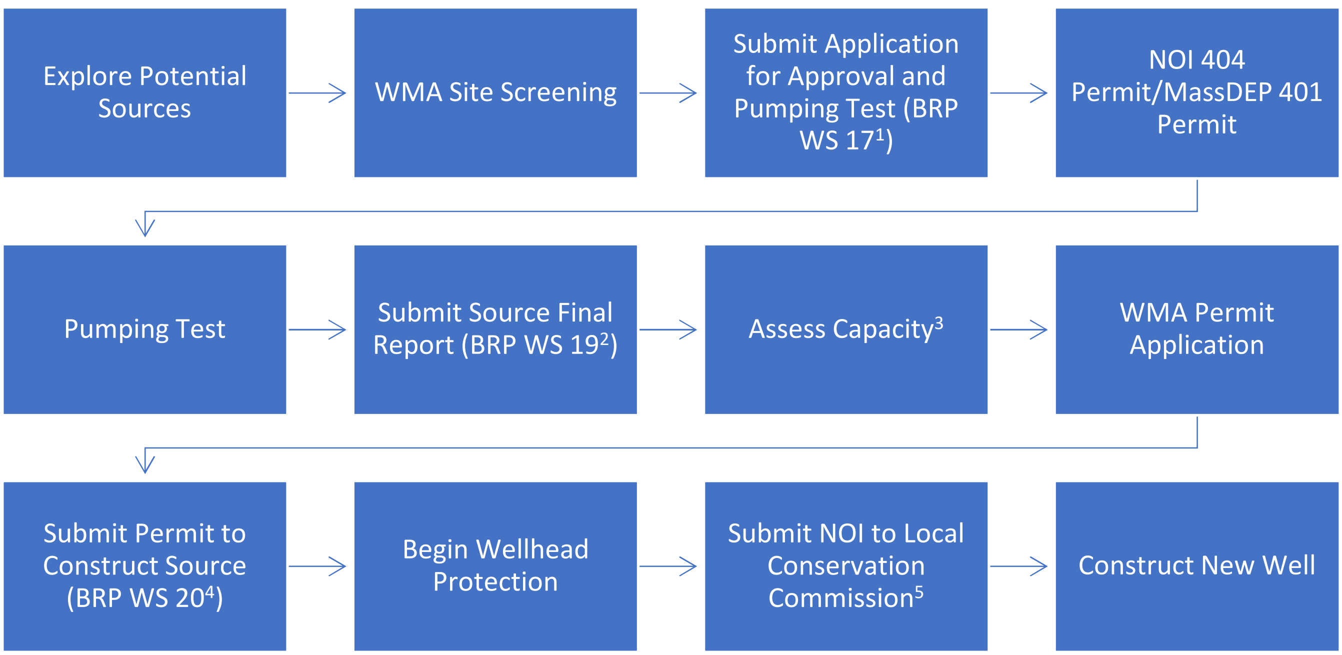


Figure 3-1 New Source Approval Process

[1] BRP WS 17 Approval to Site a Source and Conduct a Pumping Test for a Source Greater Than 70 Gallons per Minute.
[2] BRP WS 19 Approval of Pumping Test Report application required for New Source Approvals Greater Than 70 Gallons per Minute.
[3] A new public water system (for community or non-transient-non-community (NTNC) systems only) must demonstrate the managerial, technical, and financial ability to comply with the Safe Drinking Water Act and other drinking requirements pursuant to 310 CMR 22.00.
[4] BRP WS 20 Approval to Construct Source Permit application required for New Source Approvals Greater Than 70 Gallons per Minute
[5] Following the approval of the Source Final Report, additional wetlands or 100-foot wetlands buffer work may be required. This may require the submittal of a NOI to the local conservation commission.

Table 3-3 provides a planning level estimated schedule associated with developing a new source of supply that would consist of at least one new gravel packed well. The well would be drilled within proximity of the existing chemical building and a transmission main would be provided to the existing process piping connection. Tighe & Bond developed a planning level cost for construction of the new well of $2,000,000 to install a new well. Costs include drilling the well, conducting a 48-hour pumping test, purchase and installation of the well pumps, instrumentation, electrical equipment, associated site work, and the permitting process shown in Figure 3-1. The costs include markups for general conditions, engineering, design, and bidding contingencies. This cost opinion is an AACE International Class 5 opinion, which is typical for feasibility or study level projects and includes 25% for contractor general conditions, 25% engineering, 30% design, and 10% project contingencies to reflect a planning level of detail. These costs are being provided for planning purposes only.

TABLE 3-3
Estimated Schedule for New Source Construction

Phase	Project / Phase Description	Estimated Schedule
1	Well Siting & Test Drilling	3 - 6 months
2	BRP WS 17 Approval to Site a Source and Conduct a Pumping Test	6 months
3	Conduct Pumping Test	2 – 4 months
4	BRP WS 19 Pumping Test Report Permit & Approval	6 – 12 months
5	Construct Production Well	8 months
6	Well Facility Preliminary Design	12 months
7	BRP WS 20 Approval to Construct Source Permit & Approval	3 - 6 months
8	Final Design and Bidding	6 - 12 months
9	Well Construction	12 months
	New Source Approval Total Time	**5+ years**

TABLE 3-4
Rosenfeld New Source Well Cost Summary

Description	Cost
Well Drilling	$200,000
Contractor General Conditions, Bonds & Insurance, OH&P (25%)	$150,000
Civil / Site Improvements	$400,000
Pumps and Pitless Adapters	$100,000
Process Piping and Instrumentation	$50,000
Electrical	$300,000
Probable Construction Costs	**$1,200,000**
Engineering & Permitting through Construction (25%)	$300,000
Design Contingency (30%)	$360,000
Project Contingency (10%)	$120,000
Recommended Project Budget (Rounded)	**$2,000,000**

Section 4 Water Quality Planning

In 2020, Tighe & Bond performed an evaluation of the Town's Water System. This study included a review of existing facility permits and records, and an evaluation of the existing water distribution system infrastructure using the Uxbridge hydraulic model. This report found that if additional wells need to be taken offline due to water quality issues such as elevated iron and manganese or PFAS, current and projected maximum day demands may not be met.

To meet the challenges associated with water supply, the Town should consider installing a manganese treatment facility to return Blackstone Well #1 to service. The Blackstone wellfield has an average PFAS6 concentration of 15.56 ng/L.. While currently under the PFAS6 MCL, it is possible that PFAS regulations will change, or sampled concentrations at the wellfield may increase in the future, requiring the Town to treat or mitigate PFAS contamination. To better prepare for the need to treat or mitigate PFAS, the Town should consider PFAS treatment options.

4.1 Design Assumptions

The Blackstone Wellfield has a maximum authorized daily withdrawal of 1.19 MGD, which corresponds to a flowrate of approximately 826 gpm over 24 hours. Typical production at the site has been reduced due to the aging wells and Well #1 being offline due to poor water quality. A manganese treatment facility would allow the Town to use Well #1, and/or safeguard against changing water quality of the future replacement wells to ensure a consistent production capacity of 1.19 MGD from the site. The design parameters listed in Table 4-1 are the basis for sizing the treatment systems described in the following sections:

TABLE 4-1
Design Assumptions

Source	Iron (mg/L)1	Manganese (mg/L)	PFAS (ng/L)	Pumping Rate (gpm)	Approved Withdrawal (MGD)
Well 1	0.3	1.2	2.3	299	0.43
Well 2	0.3	0.1	21.8[2]	305	0.44
Well 3	0.3	0.2	8.26[2]	222	0.32
WTP Design	**0.3**	**0.5**	**14.75[3]**	**826**	**1.19[4]**

[1] The SMCL value of 0.1 mg/L was assumed for the design parameter.

[2] Based on raw water sampling collected on April 21, 2021

[3] Based on average blends of Wells 2 and 3 in 2021

[4] Daily approved withdrawal total is 1.19 MGD, but the annual approved withdrawal is 0.66 MGD due to Registration limits

Most PFAS samples collected for Blackstone Wellfield were of the finished water blend. The average PFAS concentration of the Blackstone Wellfield's finish water is 14.75 ng/L, based on monthly samples collected from April to September 2021. On April 21, 2021, samples from Blackstone Wells #2 and #3 were analyzed for PFAS, along with Blackstone Wellfield finished blend water. Blackstone Well #1 was sampled as part of a MassDEP sampling program but remains inactive due to manganese. Blackstone Wells #2 and #3 had raw water PFAS concentrations of 21.8 and 8.26 ng/L, respectively. While the Blackstone Well #2 water sample from April had a PFAS concentration exceeding the state MCL, the blended water had a PFAS level of 16 ng/L, below the MCL. However, PFAS concentrations may increase or contaminant restrictions may become more stringent in the future. The PFAS concentration at Blackstone Well #1 have been reported as low, but due to the lack of regular pumping, when Blackstone Well #1 is brought back online, the PFAS level of the well may rise. Tighe & Bond recommends upgrades to the Town's water treatment facilities to ensure that PFAS regulations are not exceeded in the future.

4.2 Manganese Treatment Alternatives

Both treatment processes involve the oxidation of soluble Fe(II) and Mn(II) to insoluble Fe(III) and Mn(IV), which precipitate as metal oxides/hydroxides and are removed in the filter. The two primary treatment alternatives for municipal-scale drinking water treatment include greensand and biological filtration.

- **Greensand Filtration:** Filtration through manganese greensand is the industry standard for removing manganese from groundwater, going back decades. Traditional greensand media was originally a product mined from a naturally occurring geological formation; however, over recent decades artificial products such as media which receives a manganese dioxide (MnO_2) coating have become the industry standard. There are several other popular media on the market that use a host material and coat it with manganese dioxide.

  These oxide-coated media systems involve the addition of an oxidant (e.g. chlorine or potassium permanganate) and filtration through media coated with manganese-containing metal oxides. Chlorine oxidizes iron rapidly in solution, causing iron to precipitate and then be removed by filtration, typically in a top layer above the greensand media, such as anthracite. Chlorine oxidizes manganese very slowly in solution but very rapidly in the presence of manganese oxide, which acts as a catalyst. In filters packed with manganese oxide-coated media, Mn2+ adsorbs onto the manganese oxide where it is oxidized autocatalytically or by chlorine. Thus, iron and manganese are removed simultaneously through different reactions when chlorine is applied continuously to a filter packed with manganese oxide coated media.

- **Biological Filtration:** In bio filters, iron- and manganese-oxidizing bacteria (IOB and MOB) naturally present in the groundwater form a biofilm on the filter media. These bacteria generate energy through the aerobic oxidation of Fe^{2+} to $Fe(OH)_3$ or Mn^{2+} to MnO_2. The metal precipitates formed by biological oxidation are denser and more crystalline than those formed through chemical oxidation; therefore, they foul the filter less rapidly and produce denser backwash sludge. Biological iron and manganese oxidation typically are accomplished in two successive stages (iron followed by manganese) because IOB and MOB have different preferential ranges of pH and oxidation-reduction potential (ORP). Other water quality constituents that result in higher oxidation potentials may affect performance or require pre-treatment (e.g. sulfate, natural organic matter and ammonia).

  Optimal pH, ORP, and dissolved oxygen (DO) are required for the correct operation of the biological process. This can be achieved through controlled injection of process air (depending on the raw water pH) to increase the DO and achieve specific target process conditions. Target pH and DO ranges are as follows:

- Bio-Iron Oxidation Process:
  - pH: 6 - 7.0 s.u., or typical raw water pH
  - DO: < 1 – 3 mg/L

- Bio-Manganese Oxidation Process:
  - pH: 7.5 – 8.0, typically filter effluent targeting distribution system pH
  - DO: 5 – 6 mg/L

In some applications, pH adjustment may require the injection of caustic, particularly for two-stage systems due to the difference in operating ranges for the processes. The time required for the initial establishment of the bacterial colony is referred to as the "seeding time," which is how long it takes for a biological filter to removal significant quantities of iron/manganese. The amount of seeding time depends on the raw water quality, background bacterial levels, temperature, and other factors, but can be reduced by introducing a small amount of filter media or backwash waste from another mature, biologically active filter. Typical seeding times for iron filters may be within hours/days while manganese filters are typically days/weeks. However even after initial startup, additional time is needed to establish a "robust biofilm" which is resistant to influent quality swings, process changes, and washout. At some sites, where only raw water manganese and background biology is used, it may take 6 to 12 months, or beyond, to establish the desired biological community.

In addition, these filters are typically a mono-media and do not require a re-stratification step typical for dual media, such as manganese greensand with an anthracite cap. However special care should be taken to not provide backwash supply water from a distribution system or a chlorinated clearwell to avoid damaging the bacterial catalysts through disinfection. A clearwell downstream of the bio-filters is recommended to provide unchlorinated backwash water and allow any entrained air that may be present in the water to escape, thereby eliminating the risk of "milky" (supersaturated) water at customer taps.

Biological iron and manganese filtration is a relatively newer process than traditional chemical oxide coated media filtration in the United States. There are less than a dozen full-scale biological filtration systems operating in New England at this time, but the field is actively expanding. However, for this reason, no manufacturer offers a process guarantee of filtration effluent water quality. Piloting-scale testing is recommended to confirm operational design criteria.

Based on recent Tighe & Bond experience with over ten greensand and three biological filtration plants in operation, it is our opinion that both treatment technologies can achieve effluent iron and manganese concentrations consistently below their respective SMCLs (see Section 1.4). Bio-filters have a longer start-up period and can be inhibited at low temperatures (<45°F), but they tend to develop head loss more slowly, have longer filter run times compared to chemical oxidation/oxide-coated media filters, and use less chemicals. The longer runtimes, reduced backwash supply rate, and reduced chemical usage result in lower residuals production and lower annual O&M costs. Table 4-2 summarizes the advantages and considerations for iron and manganese removal with greensand filters and bio-filters.

TABLE 4-2
Comparison of Iron and Manganese Treatment Alternatives

	Advantages	Considerations
Greensand Filters	• Short start-up periods • Widely adopted technology	• More frequent backwashing • More residual backwash water • Requires chemical oxidant and labor for managing chemicals • Residual oxidant must be quenched for PFAS treatment with ion exchange (IX).
Bio-filters	• Less frequent backwashing • Less residual backwash wastewater • No chemical oxidants that interfere with PFAS treatment • Reduced labor costs. • Lower annual O&M costs	• Longer piloting and startup phases • Requires non-chlorinated backwash water • May require reconditioning after prolonged shut-down • Clearwell and repumping recommended prior to PFAS treatment

4.2.1 GreensandPlus™

The Technical Data Sheet published by Inversand, the manufacturer of GreensandPlus™, states that GreensandPlus™ capacity is between 700 and 1200 grains of oxidized iron and manganese per square foot of bed area. Specific water quality information for each well can be found in Table 1-6. The iron and manganese concentrations assumed for the Blackstone Wells WTP blended raw water are approximately 0.3 mg/L and 0.5 mg/L, respectively. Therefore, based on the assumed iron and manganese loading, we can assume a total oxidant demand of 1.3 mg/L. Oxidant demand is calculated by the following equation: Oxidant Demand = (1 x [Fe-mg/L] + 2 x [Mn-mg/L]). Dividing this value by a GreensandPlus™ media factor of 17.1 yields approximately 0.08 grains per gallon. Using an assumed media capacity of 800 grains per square foot and the grains per gallon in the above calculation; the conceptual treatment system would be sized at approximately 10,000 gallons per square foot between backwashes.

The Maximum Authorized Daily Withdrawal for the three wells is approximately 1.19 MGD or 826 gpm. We target a filter run time between backwashes of 48 hours at the approved design flow rate. This corresponds to a unit filter run volume (UFRV) of 2.4 MG between backwashes. Based on these factors, we estimate that the treatment system would require approximately 240 square feet of filtration area.

Table 4-3 presents details of a conceptual GreensandPlus™ filtration system composed of three 10-ft diameter filters, which contain 235.5 square feet of media, which is slightly less than the 240 square feet required to achieve a runtime between backwashing of greater than 48-hours at the peak flow rate. Longer runtimes may be achievable depending on the flowrate selected to reach 2.4MG and selected oxidant or operational scheme chosen by the Town at full scale.

TABLE 4-3
Conceptual GreensandPlus Filter System Sizing

Filter System Information	Recommendation
Design Flow Rate (gpm)	826
Number of filters	3
Filter diameter (feet)	10
Filter surface area (1 filter) (SF)	78.5
Total filter surface area (3 filters) (SF)	235.5
Filter surface loading rate (FSLR) (gpm/sf) @ 826 gpm (SF)	3.5
Head loss (PSI)	8 – 10
Filtered water run volumes between backwashes (MG)	2.4 – 3.0
Backwash Rate (gpm)	400 – 950
Backwash volume for all filters (gallons)	32,000

For the purposes of a conceptual design, we included a 1-foot bed of anthracite coal media above a 2-foot bed of GreensandPlus™ media. The total media volumes are 78.5 c.f. of anthracite and 157 c.f. of greensand. We also recommend that space for an additional fourth filter be provided to account for unknown or future changes in water quality. Additional design criteria should be evaluated in a pilot study as required by MassDEP.

To ensure efficient treatment through a GreensandPlus™ filtration system, the catalytic characteristics of the media must be maintained through regeneration by exposure to an oxidant. Chlorine or permanganate are the most common oxidants used. Regeneration can be performed continuously by feeding permanganate or chlorine during filter service (continuous regeneration, CR) or intermittently by occasionally backwashing or soaking with permanganate (intermittent regeneration, IR). Operation with hypochlorite as the sole oxidant leads to higher runtimes as potassium permanganate is a stronger oxidant and will often lead to full oxidation of the dissolved manganese to a particle. A buildup of manganese in addition to the iron particles in the media bed may lead to higher headloss buildup than when manganese is only removed via adsorption and catalyzed by the media. In addition, injection of potassium permanganate increases the total manganese loading on the filters increasing the mass required for treatment. Operation with hypochlorite alone may weaken the surface charge of the media over time and require earlier replacement or intermittent regeneration with potassium permanganate. Operation with both oxidants should be tested during a pilot phase to determine the optimal pre-treatment levels prior to filtration.

Assuming an annual average daily withdrawal limit of 0.66 MGD as required by the Blackstone River Basin Registration, the WTP would typically backwash twice per week. A backwash water supply volume of approximately 10,000 gallons per filter would be required at a maximum backwash rinse rate of 12 gpm/sf, or 1,360 gpm. To provide these rates for backwash and prevent flow reversals within the distribution system, a separate backwash storage and pumping system would be required. This storage system can be sized for one or all of the filter's required backwash storage volume. We've assumed a storage volume in excess of 30,000 gallons will be required. Based on the backwashing schedule above, the system would produce approximately 3.2 MG per year of backwash wastewater. The system would require storage in excess of 30,000 gallons of backwash wastewater. A backwash recycle/reclamation system is also recommended to reduce the water weight of residuals needing disposal. For the purpose of this analysis we estimated that the backwash recycle system would reduce the annual backwash volume by approximately 60% resulting in 1.3 MGY of backwash water disposal.

The filtration system would be located within a building with a footprint of at least 4,000 square feet. This conceptual building would house the filter units, associated process piping, chemical feed and storage, as well as control room space. The raw water will be conveyed to the WTP through a common header pipe. Chlorine and hydroxide would be injected before the filters, with provisions to inject $KMnO_4$, for pretreatment. Filtered water would need to be compatible with PFAS treatment, if present. Removal of the chlorine residual may be required if ion exchange (IX) is to be used for PFAS treatment and additional chlorine feed systems may be required downstream if GAC is used.

4.2.2 Biological Filtration

Biological filtration has been widely adopted in Europe for decades and has been successfully implemented in New England over the last decade. However, due to the nature of a biological system, predicting the performance of biological filtration is more complex and is not simply estimated from a technical datasheet provided by a manufacturer. However, based on previous work performed by Tighe & Bond, we can make a conservative estimate of runtimes between backwashes based on the results of pilot and full-scale filters with similar water quality as the Blackstone Wells. It is our opinion that the biological filtration systems will likely meet a minimum 48 hour run time at the design flow for loading rates of 10 gpm/sf and below. A rigorous pilot study would be required prior to construction of a full-scale biological filtration system to confirm the assumptions in this report.

Typically, biological filtration systems require a two-stage filtration system, iron followed by manganese, due to the biological preference towards higher oxidation potential. In some instances, other constituents such as sulfates, ammonia, and organics can reduce the effectiveness of biological iron oxidation because of the higher oxidation potential of nitrogen and carbon nutrients. Due to the relatively limited water quality concerns, beyond manganese and PFAS, biological manganese filtration may be possible in a single stage as the water quality data provided did not indicate a significant presence of iron, ammonia or other constituents that would reduce the effectiveness of biological manganese filtration. However, due to the limited data for Well #1, we assume that both biological iron and manganese filtration systems will operate in series.

The conceptual filtration system consists of two 8-foot diameter biological iron filter, followed by two 8-foot diameter biological manganese filters for a typical filter surface loading rate of 8.3 gpm/sf. We have included a conservative estimate for filter runtimes between backwashes based on the results of other pilot and full-scale facilities in New England. For the purpose of this conceptual design, a filter runtime of 96 hours between backwashes for biological iron and 60 hours for biological manganese filtration at peak flows has been assumed. This corresponds to a unit filter run volume of approximately 4.75 MG and 2.98 MG of treated groundwater before backwashes, respectively.

Biological filtration has been observed to adapt well with changing water quality. Because the design expectations of the biological filters are significantly above the conceptual design of the GreensandPlus™ filter, it is likely these conceptual assumptions will have redundancy built into the filter loading rate. Instead of providing space or a third, redundant filter for each train, it is likely that data from the pilot will suggest the ability to significantly increase the filter surface loading rate while maintaining runtimes above the 48-hour minimum.

Table 4-4 presents details of a conceptual biological filtration system composed of two 8-ft diameter biological iron filters followed by two 8-ft diameter biological manganese filters, each with an approximate 200 cubic feet of sand media. To ensure efficient treatment through the biological treatment system, the bacteria will need to provide the proper conditions for growth. pH and DO will be criteria design criteria, among others, which should be evaluated in a pilot study as required by MassDEP. Assuming an annual average daily withdrawal limit of 0.66 MGD as listed in the WMA permit, the WTP would typically backwash once per week.

TABLE 4-4
Conceptual Biological Filtration Sizing

Filter System Information	Recommendation
Design Flow Rate (gpm)	826
Number of filters	4
Filter diameter (feet)	8
Filter surface area (1 filter) (SF)	50.2
Biological Iron Filtration surface area (2 filters) (SF)	100.5
Biological Manganese Filtration surface area (2 filters) (SF)	100.5
Filter surface loading rate (FSLR) (gpm/sf) @ 826 gpm	8.3
Head loss (PSI)	10
Iron - filtered water run volumes between backwashes (MG)	4.5 – 5.5
Manganese - filtered water run volumes between backwashes (MG)	4.0 – 5.0
Backwash Rate (gpm)	150 - 400
Backwash volume for all filters (gallons)	10,000

A total backwash water supply volume of approximately 2,500 gallons per filter would be required. A maximum backwash rinse rate of 8 gpm/sf could be provided from the flow of the well pumps; backwashing with raw water should be investigated in the pilot study. Unchlorinated filtered flow could also be used; however, it is typical to provide an unchlorinated filtered water tank with a backwash supply pump. A reversal of the distribution system would provide chlorinated water and could lead to a die-off and reduced performance; however, it could be evaluated in the pilot study. For the purposes of this conceptual design, we’ve assumed a separate backwash storage and pumping system would be required. This storage system can be sized for one or all of the filter’s required backwash storage volume. We’ve assumed a storage volume in excess of 10,000 gallons will be required. The system would produce approximately 0.7 MG per year of backwash wastewater. The system would require storage in excess of 10,000 gallons of backwash wastewater. Due to the limited volume of backwash water produced by a biological system, additional feasibility of on-site disposal of residuals should be explored as the design progresses.

The filtration system would be located within a building with a footprint of at least 4,000 square feet. This conceptual building would house the filter units, associated process piping, chemical feed and storage, as well as control room space. The raw water will be conveyed to the WTP through a common header pipe. Air would be injected before the iron filters, with provisions to inject KOH for pretreatment; both KOH and air will be injected before the manganese filters. Filtered water would need to be compatible with PFAS treatment, if present. Biological cells in the effluent of the filter system may populate the downstream GAC filters leading to increased plugging or reduction of expected GAC life. Biological pilot filters should be operated with downstream GAC to study the impacts to GAC operations. In lieu of pilot data, disinfection, through use of UV or chlorination could also provide disinfection prior to GAC. However, chlorination would not be an option upstream of an IX treatment system for PFAS.

4.2.3 Hydraulics

Both filtration systems operate similarly, building up headloss in the media bed to a terminal headloss of approximately 10 PSI. GreensandPlus™ is typically operated to 6-8 PSI as recommended by the filtration system providers, but media data sheets indicate 10 PSI to be a safe pressure where no damage will be done to the media coating. For biological filtration, there is no typical standard headloss across the filter bed recommended by a manufacturer. In practice, biological filtration systems in New England have been operated based on total number of hours online or a terminal headloss of 10 PSI. However, in several pilot studies, Tighe & Bond has observed biological filers operating to 20 PSI and above with no observed treatment impact. Previous experience indicates the possibility of issues associated with plugging of the media with biological cell material at high differential pressures and high concentrations of iron. For biological manganese filtration, we believe plugging may be less of an issue, long term, than plugging associated with high concentrations of iron. Repeatable operations to a terminal headloss of above 10 PSI may be evaluated as part of the pilot phase. Additional capacity for backwash pump design may also be provided to mitigate longer term media plugging.

GreensandPlus™ filtration systems often operate at system pressure, allowing well pumps to pump through the filtration system directly to downstream processes and into the distribution system. Simple backwash provisions can allow for the filter system to use forward flow, through the filters, as a source of backwash water or, in cases where the source flow is less than the required filter backwash flow, flow is reversed in the distribution system, using system pressure to push the required flow rate back up through the filter for cleaning. Although economical, flow reversals in the distribution system can stir up laden solids in the distribution system, leading to dirty water calls during backwashing. To avoid the need for flow reversals, a hydraulic break tank or a side stream backwash supply tank is needed.

For a biological filter, due to the need for unchlorinated backwash supply and potential issues of dissolved air, degassing in downstream processes, biological filter systems are often provided in a double pumping scenario, where the well pumps convey raw water through the biological filter and a separate set of high lift pumps convey raw water through successive treatment processes and into the distribution system. This filter effluent tank provides both unchlorinated backwash supply and an atmospheric break to allow for dissolved gasses to be released prior to re-pressurization. In previous experience, proper control of the air injection, prefiltration and pipe routing can provide de-gassing sufficient to pump through to the distribution system. At this time, it is our understanding that no full-scale biological filtration system in New England is operating in a pump through mode. Operation of downstream PFAS treatment and the effect of dissolved air in the filter effluent should be re-evaluated during pilot testing. Operating the biological filtration system in a pump through mode, with a side-stream unchlorinated backwash supply could represent a cost saving associated with secondary high lift pumping system.

Typically, a hydraulic break is provided downstream of biological manganese filtration to allow for release of the surplus process air. Although there are no residual oxidant concerns for downstream processes, it is typical to provide post-filtration disinfection to a chlorine residual of approximately 0.3 mg/L. Special consideration should be given to downstream storage or filtration systems if chlorination or other disinfection is not provided. It is unknown if biological growth will occur on GAC or IX causing any significant additional headloss through the process stage. This should be evaluated in the pilot study phase, as needed.

4.2.4 Economic Evaluation

Planning level opinions of probable capital and operating costs were developed for GreensandPlus™ and biological filtration.

4.2.4.1 Opinions of Probable Construction Cost

Opinions of probable construction costs included in Table 4-5 are provided to highlight the differences between the two treatment technologies. Additional project level opinions of probable construction costs for the conceptual water treatment plant are provided in later sections.

TABLE 4-5
Summary of Process Equipment Capital Costs[1]

	GreensandPlus™	Biological
Pre-construction Piloting[2]	*$40,000*	*$120,000*
Backwash Supply Tank	$120,000	$235,000
Backwash Waste Tank	$270,000	$150,000
Backwash Recycle System	$100,000	-
Sewer Pump Station	$100,000	$400,000
Chemical Feed Storage & Equipment	$150,000	$100,000
Pumping Equipment	$160,000	$2,250,000
Filter Vessels & Process Equipment	$1,000,000	$1,500,000
Subtotal Process Equipment Costs	***$1,900,000***	***$2,250,000***

[1] The costs presented in this table do not include the majority of the costs for these treatment systems. The costs are for comparison of the filtration systems and associated chemical feed and pumping systems only.
[2] Piloting costs shown for reference but not included is the subtotal equipment costs. Biological pilot includes GreensandPlus pilot study for comparison.

4.2.4.2 Opinions of Probable Operation and Maintenance

Opinions of probable annual operation and maintenance (O&M) costs included in Table 4-6 were developed based on conceptual level estimates of power use, chemical use, and residuals disposal for comparison purposes. Labor costs were not included in this analysis; they were assumed to be similar among the two treatment alternatives. The costs below are assumed to be raw costs for comparative purposes only, as portion of these O&M costs may already be reflected in the existing operations of the Blackstone Wells site.

Costs are based on a daily production of 0.66 MGD. Electrical costs are based on $0.17/kWh. Chemical costs are based on bulk unit prices for potassium hydroxide, sodium hypochlorite, and potassium permanganate. Sewer disposal costs are based on a fee of $0.07 per gallon.

TABLE 4-6
Estimated Average Annual Operation and Maintenance Costs

Description	GreensandPlus™	Biological
pH Adjustment Chemical Usage (1)	$30,000	$35,000
Chemical Oxidant Usage (2)	$5,000	$0
Residuals Disposal (3)	$90,00	$50,000
Electricity (4)	$140,000	$145,000
Total Estimated O&M Costs	**$265,000**	**$230,000**

(1) Based on 45% potassium hydroxide.
(2) Based on 13% sodium hypochlorite and 2-4% solution of potassium permanganate.
(3) Based on $70/1,000 gallons disposal at the Uxbridge WWTF
(4) Includes, as applicable, well pumping, finished water pumping, backwash, sewer transfer pump, filtration system blower and bio-filter process compressor.

4.2.4.3 Life Cycle Cost Analysis

A life-cycle cost (LCC) analysis was performed as a present worth analysis based on a 20-year life cycle, including capital costs and annual O&M costs. The annual O&M and capital costs were compared using a present worth analysis, with a 4% discount rate, an inflation rate of 2%, and 10 and 20 year terms. A summary of the life cycle cost analysis for the two treatment alternatives is included in Table 4-7. GreensandPlus™ has a slightly lower estimated 10 year LCC due to the lower capital cost, however, the cost to dispose of backwash wastewater over a longer period reduces the cost effectiveness of GreensandPlus™ filtration.

TABLE 4-7
Summary of Life Cycle Cost Analysis

Description (2021 Dollars)	GreensandPlus™	Biological
Capital Cost (Table 4-5)	$1,900,000	$2,300,000
Annual Cost (Table 4-6)	$265,000	$230,000
NPV – 10 year	$4,330,000	$4,360,000
NPV – 20 year	$6,330,000	$6,100,000

(1) NPV based on 10 year and 20 year terms, 4% discount rate, and 2% inflation rate. Discount rate based on Dec 2021 Bureau of Reclamation rate for FY 2022.

4.2.5 Manganese Treatment System Evaluation Recommendation

Life-cycle costs comparing GreensandPlus™ and biological filters are relatively similar with GreensandPlus™ estimated to be a slightly cheaper option. However, the Town should also consider the following before making a final selection of the treatment technology to be used:

- Biological filters are gaining in popularity, but there are more GreensandPlus™ style filter installations in the United States, many of which have been operating for a longer period of time than biological filter plants. There are active full-scale biological filter plants in Cavendish, VT; Middleborough, MA; Shrewsbury, MA; Putnam, CT; and others outside of New England. At least three additional WTPs, utilizing biological filtration, are currently in construction in Massachusetts.

- Biological filters require less frequent backwashing and produce lower amounts of residuals than GreensandPlus™ filters. This could be an advantage when evaluating discharge of residuals to the sewer system. The need to utilize a private contractor for hauling backwash water offsite for disposal would be extremely costly if connection to Town sewer is not feasible. In addition, the results of future evaluations of on-site backwash disposal would also have a significant impact in comparing each of these treatment technologies.

- The start-up period for biological filters can be sensitive to upsets and can take much longer than for greensand filters. However, once established, the biological media is fairly robust and insensitive to varying conditions. Due to the unknown long-term water quality of Well #1, biological filtration offers more flexibility associated with rising manganese concentrations, while a GreensandPlus™ system may require future capital for expansion.

- The equipment setup for both types of filters is very similar, consisting of steel pressure vessels, process piping with motor operated valves, backwash pumping systems and process control systems. Therefore, operationally, both types of systems have similar operational non-cost factors.

- Pilot testing for either treatment system would be required by MassDEP. However, pilot testing both technologies would help establish a more confident estimate of allowable filter loading rates and run times, appropriate chemical feed rates, finished water quality, backwash volumes and characterization, and residuals production, which can better aid with the selection of these technologies. GreensandPlus™ is significantly more predictable, while biological filtration performance is more closely tied to site specific conditions. The need for biological iron filtration with redundancy should be considered a conservative assumption which may be reduced with additional piloting data, leading to a more advantageous life cycle cost analysis.

- Considerations should be given to downstream processes, such as PFAS treatment. Evaluation of the effect of effluent chlorine on IX resin and effluent biomass on Granular Activated Carbon should be explored in the pilot and preliminary design phase. It is our understanding, from discussions with Carbon Vendors that a residual chlorine concentration of < 1 mg/L should not significantly impact the performance of the GAC media. However, chlorine can negatively impact IX resin media.

For the purpose of our analysis, we selected GreensandPlus™ for the treatment system of the Blackstone Wells due to this style of treatment being industry standard. However, we recommend the Town explore both a traditional filtration system and biological filtration systems in a site-specific pilot study to better refine the planning level assumptions presented in this document.

4.3 PFAS Treatment Alternatives

Three main treatment technologies have been shown to be effective for PFAS treatment (Dickenson and Higgins, 2016; Dudley et al., 2015; Campos et al. 2017)

- Granular Activate Carbon (GAC)
- Ion Exchange (IX)
- High pressure membrane filtration (nanofiltration and reverse osmosis)

High pressure membrane filtration has been shown to be highly effective for PFAS removal and provides one of the more reliable methods of preventing any breakthrough of PFAS. However, membrane filtration is typically considered cost prohibitive and generates a concentrated waste brine stream that must still be treated for PFAS or disposed of to a sanitary sewer. Due to the complexity, high expected operational costs, and potential permitting concerns, membrane filtration will not be considered as part of this evaluation.

GAC and IX have been shown to be effective for a range of PFAS. Both have the ability to remove PFAS to less than the MRL with breakthrough rates being dependent on the PFAS compounds present and background water quality parameters. Table 4-8 summarizes some of the considerations for GAC and IX treatment for PFAS and the following sections present conceptual sizing information.

TABLE 4-8
Comparison of GAC and IX for PFAS Treatment

	Advantages	Considerations
GAC	• Proven technology at full-scale • Simple operation • GAC can be re-activated and reused	• Competition from background organics • Breakthrough driven by short chain PFAS
IX	• Simple operation • Potential for higher PFAS capacity than GAC • Lower Empty Bed Contact Times • Lower vessel heights	• Limited full-scale data on PFAS treatment • Competition from other anions • Single pass resin must be disposed of in a land fill or incinerated • Higher head loss than GAC • Breakthrough driven by short chain PFAS. • Media clogging noted at some sites. • Incompatible with residual oxidants from manganese treatment.

4.3.1 Granular Activated Carbon (GAC)

GAC has been used extensively in drinking water and remediation treatment due to its ability to adsorb a range of trace contaminants, such as volatile organic compounds. GAC has also been shown to be an effective treatment option for PFAS. GAC is generally more effective for longer chain PFAS, such as PFOA and PFOS, with breakthrough occurring faster for the shorter chain PFAS (Figure 4-1). When water is passed over the GAC media, the contaminants are adsorbed by the media, which removes them from the water. Once the capacity of the media to adsorb PFAS has been exhausted, the contaminant concentration in the treated water begins to increase, smaller PFAS compounds are typically mobilized off the media in favor of adsorption of larger compounds. As demonstrated in Figure 4-1, breakthrough of shorter chain compounds was observed earlier at a test facility. GAC will likely be effective for removing the PFAS that have been detected in the Blackstone wells because the PFAS6 concentration is mainly comprised of larger PFAS compounds PFOS and PFOA.

GAC will remove a range of compounds, and competing compounds in the water can reduce its effectiveness for PFAS removal. Organic matter, which is typically low in groundwater, is the compound that most often competes with PFAS for adsorption sites. No water quality data indicating the organics concentration in the groundwater for the Blackstone Wells was available for this analysis. Therefore, a conservative estimate for media changeout frequency was included as part of this study.

Table 4-9 provides the conceptual sizing information, and the sections below provide additional details on key design criteria. A minimum of 10 minutes of Empty Bed Contact Time (EBCT) is recommended for GAC to reduce changeout frequency. Based on a design flow rate of 826 gpm, a 12-foot diameter vessel with 40,000 lbs. of carbon is required. This results in an EBCT of approximately 12 minutes at a flow rate of 826 gpm. For this conceptual design, 40,000 lb GAC vessels were utilized for developing conservative capital cost estimates. The number of bed volumes that can be treated before PFAS breakthrough occurs varies depending on water quality as noted above. We evaluated treatment of both 40,000 and 75,000 bed volumes to account for variable conditions. Bench-scale testing would be required to better define the expected changeout frequency.

GAC media would be housed in a steel pressure vessel that prevents the need for repumping of the well water. For treatment of the Blackstone wells, the GAC vessels would be housed in a building to protect them from the elements and to prevent freezing. The spent media removed from the vessel can be landfilled or regenerated at high temperatures. During regeneration, the media is exposed to high heat, which removes any adsorbed contaminants and allows the media to be reused. The Town can utilize the regenerated media, which can reduce media replacement costs but does require longer duration for changeout (e.g., 2+ weeks).

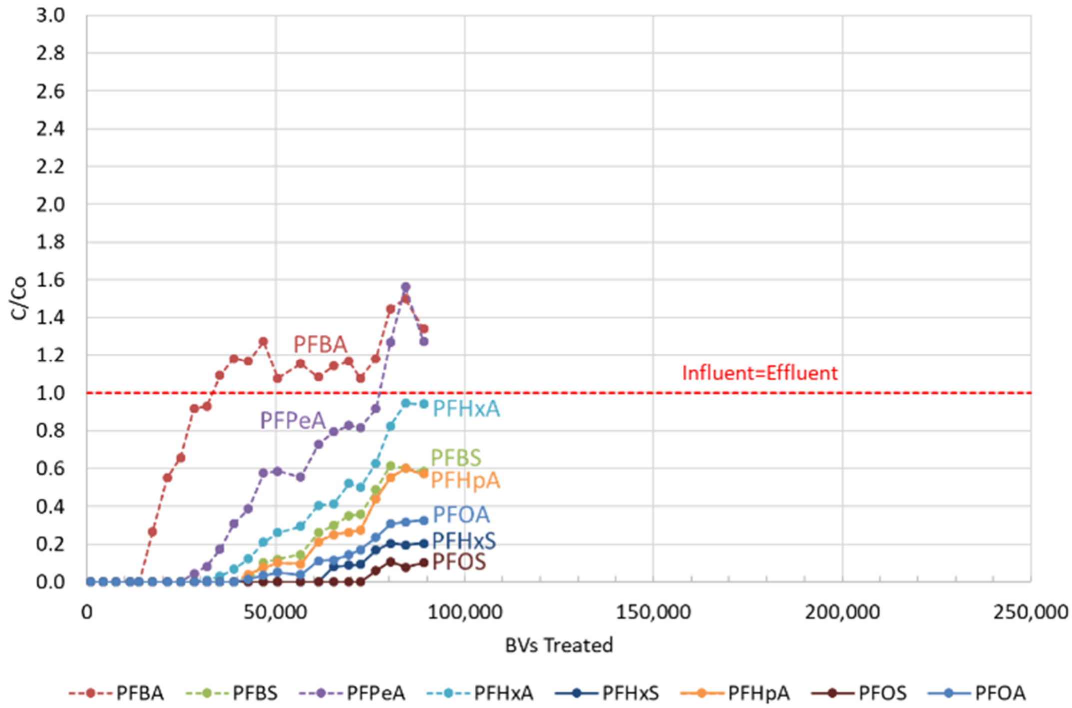


Figure 4-1 Example PFAS Breakthrough After 5 Min EBCT for F400 GAC Media

(Solid lines represent MA regulated PFAS compounds; C/C_0 is the ratio of treated water concentration to influent concentration. C/C_0 greater than zero indicate PFAS breakthrough, while C/C_0 greater than 1 indicate effluent concentrations that exceed the influent indicating remobilization of compounds.)

TABLE 4-9
Conceptual GAC Sizing

Design Parameter	Recommendation
Design flow rate (gpm)	826
Number of vessels installed	2
Number of vessel pairs	1
Vessel operation	Lead/lag
Vessel diameter (feet)	12
Vessel cross-sectional area (ft^2)	113
Hydraulic loading rate (gpm/ft^2)	7.3
Minimum EBCT (minutes)	10
Bed depth (feet)	11.8
Design EBCT (minutes)	~12
Approximate bed volume per vessel, (ft^3)	1,400
Approximate bed volume per vessel, (gallons)	10,000
Assumed media density (lb/ft^3)	30
Standard media weight class (lb)	40,000
Estimated vessel height (feet)	28
Standard vessel pressure rating (PSI)	125
Bed-Volumes to media changeout	40,000 – 75,000[1]
Estimated volume of water treated per changeout (MG)	400 – 750
Assumed life of media (years) (0.66MGD) [1]	1.5 - 3
Initial fill backwash duration (minutes)	30
Backwash flow rate (gpm)	1,000
Initial fill backwash volume (gallons)	30,000
GAC delivery truck drain volume (gallons)	10,000
Minimum backwash storage volume (gallons)	40,000

[1] Changeout frequency based on vendor recommendations. Bench/pilot scale testing is required to further refine bed volumes to breakthrough.

4.3.1.1 Hydraulic Loading Rate and Empty Bed Contact Time

For GAC treatment, equipment sizing is based on acceptable hydraulic loading rates and target EBCT. If hydraulic loading rates are too high, channeling can occur within the GAC media, which reduces treatment efficiency. Hydraulic loading rates should be less than 9.5 gpm/ft^2. The evaluated systems were also sized to achieve a minimum of 10 minutes of EBCT at the design flow rates. GAC usage rates decrease with increasing EBCTs. A minimum of 10 minutes EBCT has been shown to be effective for PFAS removal.

4.3.1.2 Vessel Configuration

For both the GAC and IX systems, the vessels can be operated in parallel or in series. In a parallel operation, the water flows through one vessel with 10 minutes of EBCT. In a series lead/lag operation, the water flows through the lead vessel that would be the primary vessel for treatment. After the lead vessel, the water flows through the lag vessel. The lag vessel would be able to remove any PFAS that were in the effluent of the lead vessel. Both the lead and lag vessels are identically sized for 10 minutes of EBCT. Once the media in the lead vessel is exhausted, the lag vessel would become the lead and the media would be replaced. The series configuration results in higher capital costs for the additional vessels and building footprint, but provides the following benefits:

- Reduced annual operations and maintenance (O&M) costs by increasing the utilization of the media. With series operations, the lead vessel is typically changed out when the effluent PFAS concentrations are approximately 50% of the influent concentrations or 50% of the target effluent concentration. With a parallel system, the media would have to be changed out prior to any PFAS breakthrough to meet the treated water quality goals.
- Increased reliability for meeting the treated water quality goals. PFAS monitoring can be reduced due to the lag vessel offering treatment if PFAS breakthrough the lead vessel.
- Ability to change out the media in the lead vessel without decreasing the treatment capacity as the flow can be fully treated in the lag vessel during media changeouts.
- Increased operational flexibility for scheduling media changeouts.

For this evaluation, sizing and costs are based on series (lead/lag) operation. MassDEP typically requests designs provide lead/lag operations for the benefits described above.

GAC vessels come in standard sizes. Typical sizing for a facility of the Blackstone Wellfield flow rate would consist of 12’ diameter with a bed depth sufficient for achieving a design EBCT of 10 minutes. Backwash flow rates are based on the GAC surface area.

4.3.1.3 GAC Replacement

As the adsorption capacity of the GAC media is exhausted, PFAS will begin to break through and will require replacement of the GAC media. PFAS breakthrough and media replacement are a function of:

- Treated water quality goals / level of breakthrough acceptable
- GAC base material and characteristics
- PFAS adsorption characteristics (e.g., shorter chain PFAS tend to breakthrough faster)
- Treatment flow rates and associated bed volumes treated
- Background organics that compete for adsorption sites

The GAC media selection can have a large impact on treatment performance. The optimum GAC media is a function of the PFAS present and background water quality. The information presented in this memorandum is based on bituminous coal carbons that have been shown to be effective at full-scale PFAS treatment facilities. A more detailed analysis of GAC media selection can be performed by conducting bench-scale testing.

4.3.1.4 Backwashing

Backwashing is required during the initial GAC media installation and during each media replacement. The backwash removes GAC fines that can be created during transport and also stratifies the GAC bed. Backwash during operation is unlikely but may be required depending on the increase in differential pressure across the bed due to particulates in the well water. Therefore, backwash equalization tanks and pumps are still recommended. For this evaluation, it was assumed that the manganese backwash systems can be used for the GAC backwash for settling prior to discharge.

4.3.2 Ion Exchange

Ion Exchange (IX) has been shown to be an effective treatment technology for PFAS treatment with potential to remove long and short chain PFAS (Dickenson and Higgins, 2016; Dudley et al., 2015; Campos et al. 2017). IX has been used extensively for drinking water treatment for other contaminants such as perchlorate, nitrate and hardness. However, full-scale installations of stand-alone IX for PFAS are more limited. Recent IX facilities have anecdotally had issues with clogging of the media.

In an ion exchange process, the target contaminant is exchanged on the resin for a non-toxic compound. In this case, PFAS would be exchanged for chloride ions. IX resins are operated similar to GAC and can use the same pressure vessels as GAC media. Pressure vessels designed for GAC can also be used for IX media for treatment flexibility. Table 4-10 provides the conceptual sizing information for 10’ diameter vessels. The 10’ diameter tanks would utilize on-site media exchange. The sections below provide additional details on key design criteria.

TABLE 4-10
Conceptual Ion Exchange Sizing

Design Parameter	Recommendation
Design flow rate (gpm)	826
Number of vessels installed	2
Number of vessel pairs	1
Vessel operation	Lead/Lag
Vessel diameter (feet)	10
Hydraulic loading rate (gpm/ft^2)	7.3
Standard media weight class (lb)	40,000
Design EBCT (min) per vessel	~3
Approximate media volume per vessel (gal)	2,500
Head loss per lead/lag pair at design flow (PSI)	20-25
Estimated bed volumes to media changeout	300,000 – 490,000[1]
Assumed life of media (years) (0.66MGD) [1]	3 - 5

[1] Changeout frequency based on vendor recommendations. Bench/pilot scale testing is required to further refine bed volumes to breakthrough.

4.3.2.1 Hydraulic Loading Rate and Empty Bed Contact Time

For IX treatment, the required EBCT is much lower than for GAC. IX vendors recommended a design EBCT of 3 minutes based on their pilot and operational experience. Hydraulic loading rates can be higher for IX (up to 12+ gpm/ft^2), which may reduce the size or the number of vessels compared to GAC.

4.3.2.2 Resin Changeout

IX resins can be single pass or regenerable. Regenerable resins are currently being evaluated with use of a sodium chloride brine in a methanol solution to remove PFAS from the resin and replace them with chloride ions. Regenerable resins are better suited for low flow high mass waters and would require additional equipment for the storage and disposal of regeneration solution that would have high concentrations of PFAS. This evaluation was based on the use of single pass resins. Single pass resins are removed and landfilled or incinerated once their capacity has been exhausted. Landfill costs are an annual operation and maintenance cost uncertainty for IX. Land filling costs have increased in recent years and may continue to increase if PFAS regulations are placed on landfills.

IX resins have the potential to have a higher capacity for PFAS than GAC and can achieve treatment at lower EBCTs. IX resin capacity is also PFAS specific with many shorter chain PFAS breaking through faster than the longer chain PFAS, similar to GAC. Changeout frequency is dependent on the treatment goal. Manufacturer predicted changeout frequency ranges from 300,000 to 490,000 bed volumes treated. The IX resin media is typically more expensive than GAC media. The information presented in this analysis is based on Dowex PSR2 Plus. Bench-scale testing would be required to better define the expected changeout frequency.

IX resin capacity is less affected by background organics compared to GAC, but it is affected by background concentrations of other anions in the water. High chloride concentrations have been shown to decrease IX performance at other facilities.

4.3.2.3 Backwashing

IX vessels do not require backwashing as the manufactured media does not typically break apart into fines during manufacturing and transport.

4.3.3 Treatment Uncertainties

Conceptual sizing and costs provided in this evaluation were based on assumptions for treatment goals, background water quality, and manufacturer provided media changeout frequency estimates. Actual costs may vary depending on several treatment uncertainties:

- **Influent PFAS concentration:** the source of the PFAS contamination is currently unknown. If concentrations increase, the higher influent concentrations can be treated with the evaluated technologies but will result in more frequent media changeouts.
- **Site-specific water quality**: Background water quality parameters can compete for the adsorption or exchange sites on the GAC or IX resin and result in higher or lower changeout frequencies for the selected media. Bench-scale testing can be conducted to optimize the media selections and refine estimates for changeout frequencies.

To better determine the impacts of higher influent concentrations and the site-specific water quality, bench or pilot-scale testing of the evaluated technologies would be required.

4.3.4 Economic Evaluation

Planning level opinions of probable capital and operating costs were developed for both treatment alternatives that were evaluated for this study.

4.3.4.1 Opinions of Probable Construction Cost

Opinions of probable construction costs included in Table 4-11 below are provided to highlight the differences between the two treatment technologies. Additional project level opinions of probable construction costs for the conceptual WTP are provided in later sections.

TABLE 4-11
Summary of Equipment Capital Costs

Description	GAC	IX
Backwash Provisions (1)	$100,000	-
Building Height Provisions (2)	$200,000	-
Filter Equipment (3)	$1,100,000	$1,200,000
Total Variable Capital Costs	***$1,400,000***	***$1,200,000***

(1) Backwash waste tank cost to be partially shared with Manganese Treatment system
(2) Costs are assumed to be the additional capital to add 10-ft of building height at $75/sf of wall
(3) Costs are installed equipment costs

4.3.4.2 Opinions of Probable Operation and Maintenance

Opinions of probable annual operation and maintenance (O&M) costs were developed based on high level estimates of media replacement for comparison purposes. Disposal of backwash water costs were assumed to be negligible due to limited backwash volumes and long changeout frequencies. Labor costs were not included in this analysis; they were assumed to be similar among the two treatment medias. A summary of the probable annual O&M costs for the two treatment alternatives is included in Table 4-12. Costs are based on an annual average day production of 0.66 MGD.

TABLE 4-12
Summary of Estimated Operation and Maintenance Costs

Description	GAC	IX
Annual Media Replacement	\$25,000 - \$50,000(1)	\$40,000 - \$80,000(2)
Media Disposal (3)	-	\$2,000
Backwash Disposal	\$2,000	-
Monthly PFAS Sampling (3)	\$30,000	\$30,000
Total Estimated O&M Costs	**\$59,000 - \$84,000**	**\$74,000 - \$114,000**

(1) Assumes 40,000 to 75,000 BV to changeout, 0.66 MGD average treatment

(2) Assumes 300,000 to 490,000 BV to changeout, 0.66 MGD average treatment

(3) GAC is to be regenerated by the manufacturer as part of the annual media replacement. IX is to be dewatered and disposed by warehousing/incineration/landfilling. We've assumed \$0.10 per pound however this cost is highly volatile due to rapidly changing regulations

(4) Assumes 7 monthly samples at \$350 per sample for 12 months

4.3.4.3 Life Cycle Cost Analysis

A life-cycle cost (LCC) analysis was performed as a present worth analysis based on a 20-year life cycle, including capital costs and annual O&M costs. The annual O&M and capital costs were compared using a present worth analysis, with a 4% discount rate, an inflation rate of 2%, and 10 and 20 year terms. A summary of the life cycle cost analysis for the two treatment alternatives is included in Table 4-13. IX has a higher 20 year LCC primarily due to additional operational costs to rebed the media prior to PFAS breakthrough.

TABLE 4-13
Summary of Life Cycle Cost Analysis

Description (2021 Dollars)	GAC	IX
Capital Cost (Table 4-11)	\$1,400,000	\$1,200,000
Annual Cost (Table 4-12)	\$84,000	\$114,000
NPV – 10 year	\$2,170,000	\$2,250,000
NPV – 20 year	\$2,810,000	\$3,110,000

(1) NPV based on 10 year and 20 year terms, 4% discount rate, and 2% inflation rate. Discount rate based on Dec 2021 Bureau of Reclamation rate for FY 2022.

4.3.5 PFAS Treatment System Evaluation Recommendation

Life-cycle costs between GAC and IX are relatively similar with a small advantage for GAC; therefore, selection of a treatment technology should also consider non-cost factors.

- IX has a lower capital cost due to the lower required EBCT resulting in a lower profile 12-foot diameter vessel. Changeout frequency is lower for IX due to its the larger treatment capacity, but the cost media outweighs the additional treatment volume, based on planning level assumptions.

- IX media cannot be regenerated at this time and is typically disposed of at a landfill. Landfill disposal costs have increased recently and may increase further as PFAS regulations expand.

- IX media is not tolerant of chlorine. If GreensandPlus™ is selected for manganese treatment, the chlorine residual must be quenched prior to IX. This can be done chemically or physiochemically

- GAC has a long track record for PFAS treatment with many successful installations across the northeast. GAC media is cheaper on a per cubic foot basis but has a lower PFAS capacity. GAC also requires a longer EBCT to effectively remove PFAS. The higher EBCT results in larger vessels. GAC is also tolerant of low chlorine levels that may be present after GreensandPlus™ treatment.

- Pressure vessels can be designed to accommodate either GAC or IX. If designed large enough for GAC, the vessel is compatible with IX if the underdrain slot size is designed to accommodate either media. This option would allow for flexibility to account for future advances in media design or changes to disposal costs.

- For this evaluation, GAC was the selected alternative to provide maximum flexibility for future unknowns and better compatibility with greensand treatment.

- Bench-scale testing is recommended to confirm media selection and performance. We anticipate bench-scale testing to costs $50,000 - $150,000 depending on the number of media columns and samples tested.

4.4 Conceptual Water Treatment Plant Plan

The treatment process selected for the Blackstone Water Treatment Plant conceptual plan consists of three 10-foot diameter GreensandPlus™ filters for iron and manganese removal, space for a future fourth filter, and two 12-ft diameter GAC adsorption vessels operating in lead/lag orientation. All chemical treatment for the site will be located within the new facility. For the purposes of this plan, compliance with 4-log disinfection requirements is not included.

The conceptual process utilizes groundwater conveyed from each of the three Blackstone wells at a maximum rate of 826 gpm for a total average daily flow of 0.66 MGD. Each of the existing wells would likely require an increase in motor horsepower to pump through the new WTP to the distribution system. Backwash supply will be provided by a pair of pumps, operating duty/standby, pumping water out of a 10-ft by 48-ft buried precast concrete tank. This tank would be filled in a batch process, as a side stream off of the treated watermain and is sized to backwash one 12-ft filter. The conceptual system also includes two additional 10-foot x 48-foot buried precast concrete settling tanks for backwash wastewater storage. As the conceptual design has included GreensandPlus™ a backwash recycle system should be provided to reduce the overall water treatment residual wastewater at the new WTP. The recycle system will consist of a floating weir with a hose connection to a set of recycle pumps. A buried 10-foot by 16-foot precast residuals pumping vault has been included adjacent to the tanks to house the recycle pumps and backwash residual wastewater pumps. Wastewater residuals will be pumped from the holding tanks up through an air gap and discharge to an adjacent sewer pump station. The pump station will pump residuals from the treatment facility to the sewer system.

4.4.1 WTP Siting

The existing Blackstone Wellfield treatment facility does not have the space required for manganese or PFAS treatment. The Blackstone Wellfield parcel has adequate space for the proposed 5,600 square foot WTP approximately 250 feet northeast of the existing site. Siting considerations for the conceptual design include:

- Location of the new building and tankage should be at least 100 feet from the existing wells and wetlands.
- 12-inch DI raw and treated watermain to connect to the existing site piping, a portion of the existing piping will be upsized to 12-inch and new isolation/bypass valves/hydrants will be installed.
- Truck access for chemical delivery and media exchange
- Backwash waste tank sizing to accommodate manganese and PFAS treatment. Waste tank was assumed to be separate from the WTP but can also be designed under the WTP.
- Sewer pump station and force main will connect the facility to the Town sewer.

4.4.2 WTP Building Layout

The new proposed WTP will be a 70-foot by 80-foot building constructed of insulated precast concrete wall panels. It would house the GreensandPlus™ and GAC treatment equipment. The building walls will be 30-feet or taller to accommodate the height of the GAC vessels. The building roof will be constructed of a 12-inch hollow core precast concrete roof plank system which includes roof insulation, coverboard, and a membrane roofing system. The building envelope will be designed to meet the Massachusetts uniform energy code. Due to the length of the building, structural roof beam and support columns will likely be required to reduce the overall span of the precast concrete roof planks. Interior structures will be constructed of precast concrete panels or masonry. The conceptual building design provides for limited office or storage space, as we've assumed sufficient space is provided by the existing buildings. Interior spaces consist of minor control, electrical and mechanical rooms as well as a new chemical storage and feed room.

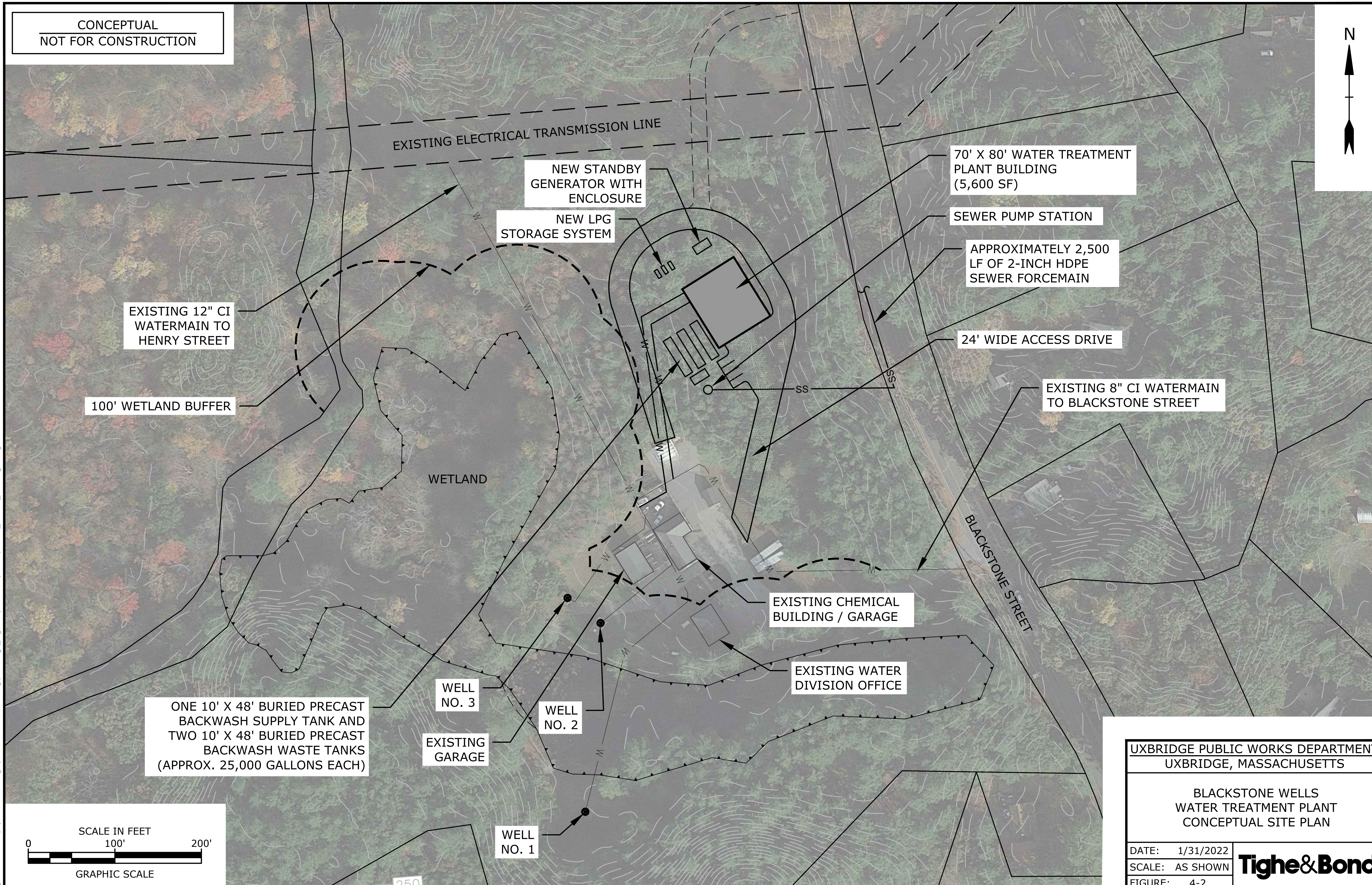
Propane-fired unit heaters will be installed in the WTP building to prevent freezing of process piping. An air conditioning unit will be installed in the Electrical room to maintain a constant temperature for the electrical and networking gear. The ventilation system will be accomplished with ductwork and exhaust fans either through the walls or over door intake louvers. Exhaust fans will be interlocked with a timer to move air to the outside of the building when started by the operator. Air intake louvers will be installed with both bird and insect screens.

Plumbing for the subject facility will consist of the necessary piping and water appurtenances for functionality of the WTP. The WTP will not include any sanitary bathrooms as there are bathrooms at the other buildings onsite. Additional information is needed to determine whether the existing septic system can be maintained or relocated. During final design the existing leach field may be determined to be abandoned and the sanitary waste redirected to the sewer pump station. The current assumption is that a sewer pump station will be installed to convey domestic waste and backwash residuals waste to the Uxbridge Wastewater Treatment Facility.

Domestic water will enter the building through two water service lines sized to satisfy all domestic (2-inch line) and analytical needs (1/2-inch line) and will be tapped off of the treated water line 100 feet from the building finished water exit. This conceptual design does not include provisions for 4-log compliance. The domestic water system will be used to feed a tempered water system which will provide water for an emergency eyewash/shower. Due to the volume of chemicals stored in the new WTP building, we anticipate the need for a fire suppression system, however a variance for fire suppression can be discussed with local building officials in final design.

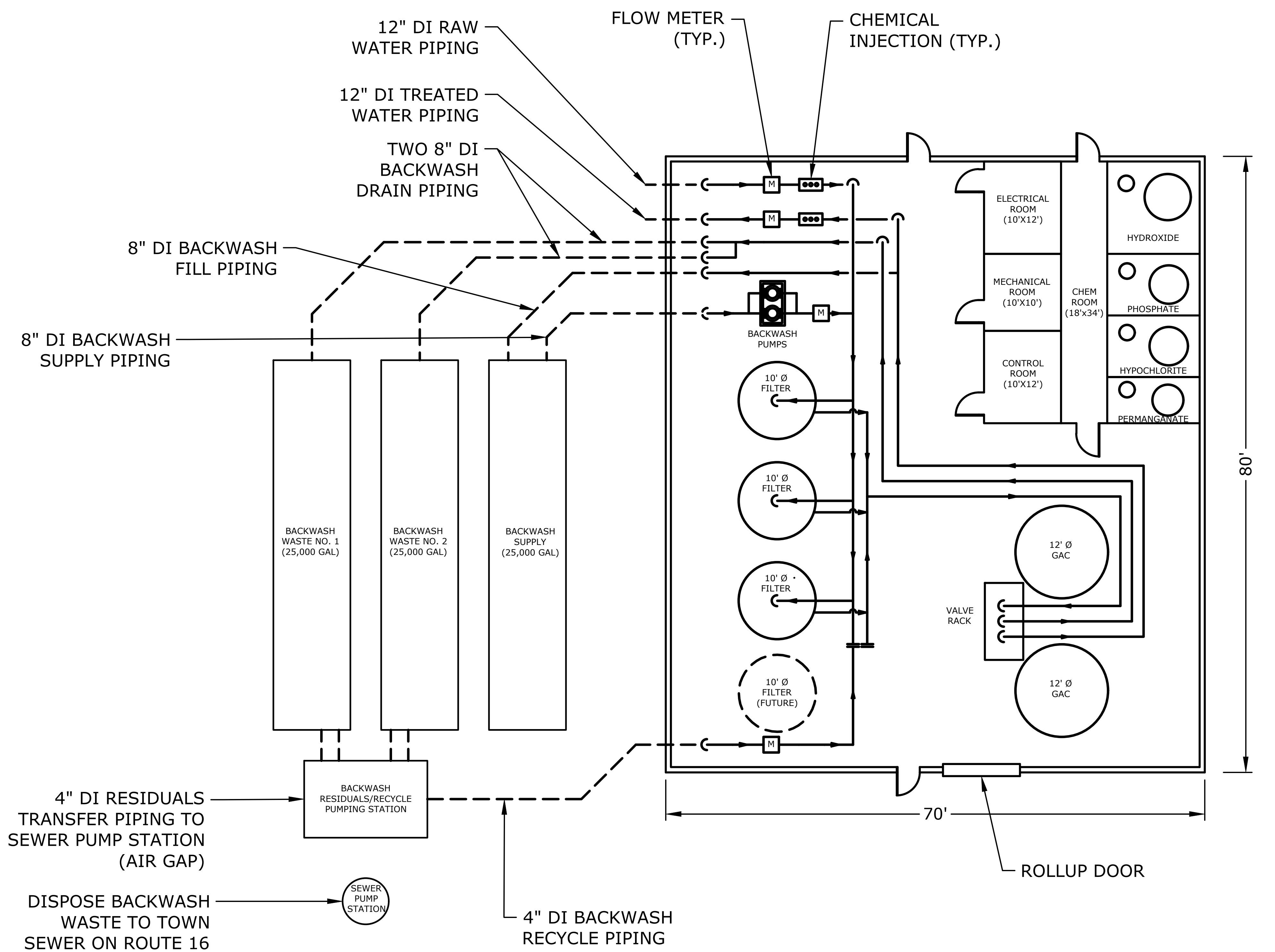
During final design we will confirm what modifications to the existing electrical site service (if any) are needed. The WTP contractor will be responsible for coordinating with the electrical company for the electrical service connection between the building and the limit of work. Final loads will be examined during final design.

Figures 4-2 and 4-3 present a conceptual site layout and floor plan for the Blackstone WTP, respectively.



Plotted On:Feb 02, 2022-11:33am By: BJL
Tighe & Bond:J:\U\U5004 Uxbridge\010 Facilities Planning\Drawings_Figures\AutoCAD\Sheet\U5004_C-WTP_Uxbridge.dwg

CONCEPTUAL
NOT FOR CONSTRUCTION



0 8' 16' 32'
SCALE: 1/16"=1'-0"

NOTE:
1. PIPES ARE SHOWN DIAGRAMMATICALLY FOR CLARITY.

UXBRIDGE PUBLIC WORKS DEPARTMENT UXBRIDGE, MASSACHUSETTS	
BLACKSTONE WELLS WATER TREATMENT PLANT CONCEPTUAL FLOOR PLAN	
DATE: 1/31/2022 SCALE: AS SHOWN FIGURE: 4-3	Tighe&Bond

4.5 Project Implementation

4.5.1 Project Budgeting

The total opinion of probable construction costs for the treating iron, manganese and PFAS6 with the Blackstone Wells WTP project is approximately $15 million, as shown in Table 4-14. This cost opinion is an AACE International Class 5 opinion, which is typical for feasibility or study level projects. We've included 25% for contractor general conditions, and 25% engineering, 30% design, and 10% project contingencies to reflect a planning level of detail. These costs are being provided for planning purposes only.

Table 4-14 Blackstone Wells WTP Opinion of Probable Cost

Description	Cost Opinion
Contractor General Conditions, Bonds & Insurance, OH&P (25%)	$1,750,000
Demolition	$50,000
Site/Civil	$1,000,000
Water Treatment Plant Building (5,600 sq.ft)	$1,700,000
Building Systems (Plumbing, Fire Protection, HVAC)	$300,000
Process Mechanical Equipment	$2,800,000
Water Storage Tanks	$500,000
Electrical (Including I&C)	$900,000
Probable Construction Costs	**$9,000,000**
Engineering & Permitting through Construction (25%)	$2,300,000
Design Contingency (30%)	$2,700,000
Project Contingency (10%)	$1,000,000
Recommended Project Budget	**$15,000,000**

4.5.2 Permitting Requirements

Pilot Study and Pilot Proposal

A pilot proposal is typically required to construct most forms of water treatment in Massachusetts. This involves submitting a pilot proposal for MassDEP in advance of the pilot study, including preparation of WS 21 – Approval to Conduct Pilot Study forms. The pilot study/bench studies typically last a few weeks and up to several months. A pilot study report and WS 22 – Approval of Pilot Study permit is required to summarize the pilot study findings to MassDEP.

Request for Determination or Notice of Intent

A Request for Determination or Notice of Intent (NOI) submittal to the Uxbridge Conservation Commission will be required for this work. A NOI would be required if construction activities are located within buffer zones associated with wetland resource areas.

Planning Board Site Plan Review

Our preliminary zoning research indicates that Site Plan Review by the Planning Board will be required for the proposed project. However, no Special Permit will be required as municipal facilities are allowed by right. A stormwater permit will be required.

Plumbing Variance for No Bathroom

A variance from the State Plumbing Code is required if the Town decides not to include a bathroom within the treatment facility, in lieu of a separate men's and woman's bathroom that is typically required for a public building. If a single bathroom is recommended, variance would still be needed. Coordination will be required with the local building official for the approval. If approval is not provided by the Town's building officials, a variance permit application will need to be prepared to the Massachusetts Plumbing Board to request a approval for a building either without a bathroom or provide only a single/unisex bathroom.

Town Sewer Connection

The project would include a new connection to the Town's sewer system in Route 16. This connection will require local coordination and approval.

MassDEP Permit to Construct a WTP

The BRP WS 24 – Approval to Construct Water Treatment Facility is required by MassDEP. This permit typically includes a 75% design set of drawings and technical specifications, and applicable permit forms. This also involves a meeting between Town staff, Tighe & Bond, and MassDEP to review the permit application and design documents, and to address any comments from MassDEP.

Massachusetts Environmental Policy Act

Although the permitted withdrawal of each individual well totals to 1.19 MGD, influences between all three wells running simultaneously and the water use registration limits of the site will likely limit the permitted capacity of the new WTP to below 1,000,000 gallons per day. Construction of a new drinking water treatment plant with a capacity of 1,000,000 gallons per day or more triggers the need for review under the Massachusetts Environmental Policy Act (MEPA). We've assumed this WTP will not require submission of a Environmental Notification Form (ENF) under MEPA because the permitted capacity will be below 1,000,000 gallons per day.

Section 5 Capital Planning

The purpose of this study is to provide the Town of Uxbridge with a planning level estimate of capital costs expenses necessary to improve the existing level of operation of the water system. For the purposes of this study, we evaluated potential capital costs associated with a 20-year planning period. Assets with a remaining useful life of greater than 20 years have not been included but will still pose a capital cost to the Town beyond this study's planning period.

Much of the equipment at Blackstone and Bernat wellfields is near the end of its service life. Rosenfeld is the newest wellfield. Most of its equipment still has useful life remaining and will not need replacement for multiple years if properly operated and maintained. Other assets have exceeded their life expectancy or are damaged and in need of replacement. Additional capital projects to provide additional water supply, as outlined in Section 3 and 4 have been included.

Budgetary cost estimates for each item are developed for consideration in the Town's capital planning budgets. Budgetary costs include equipment costs, demolition/removal of existing equipment (if applicable), allowances for contractor installation, general conditions, bond and insurance, and overhead and profit; engineering; and contingency. The budgetary costs are based on the February 2022 ENR Construction Cost Index of 12,684.

The conceptual level budgetary cost estimates are based on Class 5 level construction cost estimates, as defined by AACE International. According to these standards, the estimate class designators are labeled Class 1, 2, 3, 4, and 5, where a Class 5 estimate is based on the lowest level of project definition and a Class 1 estimate is closest to full project definition and maturity. The end usage for a Class 5 estimate is project screening or feasibility purposes. The expected accuracy range of a Class 5 estimate is between +50% to -30%. The level of project definition for a Class 5 estimate is between 0% and 2%. Costs listed in Table 5-1 are for planning purposes only.

TABLE 5-1
Capital Improvement Planning Summary

Project Location	Project Name	Probable Construction Cost[1]	Contingency + Engineering[2]	Budget	Action Category
Blackstone	Blackstone Wellhouse Roof Replacement	$70,000	$50,000	$120,000	Immediate
Blackstone	Wells 1-3 Replacement Project	$1,050,000	$690,000	$1,740,000	Immediate
Blackstone	Manganese Pilot and PFAS Bench Scale Test			$300,000	A
Blackstone	Manganese and PFAS WTP	$9,000,000	$6,000,000	$15,000,000	A
Blackstone	Blackstone Wellfield Refurbishments	$940,000	$610,000	$1,550,000	B
Bernat	Wells 4-6 Replacement Project	$1,100,000	$720,000	$1,820,000	Immediate
Bernat	Bernat Wellfield Refurbishments	$1,580,000	$1,030,000	$2,610,000	A
Rosenfeld	Rosenfeld Wellfield Refurbishments	$520,000	$340,000	$860,000	C
Rosenfeld	New Groundwater Source	$1,200,000	$780,000	$2,000,000	C
			Total	**$26,000,000**	

Action Category Definitions:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.

Category A - High Priority Items (implement within 5 years), and Items that have an expected remaining service life of 6 or fewer years - repair or replacement is expected to be necessary during this period.

Category B - Medium Priority Items (implement within 10 years), and Items that have an expected remaining service life of 7 to 11 years - repair or replacement is expected to be necessary during this period.

Category C - Low Priority Items (implement within 20 years), and Items that have an expected remaining service life of 12 to 20 years - repair or replacement is expected to be necessary during this period.

[1] 25% in General Conditions was included in construction costs.

[2] 25% Engineering and permitting through construction, 30% design, and 10% project contingencies were added.

\\Nas-wfo\data\Projects\U\U5004 Uxbridge\010 Facilities Planning\Report Evaluation\Uxbridge Well Sites Evaluation Report_July2022.docx

Appendix A
Capital Improvements Costs

Blackstone Wellfield - Water System Capital Improvements Plan

Evaluation Description	Location	Asset/Defect Description	Proposed Improvement	Corresponding Capital Project	Estimated Capital Cost[1]	Estimated Cost for Each Action Category			
						Immediate	Cat A	Cat B	Cat C
Process/Mechanical									
GreenSand Pilot Test, GAC Bench Test	Blackstone Wellfield	High levels of manganese and PFAS	Manganese and PFAS Pilot and Bench Scale Tests	GreenSand Pilot and GAC Bench Scale Test	$300,000		$300,000		
Water Treatment Plant	Blackstone Wellfield	High levels of manganese and PFAS	Manganese and PFAS WTP	Manganese and PFAS WTP	$9,000,000		$9,000,000		
All three existing wells are over 70 years old, have been sleeved, and cannot produce the permitted capacity	Blackstone Wellfield	Reached the end of useful life	Install three replacement wells with submersible pumps	Wells 1-3 Replacement Project	$1,050,000	$1,050,000			
Structural/Architectural									
The concrete slab roofs are over 30 years old. The roof for Well No. 2 is crumbling. Roof hatches appear stained and corroded in places and are probably near the end of their useful life.	Wellhouses 1, 2, and 3	The estimated useful life is 30 years	Replace roofs of all three well buildings, roof hatches included.	Blackstone Wellhouse Roof Replacement	$70,000	$70,000			
Siding appears to be over 10 years old	Wellhouses 1, 2, and 3	The estimated useful life is 30 years	Replace siding	Blackstone Wellfield Refurbishments	$25,000			$25,000	
Doors and windows appear to be over 10 years old	Wellhouses 1, 2, and 3	The estimated useful life is 30 years	Replace Doors and Windows	Blackstone Wellfield Refurbishments	$30,000			$30,000	
Interior finishes	Wellhouses 1, 2, and 3	The estimated useful life is 10 years	Replace paint	Blackstone Wellfield Refurbishments	$5,000			$5,000	
Slate roof has some cracked and/or loose slates, some gins of corroded ridge caps	Office Building	Periodic Maintenance	Reattach loose slates, replace cracked slates, check / repair ridge caps	Blackstone Wellfield Refurbishments	$35,000			$35,000	
Chimney mortar joints appear to be somewhat recessed	Office Building	Periodic Maintenance	Repoint mortar joints	Blackstone Wellfield Refurbishments	$6,000			$6,000	
Siding appears to be over 10 years old	Office Building	The estimated useful life is 30 years	Replace Siding	Blackstone Wellfield Refurbishments	$40,000			$40,000	
Doors and windows appear to be over 10 years old	Office Building	The estimated useful life is 30 years	Replace Doors and Windows	Blackstone Wellfield Refurbishments	$45,000			$45,000	
Stone lintels have been coated for weather resistance	Office Building	The estimated useful life is 10 years	Replace Coating	Blackstone Wellfield Refurbishments	$5,000			$5,000	
Interior Finishes	Office Building	The estimated useful life is 10 years	Replace paint	Blackstone Wellfield Refurbishments	$15,000			$15,000	
Interior Finishes	Office Building	The estimated useful life is 20 years	Replace flooring	Blackstone Wellfield Refurbishments	$35,000			$35,000	
Asphalt roof appears to be more than 15 years old	Treatment facility	The estimated useful life is 30 years	Replace shingles, underlayment, patch deck where required	Blackstone Wellfield Refurbishments	$45,000			$45,000	
Siding appears to be over 10 years old	Treatment facility	The estimated useful life is 30 years	Replace siding	Blackstone Wellfield Refurbishments	$50,000			$50,000	
Doors and windows appear to be over 10 years old	Treatment facility	The estimated useful life is 30 years	Replace Doors and Windows	Blackstone Wellfield Refurbishments	$60,000			$60,000	
Interior Finishes	Treatment facility	The estimated useful life is 10 years	Replace Paint	Blackstone Wellfield Refurbishments	$20,000			$20,000	
Interior Finishes	Treatment facility	The estimated useful life is 10 years	Replace Concrete Coating	Blackstone Wellfield Refurbishments	$45,000			$45,000	
Electrical									
Electrical equipment is over 20 years old	Wellhouses 1, 2, and 3	Electrical eqiupment is approaching end of useful life	Monitor and replace within 6 years	Blackstone Wellfield Refurbishments	$160,000			$160,000	
Electrical equipment is over 20 years old	Chemical Treatment Building	Electrical eqiupment is approaching end of useful life	Monitor and replace within 6 years	Blackstone Wellfield Refurbishments	$260,000			$260,000	
Plumbing and HVAC									
General HVAC and plumbing is over 20 years old	Blackstone Wellfield	General HVAC has 6 years of remaining useful life	Monitor and replace within 7 years	Blackstone Wellfield Refurbishments	$59,000			$59,000	

Action Category Definitions:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.

Category A - High Priority Items (implement within 5 years), and Items that have an expected remaining service life of 6 or fewer years - repair or replacement is expected to be necessary during this period.

Category B - Medium Priority Items (implement within 10 years), and Items that have an expected remaining service life of 7 to 11 years - repair or replacement is expected to be necessary during this period.

Category C - Low Priority Items (implement within 20 years), and Items that have an expected remaining service life of 12 to 20 years - repair or replacement is expected to be necessary during this period.

[1]Estimated Capital Cost does not include Contingencies. Contingencies are included in the Capital Improvement Summary Table in Section 5 of the Report.

Bernat Wellfield - Water System Capital Improvements Plan

Evaluation Description	Location	Asset/Defect Description	Proposed Improvement	Corresponding Capital Project	Estimated Capital Cost[1]	Estimated Cost for Each Action Category			
						Immediate	Cat A	Cat B	Cat C
Process/Mechanical									
All three existing wells are over 70 years old, have been sleeved, and cannot produce the permitted capacity	Bernat Wellfield	Reached the end of useful life	Install three replacement wells with submersible pumps	Wells 4-6 Replacement Project	$1,100,000	$1,100,000			
Potassium Hydroxide feed and storage systems are over 20 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Bernat Wellfield Refurbishments	$45,000		$45,000		
Sodium Hypochlorite feed and storage systems are over 20 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Bernat Wellfield Refurbishments	$35,000		$35,000		
Polyphosphate feed and storage systems are over 20 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Bernat Wellfield Refurbishments	$45,000		$45,000		
Badger Flow meters are over 20 years old	Wellhouses 4, 5, and 6	The estimated useful life is 15 years	Replace all three flow meters	Bernat Wellfield Refurbishments	$40,000		$40,000		
Piping and valves are over 20 years old	Bernat Wellfield	The estimated useful life is 30 years	Monitor and replace within 10 years	Bernat Wellfield Refurbishments	$25,000		$25,000		
Process instrumentation are over 20 years old	Bernat Wellfield	Approaching the end of useful life	Replace instrumentation	Bernat Wellfield Refurbishments	$25,000		$25,000		
Structural/Architectural									
Exterior Brick and Block	All Facilities	facades typically require maintenance every 50 years	Repoint and replace brick/siding as required	Bernat Wellfield Refurbishments	$125,000		$125,000		
Doors and windows appear to be over 10 years old	Wellhouses 4, 5, and 6	The estimated useful life is 30 years	Replace Doors and Windows	Bernat Wellfield Refurbishments	$30,000		$30,000		
Interior finishes	Wellhouses 4, 5, and 6	The estimated useful life is 10 years	Replace paint	Bernat Wellfield Refurbishments	$5,000		$5,000		
Exterior Finish	Treatment Facility	The estimated useful life is 5 years to protect CMU from frost action	Replace paint	Bernat Wellfield Refurbishments	$10,000		$10,000		
Exterior Passage Doors	Treatment Facility	The estimated useful life is 30 years	Replace doors	Bernat Wellfield Refurbishments	$15,000		$15,000		
Exterior Overhead Door	Treatment Facility	The estimated useful life is 30 years	Replace door	Bernat Wellfield Refurbishments	$10,000		$10,000		
Interior finishes	Treatment Facility	The estimated useful life is 10 years	Replace paint	Bernat Wellfield Refurbishments	$20,000		$20,000		
Interior finishes	Treatment Facility	The estimated useful life is 10 years	Replace floor coating	Bernat Wellfield Refurbishments	$45,000		$45,000		
Electrical									
Generator is over 20 years old	Bernat Chemical Treatment Building	Generator is approaching end of useful life	Monitor and replace within 6 years	Bernat Wellfield Refurbishments	$450,000		$450,000		
Electrical equipment is over 20 years old	Bernat Chemical Treatment Building	Electrical eqiupmentus approaching end of useful life	Monitor and replace within 6 years	Bernat Wellfield Refurbishments	$550,000		$550,000		
Plumbing and HVAC									
General HVAC and plumbing is over 20 years old	Bernat Wellfield	General HVAC is approaching end of useful life	Monitor and replace within 6 years	Bernat Wellfield Refurbishments	$60,000		$105,000		

Action Category Definitions:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.
Category A - High Priority Items (implement within 5 years), and Items that have an expected remaining service life of 6 or fewer years - repair or replacement is expected to be necessary during this period.
Category B - Medium Priority Items (implement within 10 years), and Items that have an expected remaining service life of 7 to 11 years - repair or replacement is expected to be necessary during this period.
Category C - Low Priority Items (implement within 20 years), and Items that have an expected remaining service life of 12 to 20 years - repair or replacement is expected to be necessary during this period.

[1]Estimated Capital Cost does not include Contingencies. Contingencies are included in the Capital Improvement Summary Table in Section 5 of the Report.

Rosenfeld Wellfield - Water System Capital Improvements Plan

Evaluation Description	Location	Asset/Defect Description	Proposed Improvement	Corresponding Capital Project[1]	Estimated Capital Cost[1]	Estimated Cost for Each Action Category			
						Immediate	Cat A	Cat B	Cat C
Process/Mechanical									
New Well Source	Rosenfeld Wellfield	Increase well capacity at wellfield	Install a new well or a replacement well	Rosenfeld New/Replacement Well	$1,200,000				$1,200,000
Vertical turbine pump is 9 years old	Chemical treatment building	It has 16 years of remaining useful life	Monitor and replace within 16 years	Rosenfeld Wellfield Refurbishments	$50,000				$50,000
Potassium Hydroxide feed and storage systems are 9 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Rosenfeld Wellfield Refurbishments	$45,000				$45,000
Sodium Hypochlorite feed and storage systems are 9 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Rosenfeld Wellfield Refurbishments	$35,000				$35,000
Polyphosphate feed and storage systems are 9 years old	Chemical treatment building	The estimated useful life is 20 years	Replace chemical storage and feed systems including bulk tanks, day tanks, pumps, scales and instrumentation	Rosenfeld Wellfield Refurbishments	$45,000				$45,000
Magnetic flow meter is 9 years old		It has 6 years of remaining useful life	Replace all three flow meters	Rosenfeld Wellfield Refurbishments	$15,000				$15,000
Electrical									
Electrical equipment is 9 years old	Chemical treatment building	Electrical equipment has 20 years of remaining useful life	Monitor and replace within 20 years	Rosenfeld Wellfield Refurbishments	$270,000				$270,000
Plumbing and HVAC									
General HVAC and plumbing equipment is 9 years old	Chemical treatment building	HVAC and plumbing equipment have 21 years of remaining useful life	Monitor and replace within 21 years	Rosenfeld Wellfield Refurbishments	$60,000				$60,000

Action Category Definitions:

Immediate - Items that have an immediate need for repair or replacement because of their condition or importance, or to be implemented within one year. Items that were safety concerns were included in this category.

Category A - High Priority Items (implement within 5 years), and Items that have an expected remaining service life of 6 or fewer years - repair or replacement is expected to be necessary during this period.

Category B - Medium Priority Items (implement within 10 years), and Items that have an expected remaining service life of 7 to 11 years - repair or replacement is expected to be necessary during this period.

Category C - Low Priority Items (implement within 20 years), and Items that have an expected remaining service life of 12 to 20 years - repair or replacement is expected to be necessary during this period.

[1]Estimated Capital Cost does not include Contingencies. Contingencies are included in the Capital Improvement Summary Table in Section 5 of the Report.

Appendix B1
Blackstone Wellfield Site Overview

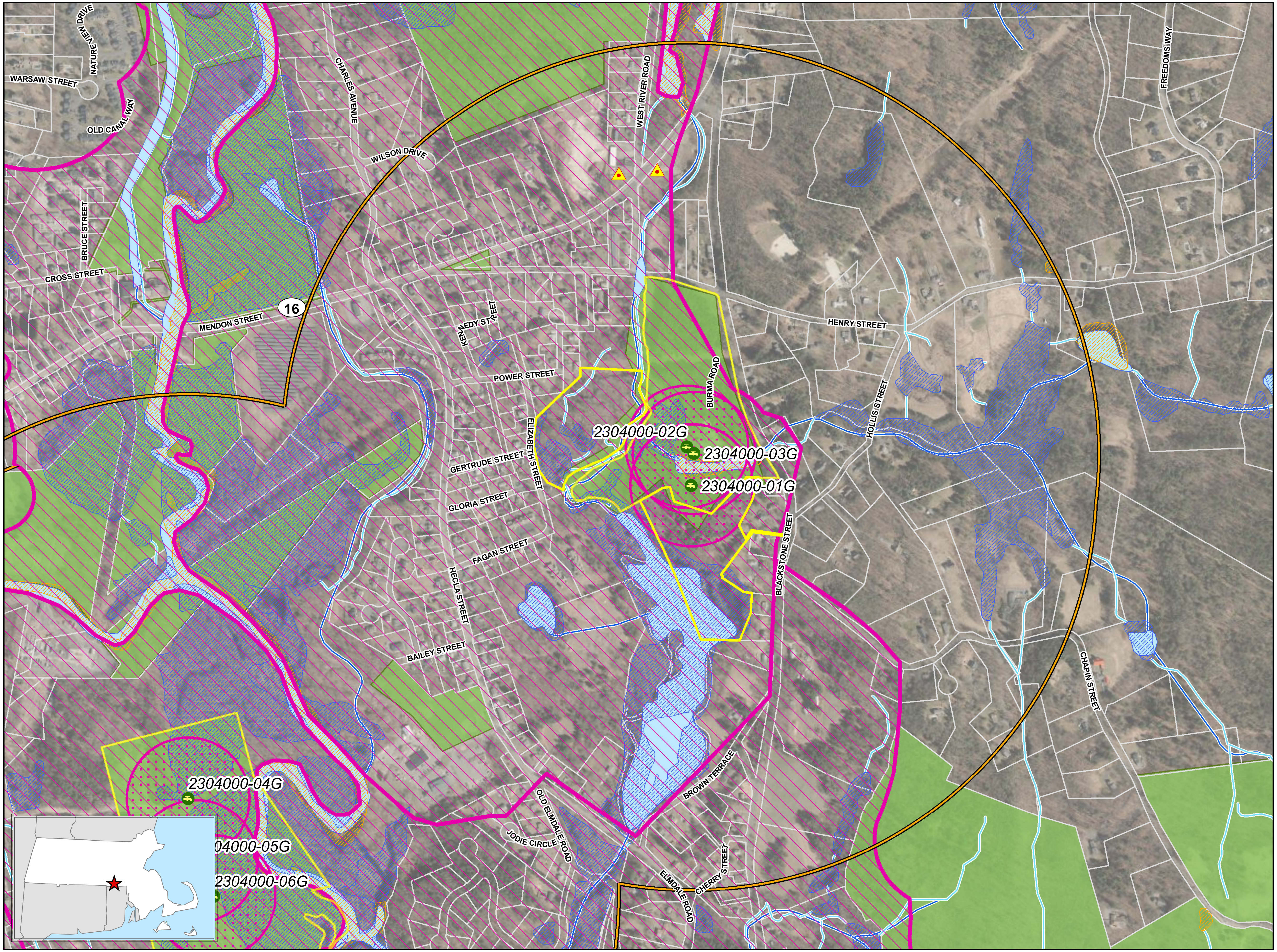


FIGURE 1
LAND USE

LEGEND

- Proposed Well
- Emergency Surface Water
- Community Public Water Supply - Surface Water
- Community Public Water Supply - Groundwater
- Non-Community Non-Transient Public Water Supply
- Non-Community Transient Public Water Supply
- MassDEP Oil and/or Hazardus Material Sites (Chapter 21E)
- Non-Landfill Solid Waste Sites
- Hydrologic Connections
- Stream/Intermittent Stream
- DEP Approved Wellhead Protection Area (Zone I)
- DEP Approved Wellhead Protection Area (Zone II)
- DEP Interim Wellhead Protection Area (IWPA)
- Protected and Recreational Open Space
- Solid Waste Landfill
- Public Surface Water Supply (PSWS)
- Water Bodies
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- MassDEP Open Water
- MassDEP Inland Wetlands
- MassDEP Coastal Wetlands
- MassDEP Not Interpreted Wetlands
- One-Half Mile Well Radius
- Town Boundary

N

0 300 600
Feet

1:7,200

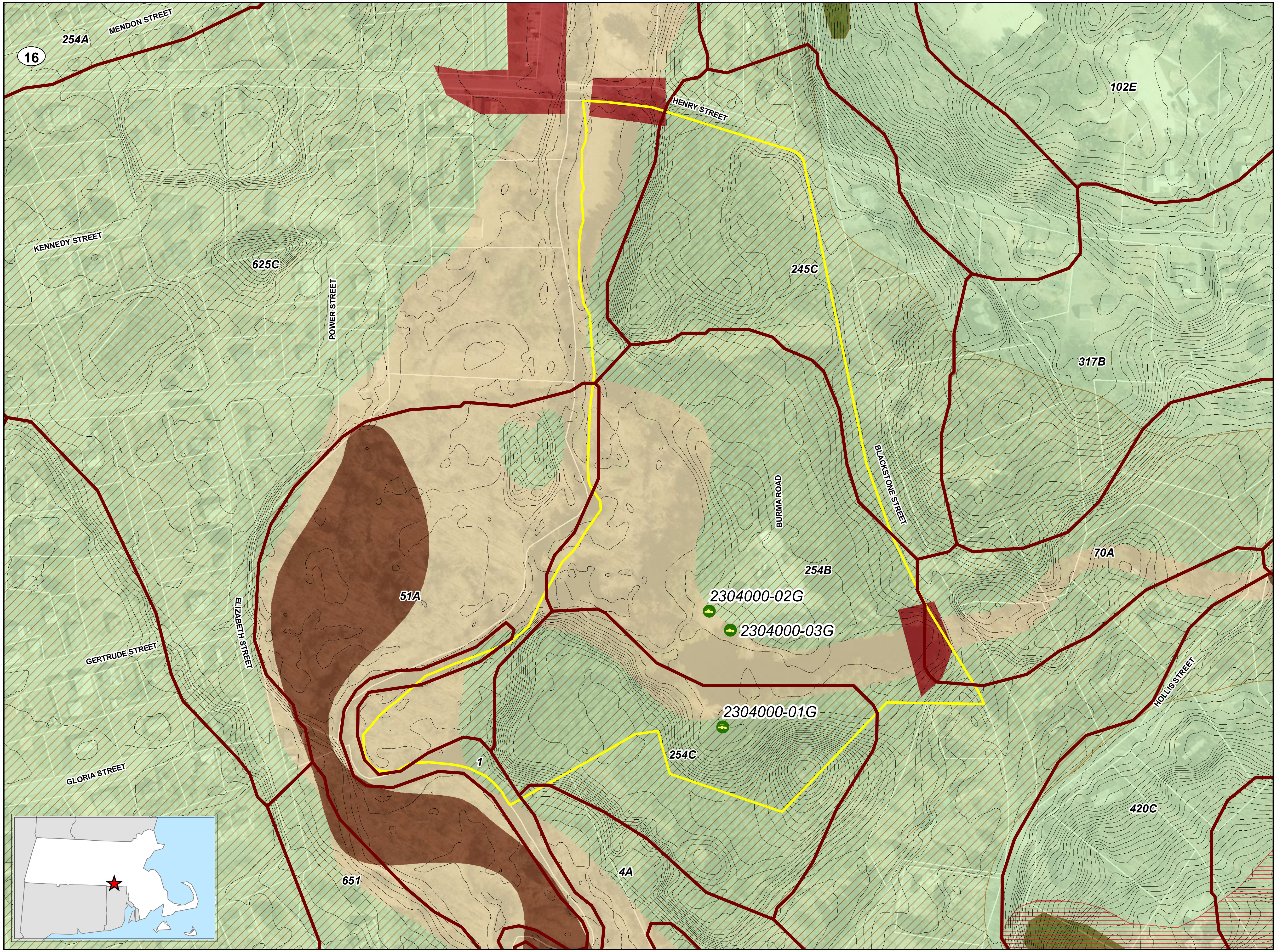
1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of January 2022.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.

Blackstone Wellfield
Uxbridge, Massachusetts

March 2022

Tighe&Bond

FIGURE 2
SITE OVERVIEW



LEGEND

- Community Public Water Supply - Groundwater
- 2-foot Contour
- Soil Boundary
- Abundant Outcrop and Shallow Bedrock
- Artificial Fill
- Swamp and Marsh Deposits
- Alluvium
- Coarse
- Bedrock Outcrop
- Thin Till
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- Town Boundary

N

0 100 200
Feet

1:2,400

1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of February 2022.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.
4. Contours generated from 2015 MA QL2 LiDAR DEM. DEM downloaded from MassGIS.

Blackstone Wellfield
Uxbridge, Massachusetts

March 2022

Tighe&Bond

V:\Projects\U\U5004\MXDs\FacilitiesPlan\OrthoZoomIns\BlackstoneWellfield_Ortho_11x17_Soils.mxd [Exported By: AFreudenberg, 2/23/2022, 12:21:55 PM]

U-5004

Appendix B2
Bernat Wellfield Site Overview

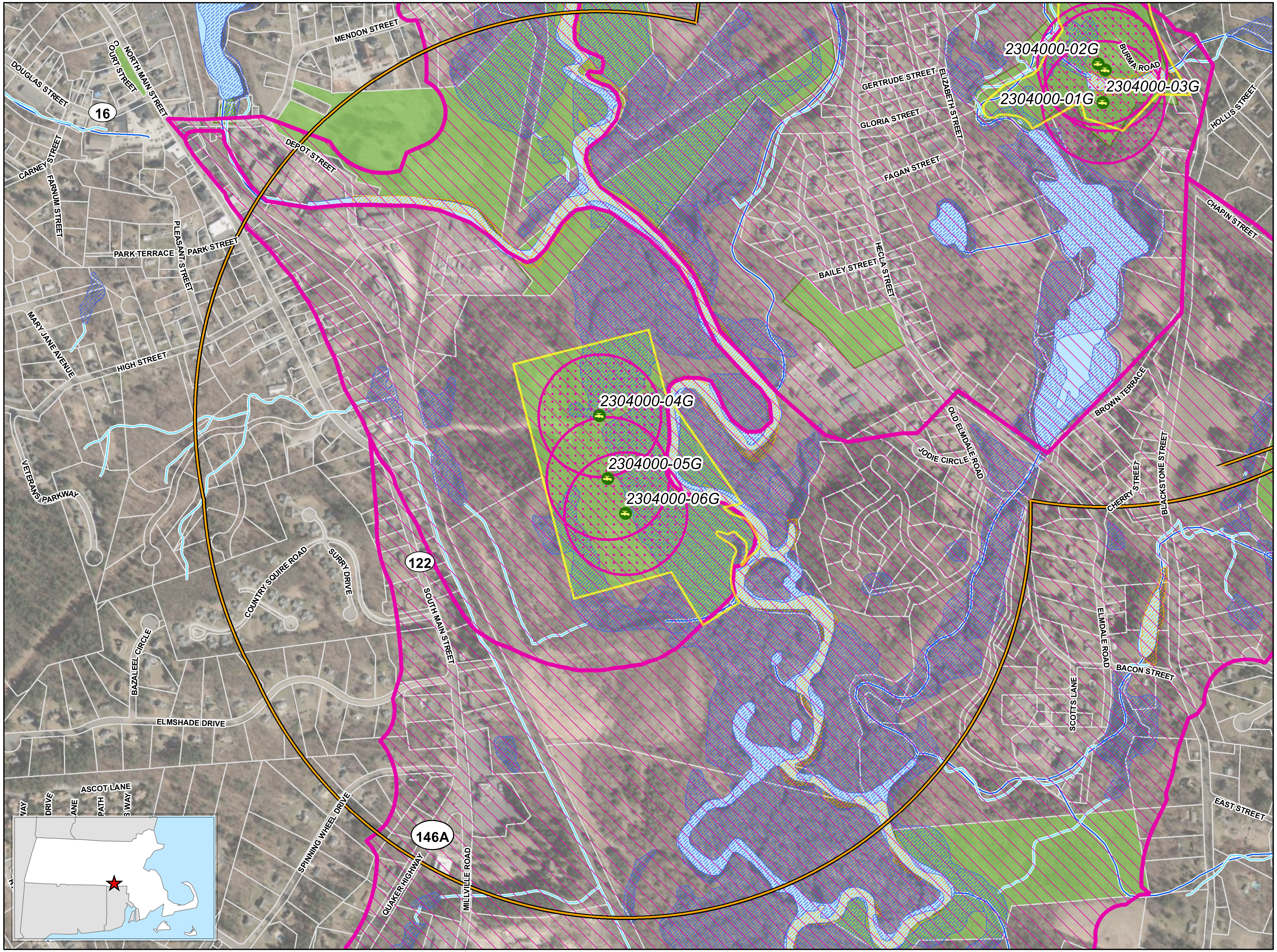


FIGURE 1
LAND USE

LEGEND

- Proposed Well
- Emergency Surface Water
- Community Public Water Supply - Surface Water
- Community Public Water Supply - Groundwater
- Non-Community Non-Transient Public Water Supply
- Non-Community Transient Public Water Supply
- MassDEP Oil and/or Hazardous Material Sites (Chapter 21E)
- Non-Landfill Solid Waste Sites
- Hydrologic Connections
- Stream/Intermittent Stream
- DEP Approved Wellhead Protection Area (Zone I)
- DEP Approved Wellhead Protection Area (Zone II)
- DEP Interim Wellhead Protection Area (IWPA)
- Protected and Recreational Open Space
- Solid Waste Landfill
- Public Surface Water Supply (PSWS)
- Water Bodies
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- MassDEP Open Water
- MassDEP Inland Wetlands
- MassDEP Coastal Wetlands
- MassDEP Not Interpreted Wetlands
- One-Half Mile Well Radius
- Town Boundary

N

0 300 600
Feet

1:7,200

1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of December 2021.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.

Bernat Wellfield
Uxbridge, Massachusetts

March 2022

Tighe&Bond

V:\Projects\U\U5004\MXDs\FacilitiesPlan\ResourceZoomIns\BernatWellfield_Resource_11x17.mxd [Exported By: kjw, 12/10/2021, 1:51:09 PM]

U-5004

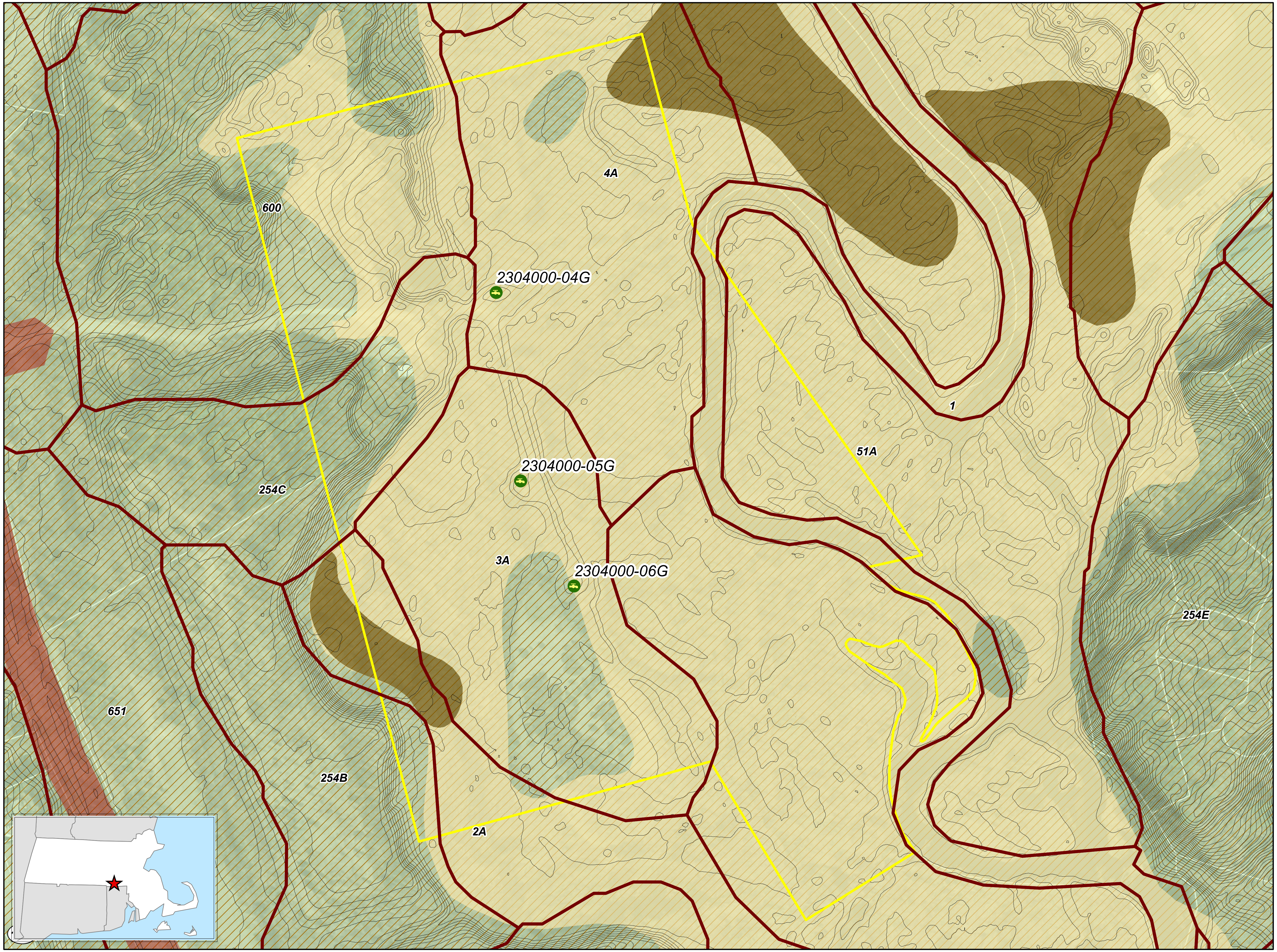


FIGURE 2
SITE OVERVIEW

LEGEND

- Community Public Water Supply - Groundwater
- 2-foot Contour
- Soil Boundary
- Artificial Fill
- Swamp and Marsh Deposits
- Alluvium
- Coarse
- Thin Till
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- Town Boundary

N

0 100 200

Feet

1:2,400

1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of February 2022.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.
4. Contours generated from 2015 MA QL2 LiDAR DEM. DEM downloaded from MassGIS.

Bernat Wellfield
Uxbridge, Massachusetts

March 2022

Tighe&Bond

V:\Projects\U\U5004\MXDs\FacilitiesPlan\OrthoZoomIns\BernatWellfield_Ortho_11x17_Soils.mxd [Exported By: AFreudenberg, 2/23/2022, 11:04:22 AM]

U-5004

Appendix B3
Rosenfeld Wellfield Site Overview

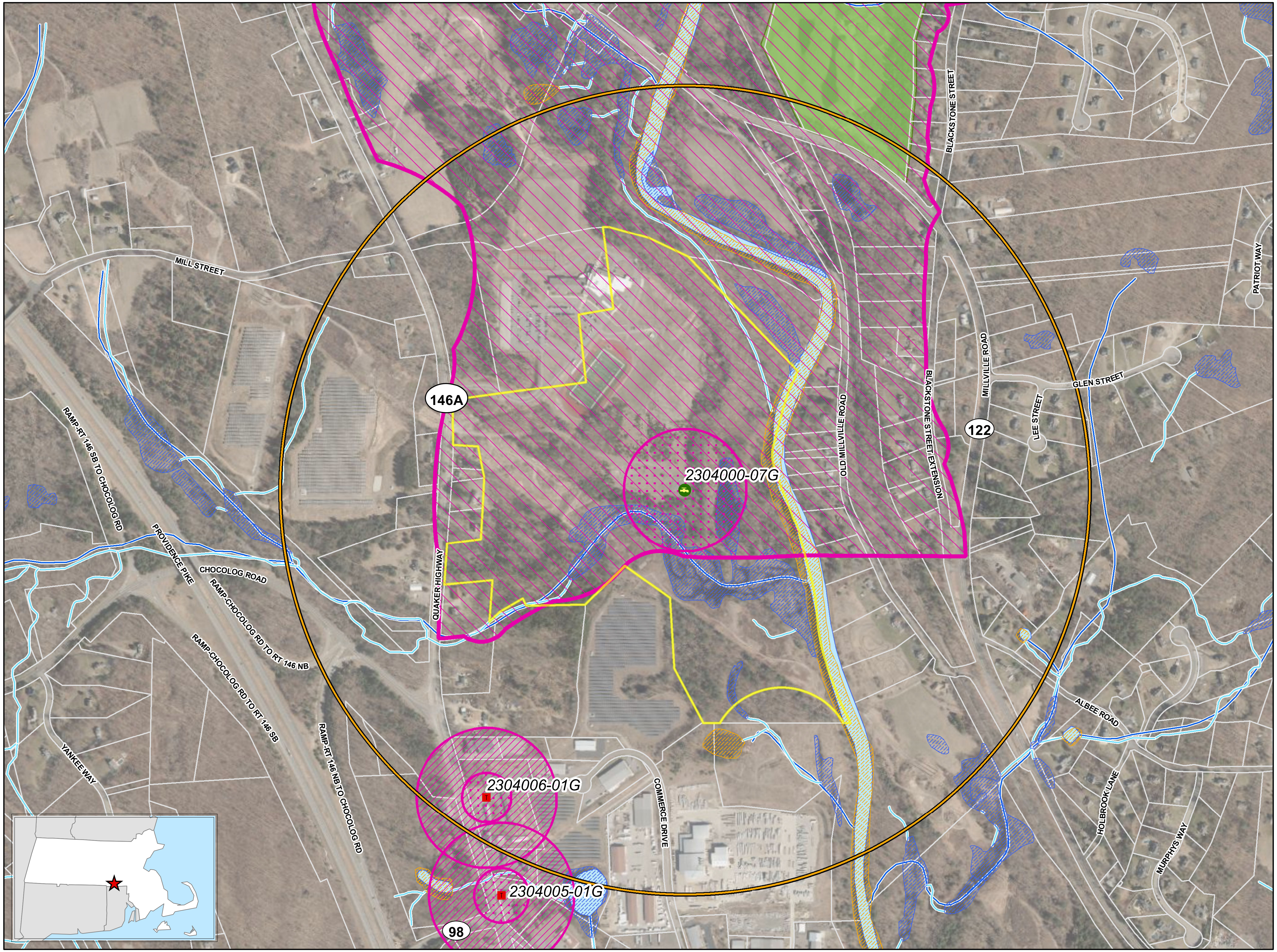


FIGURE 1
LAND USE

LEGEND

- Proposed Well
- Emergency Surface Water
- Community Public Water Supply - Surface Water
- Community Public Water Supply - Groundwater
- Non-Community Non-Transient Public Water Supply
- Non-Community Transient Public Water Supply
- MassDEP Oil and/or Hazardus Material Sites (Chapter 21E)
- Non-Landfill Solid Waste Sites
- Hydrologic Connections
- Stream/Intermittent Stream
- DEP Approved Wellhead Protection Area (Zone I)
- DEP Approved Wellhead Protection Area (Zone II)
- DEP Interim Wellhead Protection Area (IWPA)
- Protected and Recreational Open Space
- Solid Waste Landfill
- Public Surface Water Supply (PSWS)
- Water Bodies
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- MassDEP Open Water
- MassDEP Inland Wetlands
- MassDEP Coastal Wetlands
- MassDEP Not Interpreted Wetlands
- One-Half Mile Well Radius
- Town Boundary

N

0 300 600
Feet

1:7,200

1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of December 2021.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.

Rosenfeld Wellfield
Uxbridge, Massachusetts

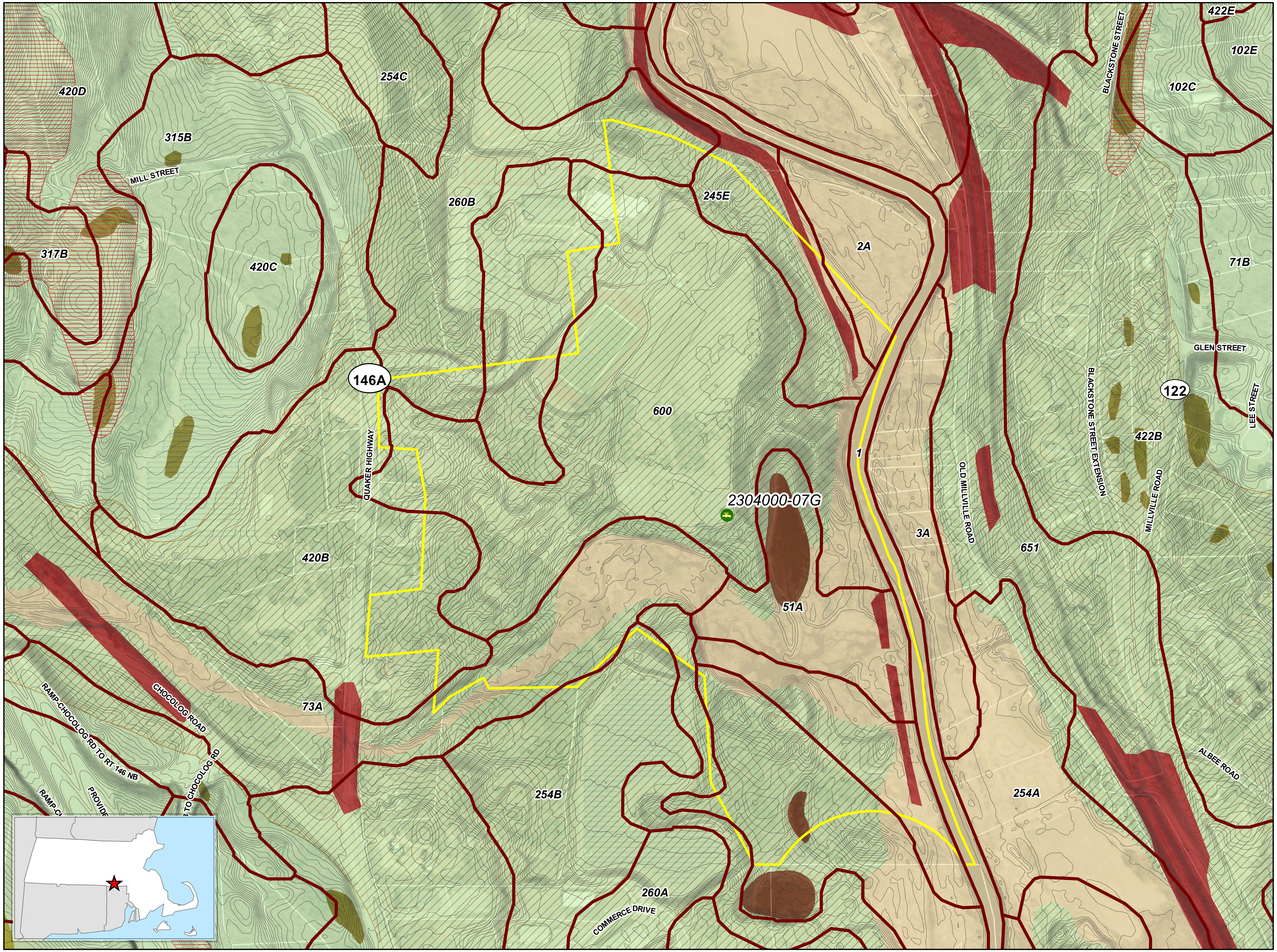
March 2022

Tighe&Bond

V:\Projects\U\U5004\MXDs\FacilitiesPlan\ResourceZoomIns\RosenfeldWellfield_Resource_11x17.mxd [Exported By: kjw, 12/10/2021, 2:09:20 PM]

U-5004

FIGURE 2
SITE OVERVIEW



LEGEND

- Community Public Water Supply - Groundwater
- 2-foot Contour
- Soil Boundary
- Abundant Outcrop and Shallow Bedrock
- Artificial Fill
- Swamp and Marsh Deposits
- Alluvium
- Coarse
- Bedrock Outcrop
- Thin Till
- Thick Till
- Town of Uxbridge Owned Parcel
- Parcel Boundary
- Town Boundary

N

0 200 400
Feet

1:4,800

1. Data source: Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT) Executive Office of Environmental Affairs. Data valid as of February 2022.
2. Based on MassGIS Color Orthophotography (2019).
3. Parcels (FY21) downloaded from MassGIS and are approximate.
4. Contours generated from 2015 MA QL2 LiDAR DEM. DEM downloaded from MassGIS.

Rosenfeld Wellfield
Uxbridge, Massachusetts

March 2022

Tighe&Bond

V:\Projects\U\U5004\MXDs\FacilitiesPlan\OrthoZoomIns\RosenfeldWellfield_Ortho_11x17_Soils.mxd [Exported By: AFreudenberg, 2/23/2022, 12:39:49 PM]

U-5004

www.tighebond.com

100% Recyclable